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Characteristics of *Julung Julung* Smoked Fish Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs Waste

Abstract

Corn cobs can be utilized as a shell ingredient for liquid smoke. Liquid smoke can be used for the smoked fish industry in North Sulawesi, Indonesia. However, the utilization of liquid smoke for the smoked fish industry has yet to be optimal. This study aimed to obtain the best smoking method for *julung julung* fish fillets (*Hemiramphus* sp.) using liquid smoke from corn cob waste. The treatment in this study was to apply liquid smoke from corn cob waste in the smoking process, which was compared with the conventional method (using shell, coconut wood, and corn cob). Parameters to determine the quality of smoked fish were total volatile bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed that the TVB of smoked *julung julung* fish fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these results, it can be concluded that the best treatment is fresh fillets preheated in a cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.

Keywords: Coconut, Indonesia, Shell, North Sulawesi, Wood

Introduction

Corn is the second most widely grown crop in Indonesia after rice. Indonesia is the 7th corn producer in the world, with more than 12 million tons of corn produced in 2020 (Nazmi *et al.*, 2021). North Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production will also produce waste, especially corn cobs, which are generally thrown away and burned by most Indonesians (Cahyadi *et al.*, 2021).

One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*, 2018). Another study reported a phenolic content of 335 mg/L in liquid smoke produced from corn cobs (Swastawati *et al.*, 2007).

Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*, 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save time, energy, and labor and reduce production costs (Krah *et al.*, 2019). In addition, using liquid smoke in food can speed up and standardize the smoking process, adding flavor and microbiological safety

37 while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used
38 to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced may
39 vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
40 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
41 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

42 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
43 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
44 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
45 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
46 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
47 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
48 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
49 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
50 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
51 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
52 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
53 (Azis & Akolo, 2020).

54 The study's reported that the conventional smoking process has disadvantages such as smoking time,
55 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
56 2020). Conventional smoking of food products has been shown to produce carcinogenic components
57 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
58 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
59 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
60 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

61 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
62 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
63 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
64 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
65 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
66 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
67 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

68 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
69 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*
70 *et al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
71 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on

72 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
73 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed
74 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
75 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
76 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
77 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
78 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
79 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
80 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
81 polycyclic aromatic hydrocarbon content, and sensory assessment.

82

83 **Materials and methods**

84 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
85 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
86 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
87 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
88 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
89 (Mishra *et al.*, 2021). Then, the fish was washed, weeded, and filleted. The cleaned fillets were dipped
90 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
91 (Berhimpon *et al.*, 2018).

92



93

94

95

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

96 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
97 of *julung julung* fish fillets, which was compared with the conventional method (using coconut wood,
98 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then heated in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets pre-heated in a cabinet dryer for 4 hours at 60 – 80 °C, and then dipped in liquid smoke for 20 minutes. After that, fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes and then dipped in liquid smoke for 20 minutes. After that, fillets were heated in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

99

100 **Liquid smoke manufacturing process**

101 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
102 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
103 cobs were gradually burned into the combustion furnace. The furnace was closed to prevent smoke from
104 escaping from the tank. The smoke generated from the combustion flows through a pipe connected to a
105 storage tank covered with ice cubes. The smoke that passes through the pipe will become cold, so
106 condensation occurs, turning the smoke into liquid. The smoke that has been formed is collected into a
107 container attached to the end of the pipe. The liquid smoke obtained is then allowed to settle the tar
108 formed for three weeks and filtered to obtain clear liquid smoke.

109

110 **Total volatile bases assay**

111 Total volatile base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
112 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
113 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
114 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
115 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
116 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
117 TVB levels in the smoked fish meat were expressed as mg N/100g.

118
$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times dilution \times 100}{sample\ weight\ (g)}$$

119

120 **Moisture content assay**

121 The moisture content by method of Indonesia National Standard (Indonesia Standardization Agency,
 122 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a porcelain
 123 cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples were
 124 then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content was
 125 expressed as %.

126
$$\text{Moisture (\%)} = \frac{B (g) - C (g)}{B(g) - A (g)} \times 100\%$$

127

128 **Water activity (Aw) assay**

129 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
 130 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
 131 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
 132 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
 133 (Saputra *et al.*, 2014).

134

135 **pH assay**

136 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28°C . The sample
 137 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
 138 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
 139 HI99192) (Lekahena & Jamin, 2018).

140

141 **Phenol level assay**

142 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
 143 50%, homogenized, and allowed to stand for 5 minutes. Then added, 1 mL of 5% Na_2CO_3 and left in
 144 the dark for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a
 145 spectrophotometer (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were
 146 expressed as mg/g (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

147
$$\text{Total Phenol } \left(\frac{\text{mg}}{\text{g}}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{\text{mg}}{\text{L}}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

148

149 **Polycyclic aromatic hydrocarbon (PAH) assay**

150 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
 151 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL

152 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,
153 the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel
154 and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained
155 and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1)
156 and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase
157 was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract
158 was dried under nitrogen gas.

159 After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and
160 transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was
161 added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane.
162 A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and
163 stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible
164 light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH
165 compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector.
166 The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20%
167 water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was
168 used for PAH concentration calculation.

169

170 Sensory assessment assay

171 Sensory assessment assay refers to Indonesia National Standard (Indonesia Standardization Agency,
172 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were
173 placed on a plastic plate with a glass of water, coded, and presented to 30 panelists randomly under
174 light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance
175 of the samples on a scale of 1 – 9.

176

177

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

178

179 **Data analysis**

180 Data analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test.

184 **Results and discussion**

185 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
186 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
187 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
188 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
189 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
190 and sensory assessment.

192 **Total volatile bases**

193 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
194 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
195 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
196 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
197 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
198 products and is emerging as the most commonly used chemical parameter to assess the palatability of
199 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
200 *julung* are presented in Fig. 2.

201

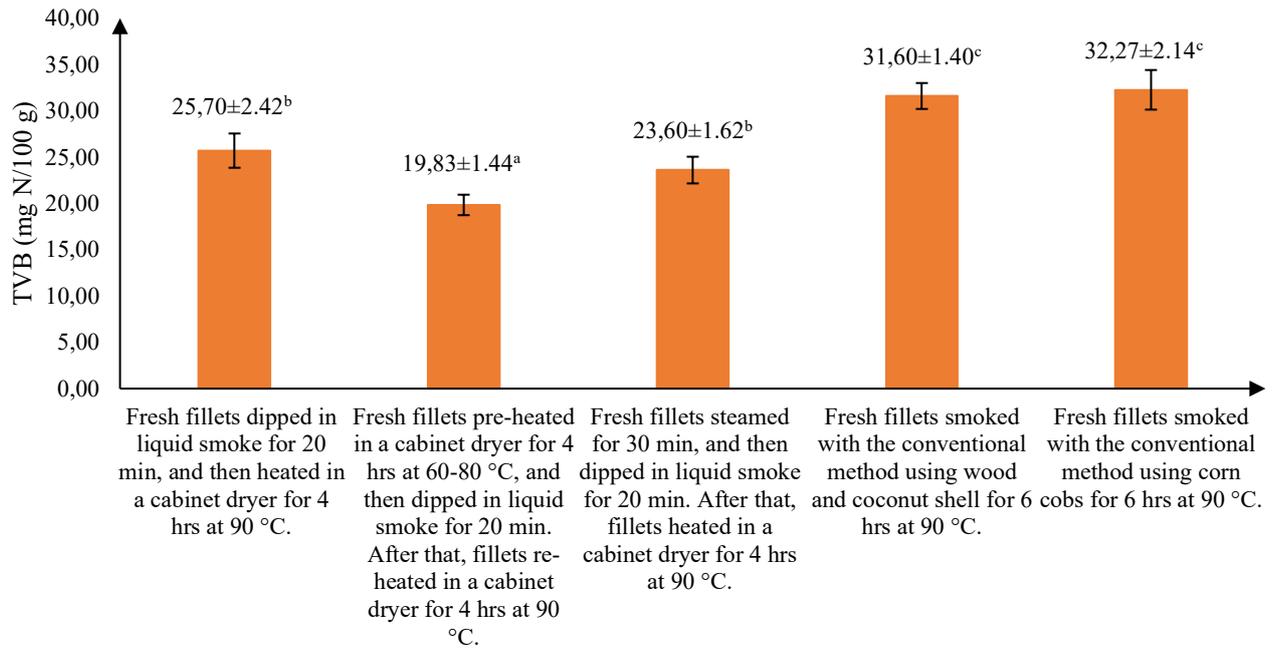


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018). Duncan's analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). Duncan's analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

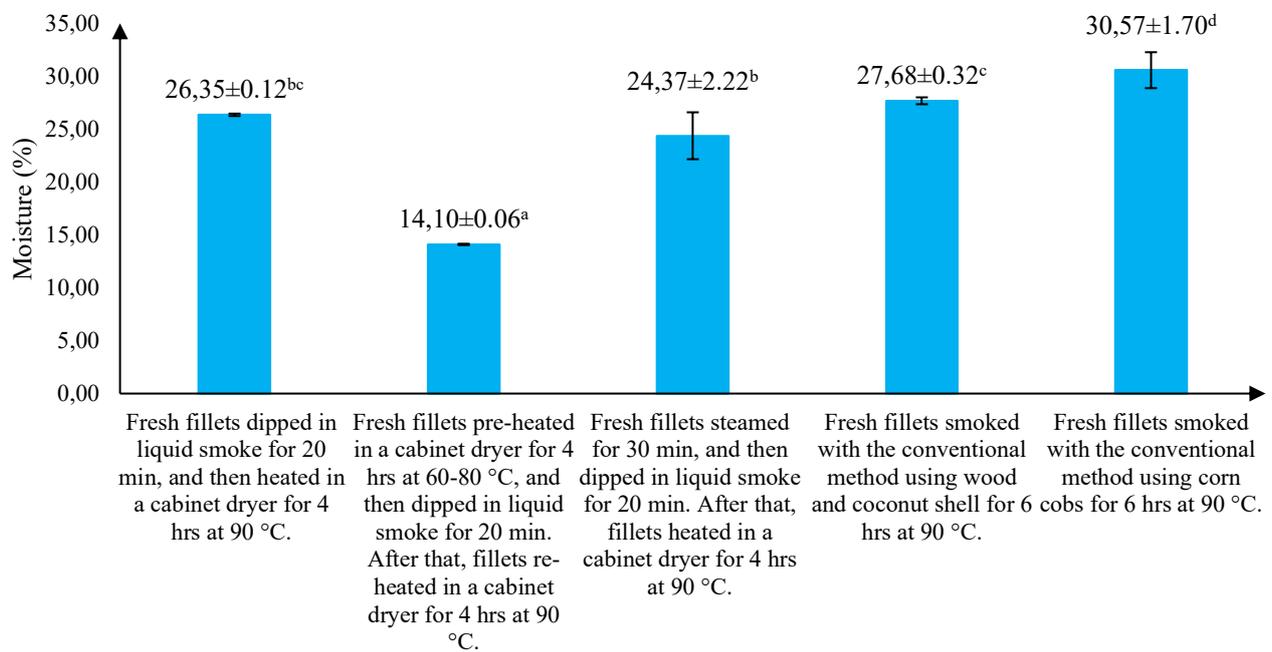
224 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 225 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 226 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 227 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 228 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 229 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 230 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 231 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 232 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

233

234 **Moisture content**

235 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 236 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 237 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 238 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 239 content of smoked fish fillets is presented in Fig. 3.

240



241

242

Fig. 3. Moisture content of *julung julung* smoked fillet

243

244 Fig. 3 shows the analysis of the variance of smoked *julung julung* fish fillets with different smoking
 245 methods treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung*
 246 *julung* fish fillets ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The

247 moisture content value in smoked fish products from all treatments still meets the Indonesian National
248 Standard No. 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization
249 Agency, 2013). Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content
250 of fish to below 40%, which can help preserve it longer. The treatment of the smoking method with
251 liquid smoke with corn cob (Treatment A, B, C) has a lower moisture content when compared to the
252 treatment of the conventional smoking method (Treatment D and E). This result is because the smoking
253 chamber is not fully enclosed in the conventional smoking method, so the heat generated could be more
254 optimal. Suboptimal heat can increase moisture content and cause the moisture content of smoked fish
255 to decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
256 temperature and humidity can be controlled better so that the moisture content of the product can be
257 reduced efficiently (Salindeho & Lumoindong, 2017).

258 Duncan's analysis showed a difference between treatment B, treatment A – C, and treatment D – E on
259 the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
260 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
261 content. This study's results are from previous research, which also reported a significant decrease in
262 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021).
263 Duncan's analysis also showed that treatments A and C were not different because steaming in treatment
264 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
265 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
266 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

267

268 **Water activity (Aw)**

269 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
270 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
271 whether water tends to move from the food product into the cells of microorganisms that may be present.
272 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
273 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
274 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
275 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
276 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
277 fillets can be seen in Fig. 4.

278

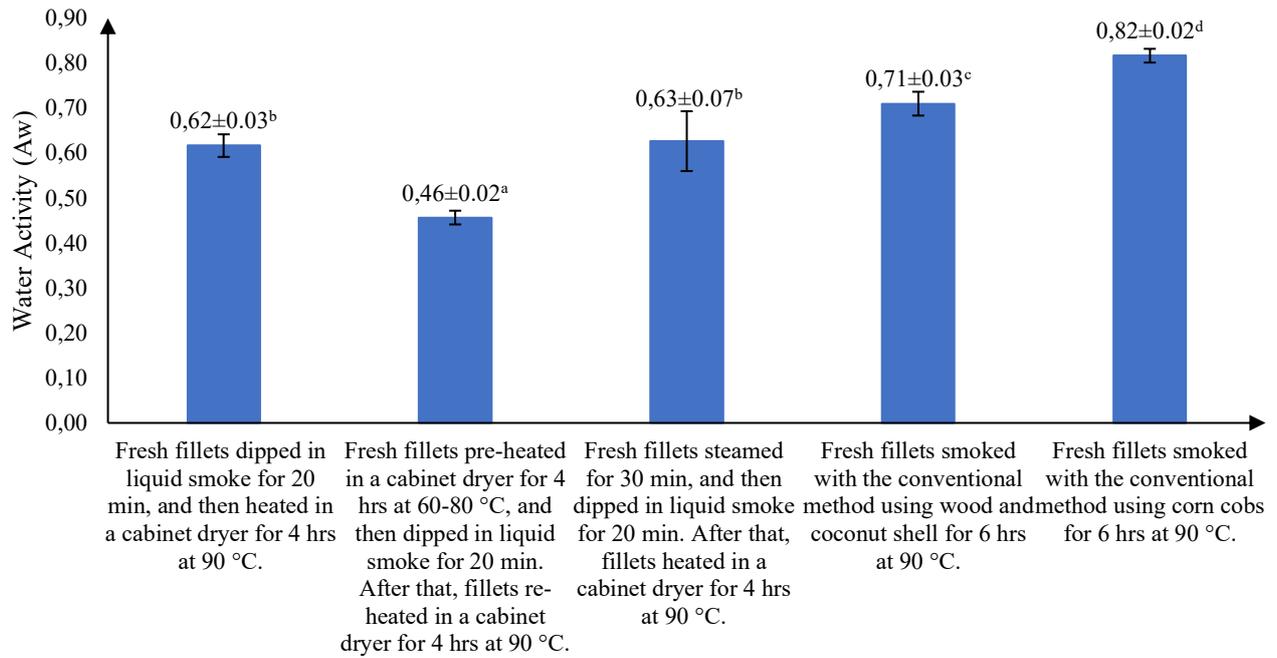


Fig. 4. Water activity of *julung julung* smoked fillet

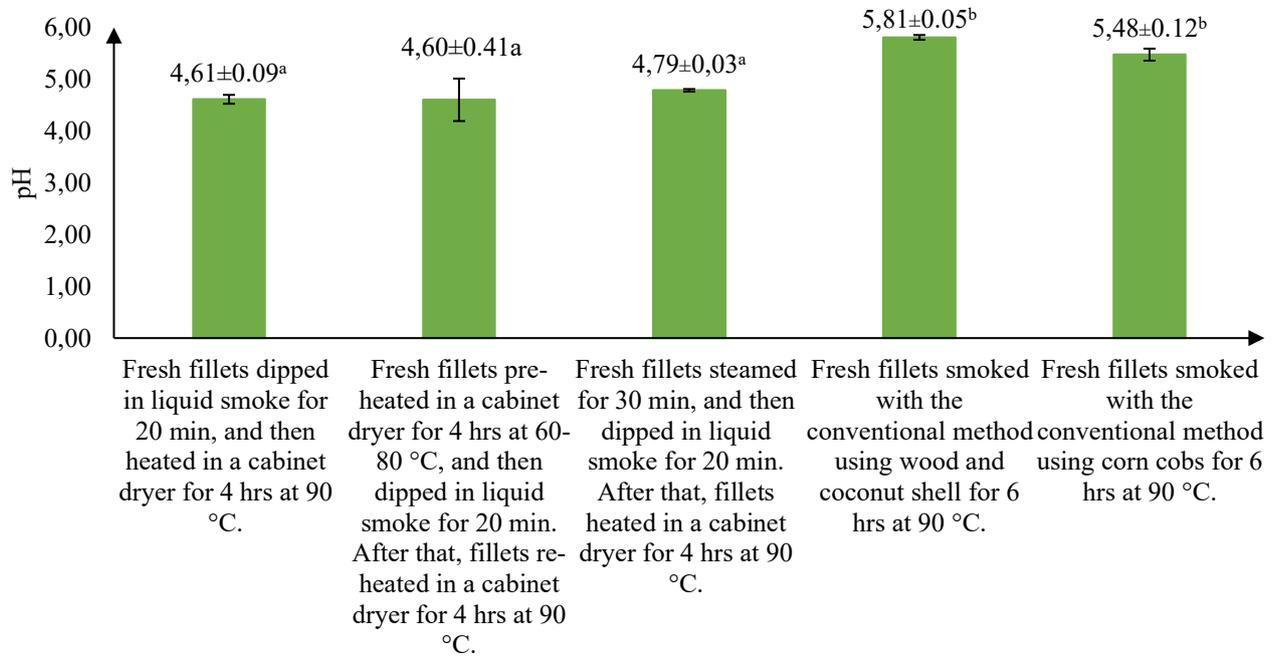
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

302 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 303 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 304 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 305 causes a decrease in pH (Berhimpon *et al.*, 2018).
 306



307

308

309

Fig. 5. pH of *julung julung* smoked fillet

310 **Phenol level**

311 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 312 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 313 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 314 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 315 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 316 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 317 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 318 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 319 conventional smoking method (treatments D and E).

320

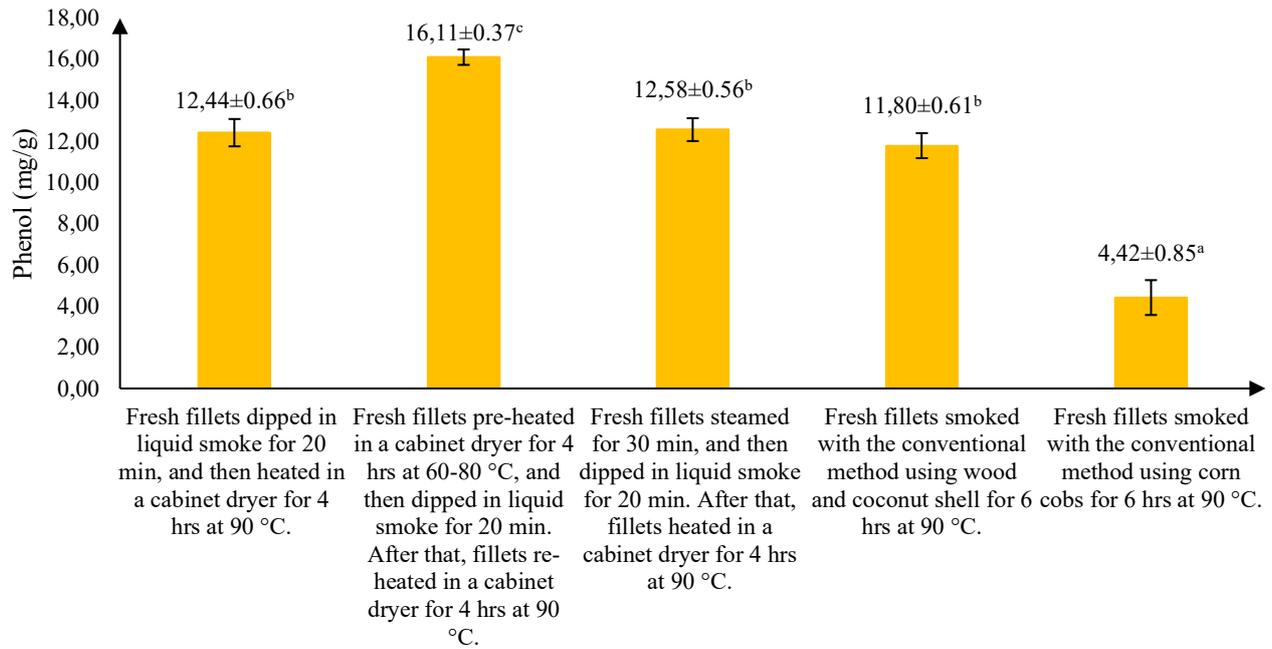


Fig. 6. Phenol level of *julung julung* smoked fillet

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323

324 Duncan's analysis showed phenol levels in treatments A, C, and D were not different. Previous research
 325 reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products
 326 (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated
 327 process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a
 328 large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there
 329 is less smoke condensation than products smoked at lower temperatures. The results of this study
 330 indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*,
 331 2019).

332 The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*,
 333 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method
 334 of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol
 335 content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol
 336 content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

337

338 **Polycyclic aromatic hydrocarbon (PAH) levels**

339 Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion,
 340 such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of
 341 smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic
 342 marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH)
 343 levels in smoked fish fillets can be seen in Table 2.

344 **Table 2.** Polycyclic aromatic hydrocarbon levels in *julung julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8%(µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

345 nd = not detected

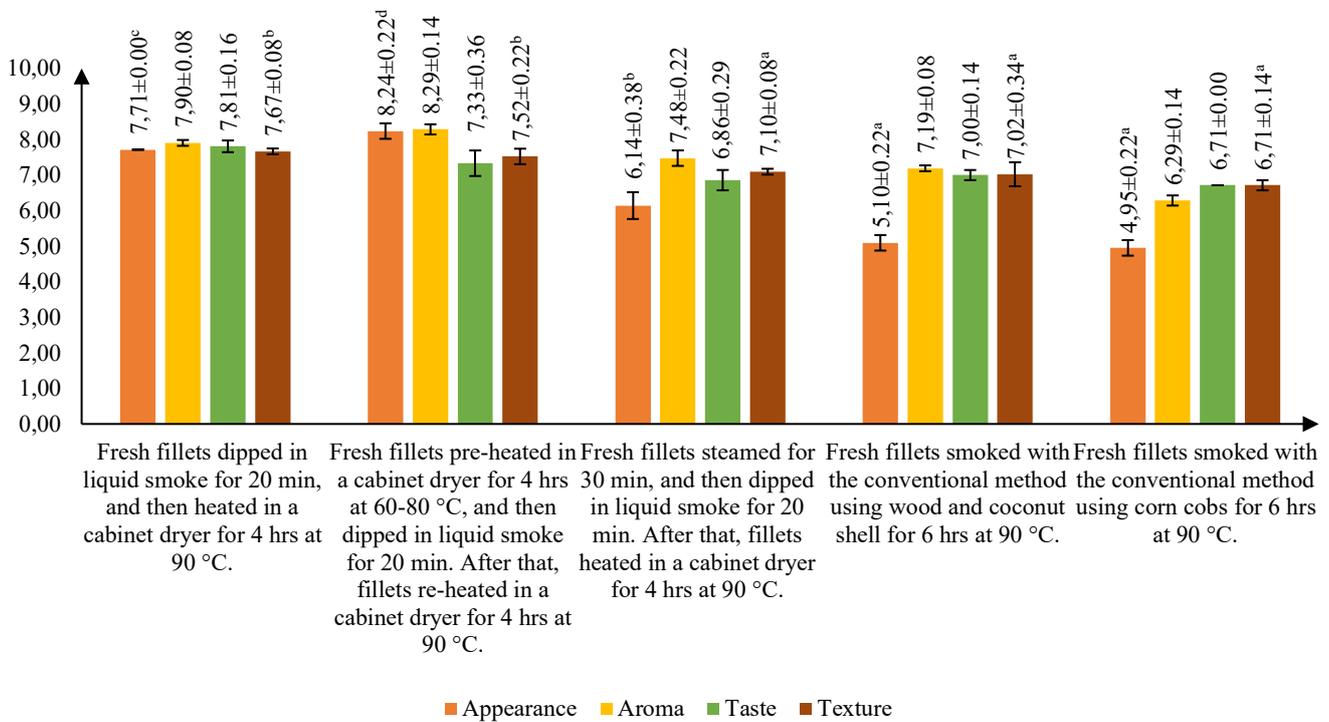
346
 347 Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian
 348 National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia
 349 Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the
 350 Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported
 351 benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about
 352 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout
 353 ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et*
 354 *al.*, 2010). Berhimpion *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25
 355 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg,
 356 benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg,
 357 and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

358 High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking
 359 process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21%
 360 (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut
 361 shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on
 362 a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH
 363 compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification
 364 processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds
 365 (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using
 366 corncobs are lower than those smoked with shells and coconut wood.

367
 368 **Sensory assessment**

369 A sensory assessment is carried out to evaluate the panelist's preference level, including appearance,
 370 aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product
 371 and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of
 372 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 373 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to

374 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 375 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 376 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 377 smoked fillet from each treatment can be seen in Fig. 7.
 378



379 **Fig. 7.** Sensory assesment of *julung julung* smoked fillet
 380
 381

382 **Appearance:** Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of
 383 smoked *julung julung* fish fillets with different smoking method treatments affecting the appearance of
 384 smoked fish ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from
 385 4.95 to 8.24, with the highest panelists' assessment in treatment B. Based on the requirements of the
 386 Indonesian National Standard, only treatments A and B met the minimum panelist assessment
 387 requirement of 7. The moisture content factor is thought to have influenced the panelists' assessment of
 388 the appearance of smoked fish, so panelists less favored treatment C with steaming. Moisture content
 389 can affect the physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*,
 390 2020a). Smoked fish with high moisture content will make the color of smoked fish look paler
 391 (Flick, 2010).
 392 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 393 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 394 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another
 395 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the

396 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
397 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et al.*,
398 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
399 to the interaction of carbonyls with amino components on the surface of the meat. The color and
400 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
401 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
402 (Montazeri *et al.*, 2013).

403 **Aroma:** Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked
404 fish fillets *julung julung* with different smoking method treatments that did not affect the appearance of
405 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
406 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
407 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
408 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
409 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
410 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
411 hours in all treatments has not influenced the taste and aroma of smoked fish.

412 **Taste:** Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
413 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
414 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
415 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
416 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
417 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
418 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
419 fish (Sukowati *et al.*, 2021).

420 **Texture:** Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish
421 fillet *julung julung* with different smoking method treatments giving effect to the texture of smoked fish
422 ($p<0.05$). Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67,
423 with the highest panelist assessment in treatments A and B. Duncan's test analysis showed that
424 treatments A and B differed from treatments C, D, and E. This result was thought to be because the fish
425 fillets were dipped in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C
426 (fish fillets subjected to steaming), the texture of the smoked fillets was rather sticky and not solid.
427 Treatments D and E produced the texture of smoked fish fillets which were less dense and not compact.
428 The texture of smoked fish is negatively correlated with its moisture content. The higher the moisture
429 content in smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content
430 in smoked fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

431 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
432 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
433 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
434 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
435 the mouth when chewed (Ticoalu *et al.*, 2019).

436

437 **Conclusion**

438 Based on the findings of this study, it can be concluded that treatment B (Fresh fillets pre-heated in a
439 cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the
440 fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.), when compared to the conventional
441 smoking treatment based on total volatile bases, moisture content, water activity, pH value, phenol level,
442 polycyclic aromatic hydrocarbon content, and sensory assessment. In general, fish smoking dipped in
443 liquid smoke from corn cob produced a better quality of smoked fish than the conventional smoking
444 method. It is necessary to evaluate different smoking times on smoked fish fillets of *julung julung* with
445 liquid smoke method from corn cob.

446

447 **Acknowledgement (bold)**

448 **Author contributions**

449 **Conflicts of interest**

450 The authors declare that there is no conflict of interest.

451

452

453 **Highlights**

- 454 • Liquid smoke from corn cobs can increase total phenols. Fillets dried and soaked in liquid
455 smoke.

456

457

458 **References**

- 459 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
460 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 461 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
462 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
463 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 464 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
465 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*
466 *T1-T2-2020)*, 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>

- 467 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
468 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
469 <https://doi.org/10.21767/2572-5459.100026>
- 470 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
471 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 472
- 473 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
474 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 475 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
476 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 477 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
478 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 479 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
480 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
481 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 482 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
483 *Global Scientific Journal*, 1(2), 77–84.
- 484 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
485 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
486 <https://doi.org/10.1080/10498850.2020.1741752>
- 487 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
488 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
489 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 490 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
491 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
492 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 493 Baten, M. A., Won, N. E., Mohibullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
494 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
495 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 496 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
497 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
498 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 499 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
500 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 501 Berhimpon, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
502 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
503 1864–1869.
- 504 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
505 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
506 <https://doi.org/10.1007/s11694-019-00347-6>
- 507 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from [http://www.bccdc.ca/resource-](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
508 [gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)

- 509 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
510 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
511 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 512 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
513 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
514 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 515 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
516 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
517 <https://doi.org/10.2139/ssrn.3793663>
- 518 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
519 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
520 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 521 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
522 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
523 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 524 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
525 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 526 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
527 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
528 *Publications*, 3(3), 8–14.
- 529 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
530 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 531 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
532 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
533 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 534 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
535 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
536 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 537 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
538 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
539 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 540 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
541 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 542 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
543 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
544 <https://doi.org/10.4172/2572-4134.1000127>
- 545 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
546 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 547 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
548 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
549 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.
550 <https://doi.org/10.3390/foods11192938>

- 551 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
552 418, 31–32.
- 553 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
554 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
555 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
556 <https://doi.org/10.3390/fermentation8120704>
- 557 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
558 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 559 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
560 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 561 Hardianto, L., & Yuniarta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
562 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 563 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
564 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
565 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 566 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
567 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 568 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
569 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
571 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
573 Jakarta: Indonesia. (in Indonesia)
- 574 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
575 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 576 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
577 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
578 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 579 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
580 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
581 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
582 (in Indonesia)
- 583 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
584 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
585 <https://doi.org/10.1016/j.asej.2021.05.013>
- 586 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
587 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
588 Indonesia)
- 589 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
590 <https://doi.org/10.1007/s10086-016-1606-z>
- 591 Kiczorowska, B., Samolińska, W., Grela, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
592 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>

- 593 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
594 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. [https://doi.org/10.20474/japs-](https://doi.org/10.20474/japs-5.2.1)
595 5.2.1
- 596 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
597 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
598 Indonesia)
- 599 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
600 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 601 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
602 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
603 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 604 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
605 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 606 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
607 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 608 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
609 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
610 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 611 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
612 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
613 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 614 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
615 *Today*, 3(5), 409–412.
- 616 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
617 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
618 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 619 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
620 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 621 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
622 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
623 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 624 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
625 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
626 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 627 Nazmi, M. S., Dardak, R. A., Rani, R. A., & Rabu, M. R. (2021). *Benchmarking Indonesia for the development of the grain*
628 *corn industry in Malaysia*. FFTC Agricultural Policy Platform. Retrieved from <https://ap.ffc.org.tw/article/2782>
- 629 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
630 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
631 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 632 Nugroho, S., Soeparma, S., & Yulianti, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
633 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
634 (in Indonesia)

- 635 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
636 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
637 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 638 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
639 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
640 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 641 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
642 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
643 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 644 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
645 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 646 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
647 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 648 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
649 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
650 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 651 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
652 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
653 180. <https://www.atlantis-pess.com/article/125938018.pdf>
- 654 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
655 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
656 <https://doi.org/10.2993/0278-0771-36.2.312>
- 657 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
658 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
659 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 660 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
661 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
662 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 663 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
664 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
665 [https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
666 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 667 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
668 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
669 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 670 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
671 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
672 *Riau*, 2(2), 1–6. (in Indonesia)
- 673 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
674 wax. *Animal Agriculture Journal*, 3(1), 34–40.
- 675 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
676 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in

- 677 Indonesia)
- 678 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
679 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
680 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 681 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
682 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
683 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 684 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
685 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
686 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 687 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
688 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 689 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
690 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
691 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 692 Stołyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
693 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 694 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
695 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 696 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
697 briquettes (corncob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
698 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 699 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
700 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
701 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 702 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
703 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
704 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 705 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
706 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 707 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
708 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 709 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
710 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 711 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
712 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 713 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
714 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 715 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
716 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*
717 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 718 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid

- 719 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
720 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 721 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
722 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
723 6(3), 281–286.
- 724 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
725 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
726 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 727 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
728 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 729 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
730 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
731 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 732 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
733 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 734 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
735 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
736 6379. <https://doi.org/10.1021/ef5013769>

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[Kutipan teks disembunyikan]

37 while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used
38 to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced may
39 vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
40 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
41 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

42 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
43 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
44 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
45 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
46 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
47 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
48 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
49 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
50 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
51 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
52 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
53 (Azis & Akolo, 2020).

54 The study's reported that the conventional smoking process has disadvantages such as smoking time,
55 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
56 2020). Conventional smoking of food products has been shown to produce carcinogenic components
57 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
58 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
59 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
60 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

61 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
62 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
63 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
64 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
65 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
66 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
67 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

68 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
69 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*
70 *et al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
71 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on

72 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
73 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed
74 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
75 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
76 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
77 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
78 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
79 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
80 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
81 polycyclic aromatic hydrocarbon content, and sensory assessment.

82

83 **Materials and methods**

84 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
85 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
86 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
87 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
88 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
89 (Mishra *et al.*, 2021). Then, the fish was washed, weeded, and filleted. The cleaned fillets were dipped
90 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
91 (Berhimpon *et al.*, 2018).

92



93

94

95

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

96 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
97 of *julung julung* fish fillets, which was compared with the conventional method (using coconut wood,
98 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then heated in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets pre-heated in a cabinet dryer for 4 hours at 60 – 80 °C, and then dipped in liquid smoke for 20 minutes. After that, fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes and then dipped in liquid smoke for 20 minutes. After that, fillets were heated in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

99

100 **Liquid smoke manufacturing process**

101 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
102 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
103 cobs were gradually burned into the combustion furnace. The furnace was closed to prevent smoke from
104 escaping from the tank. The smoke generated from the combustion flows through a pipe connected to a
105 storage tank covered with ice cubes. The smoke that passes through the pipe will become cold, so
106 condensation occurs, turning the smoke into liquid. The smoke that has been formed is collected into a
107 container attached to the end of the pipe. The liquid smoke obtained is then allowed to settle the tar
108 formed for three weeks and filtered to obtain clear liquid smoke.

109

110 **Total volatile bases assay**

111 Total volatile base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
112 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
113 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
114 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
115 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
116 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
117 TVB levels in the smoked fish meat were expressed as mg N/100g.

118
$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times dilution \times 100}{sample\ weight\ (g)}$$

119

120 **Moisture content assay**

121 The moisture content by method of Indonesia National Standard (Indonesia Standardization Agency,
122 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a porcelain
123 cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples were
124 then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content was
125 expressed as %.

126
$$\text{Moisture (\%)} = \frac{B (g) - C (g)}{B(g) - A (g)} \times 100\%$$

127

128 **Water activity (Aw) assay**

129 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
130 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
131 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
132 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
133 (Saputra *et al.*, 2014).

134

135 **pH assay**

136 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28°C . The sample
137 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
138 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
139 HI99192) (Lekahena & Jamin, 2018).

140

141 **Phenol level assay**

142 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
143 50%, homogenized, and allowed to stand for 5 minutes. Then added, 1 mL of 5% Na_2CO_3 and left in
144 the dark for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a
145 spectrophotometer (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were
146 expressed as mg/g (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

147
$$\text{Total Phenol } \left(\frac{\text{mg}}{\text{g}}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{\text{mg}}{\text{L}}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

148

149 **Polycyclic aromatic hydrocarbon (PAH) assay**

150 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
151 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL

152 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,
153 the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel
154 and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained
155 and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1)
156 and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase
157 was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract
158 was dried under nitrogen gas.

159 After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and
160 transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was
161 added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane.
162 A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and
163 stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible
164 light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH
165 compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector.
166 The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20%
167 water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was
168 used for PAH concentration calculation.

169

170 Sensory assessment assay

171 Sensory assessment assay refers to Indonesia National Standard (Indonesia Standardization Agency,
172 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were
173 placed on a plastic plate with a glass of water, coded, and presented to 30 panelists randomly under
174 light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance
175 of the samples on a scale of 1 – 9.

176

177

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

178

179 **Data analysis**

180 Data analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test.

184 **Results and discussion**

185 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
186 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
187 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
188 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
189 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
190 and sensory assessment.

192 **Total volatile bases**

193 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
194 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
195 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
196 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
197 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
198 products and is emerging as the most commonly used chemical parameter to assess the palatability of
199 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
200 *julung* are presented in Fig. 2.

201

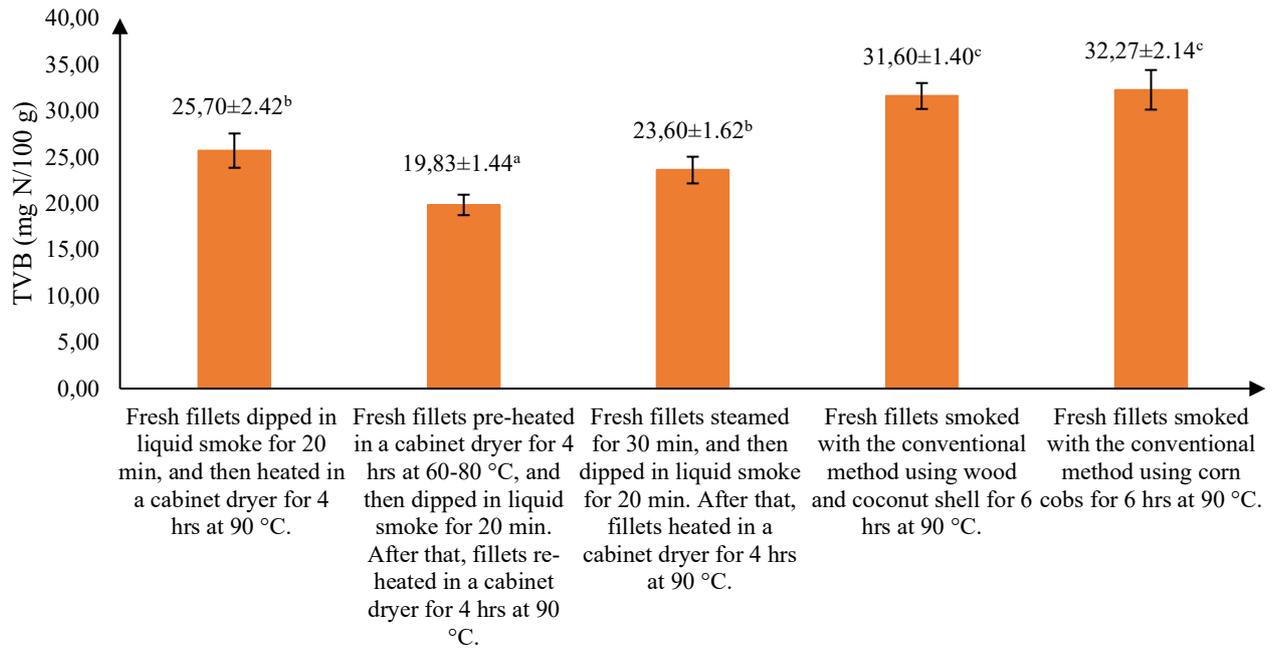


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018). Duncan's analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). Duncan's analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

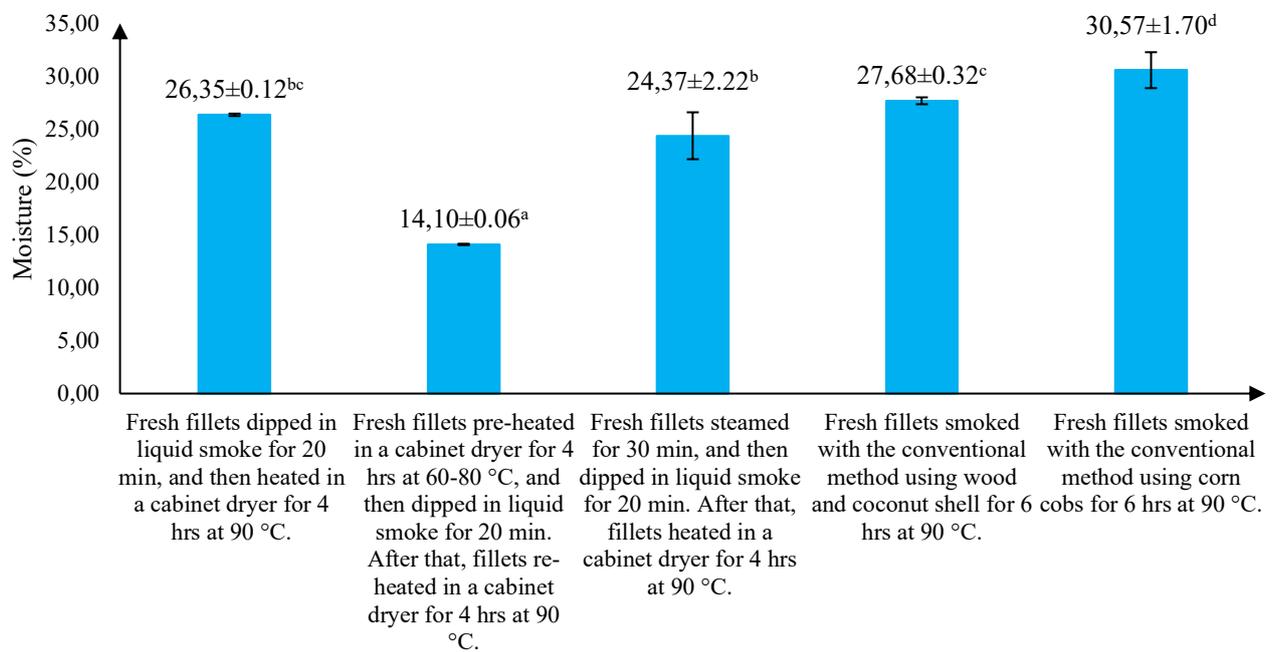
224 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 225 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 226 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 227 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 228 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 229 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 230 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 231 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 232 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

233

234 **Moisture content**

235 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 236 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 237 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 238 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 239 content of smoked fish fillets is presented in Fig. 3.

240



241

242 **Fig. 3.** Moisture content of *julung julung* smoked fillet

243

244 Fig. 3 shows the analysis of the variance of smoked *julung julung* fish fillets with different smoking
 245 methods treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung*
 246 *julung* fish fillets ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The

247 moisture content value in smoked fish products from all treatments still meets the Indonesian National
248 Standard No. 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization
249 Agency, 2013). Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content
250 of fish to below 40%, which can help preserve it longer. The treatment of the smoking method with
251 liquid smoke with corn cob (Treatment A, B, C) has a lower moisture content when compared to the
252 treatment of the conventional smoking method (Treatment D and E). This result is because the smoking
253 chamber is not fully enclosed in the conventional smoking method, so the heat generated could be more
254 optimal. Suboptimal heat can increase moisture content and cause the moisture content of smoked fish
255 to decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
256 temperature and humidity can be controlled better so that the moisture content of the product can be
257 reduced efficiently (Salindeho & Lumoindong, 2017).

258 Duncan's analysis showed a difference between treatment B, treatment A – C, and treatment D – E on
259 the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
260 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
261 content. This study's results are from previous research, which also reported a significant decrease in
262 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021).
263 Duncan's analysis also showed that treatments A and C were not different because steaming in treatment
264 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
265 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
266 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

267

268 **Water activity (Aw)**

269 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
270 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
271 whether water tends to move from the food product into the cells of microorganisms that may be present.
272 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
273 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
274 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
275 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
276 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
277 fillets can be seen in Fig. 4.

278

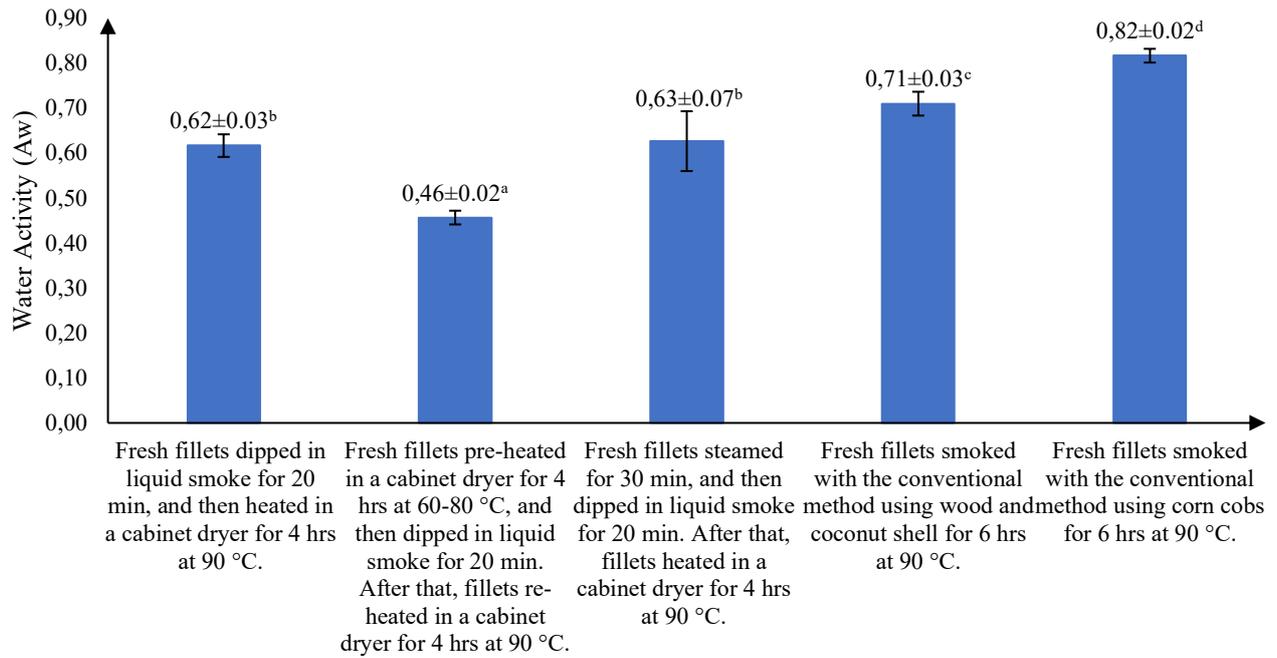


Fig. 4. Water activity of *julung julung* smoked fillet

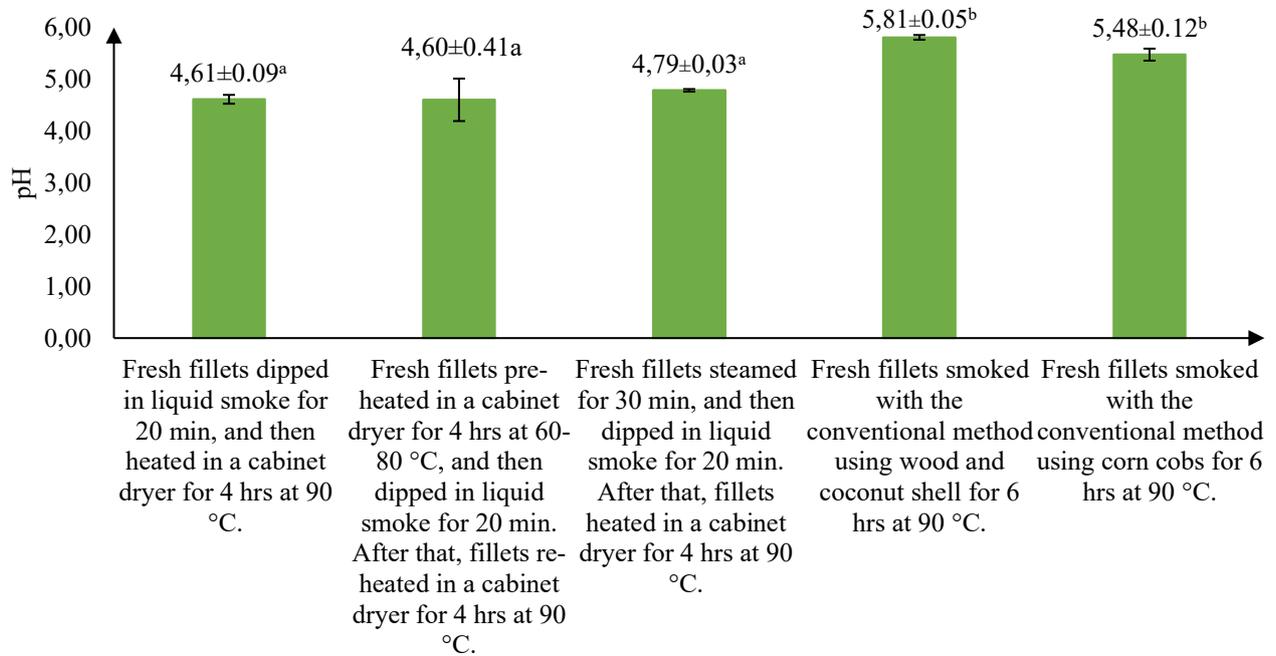
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

302 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 303 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 304 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 305 causes a decrease in pH (Berhimpon *et al.*, 2018).
 306



307

308

309

Fig. 5. pH of *julung julung* smoked fillet

310 **Phenol level**

311 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 312 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 313 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 314 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 315 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 316 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 317 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 318 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 319 conventional smoking method (treatments D and E).

320

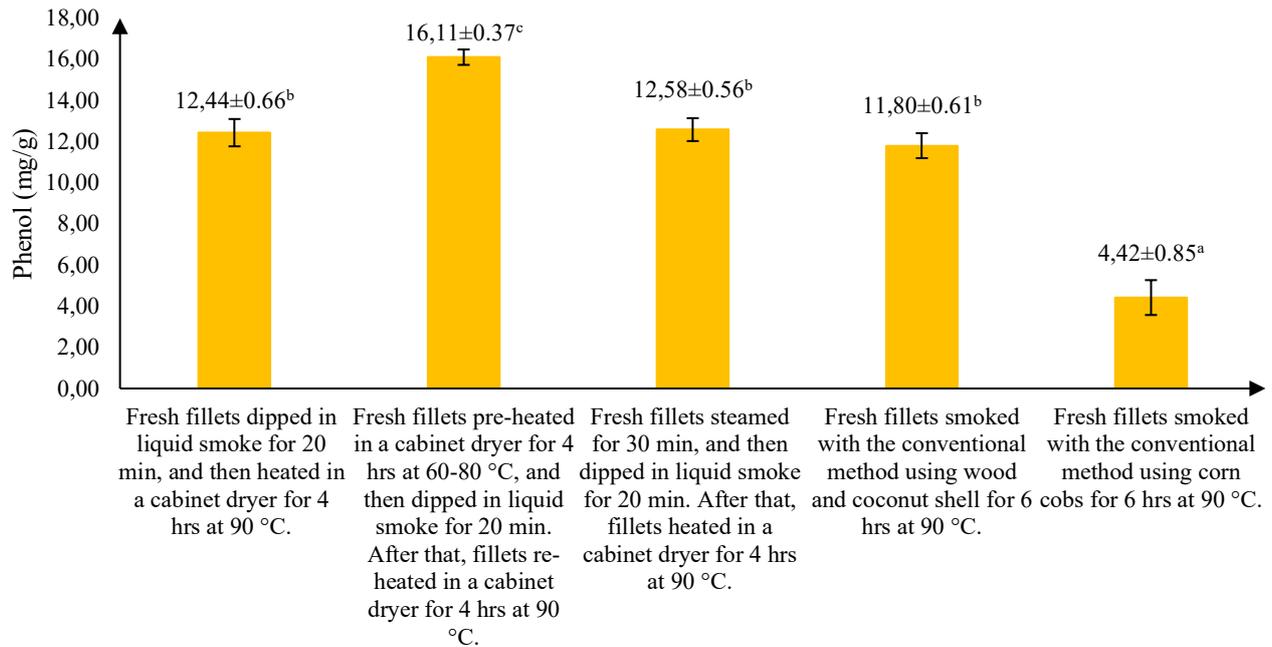


Fig. 6. Phenol level of *julung julung* smoked fillet

321

322

323

324 Duncan's analysis showed phenol levels in treatments A, C, and D were not different. Previous research
 325 reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products
 326 (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated
 327 process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a
 328 large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there
 329 is less smoke condensation than products smoked at lower temperatures. The results of this study
 330 indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*,
 331 2019).

332 The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*,
 333 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method
 334 of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol
 335 content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol
 336 content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

337

338 **Polycyclic aromatic hydrocarbon (PAH) levels**

339 Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion,
 340 such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of
 341 smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic
 342 marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH)
 343 levels in smoked fish fillets can be seen in Table 2.

344 **Table 2.** Polycyclic aromatic hydrocarbon levels in *julung julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8%(µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

345 nd = not detected

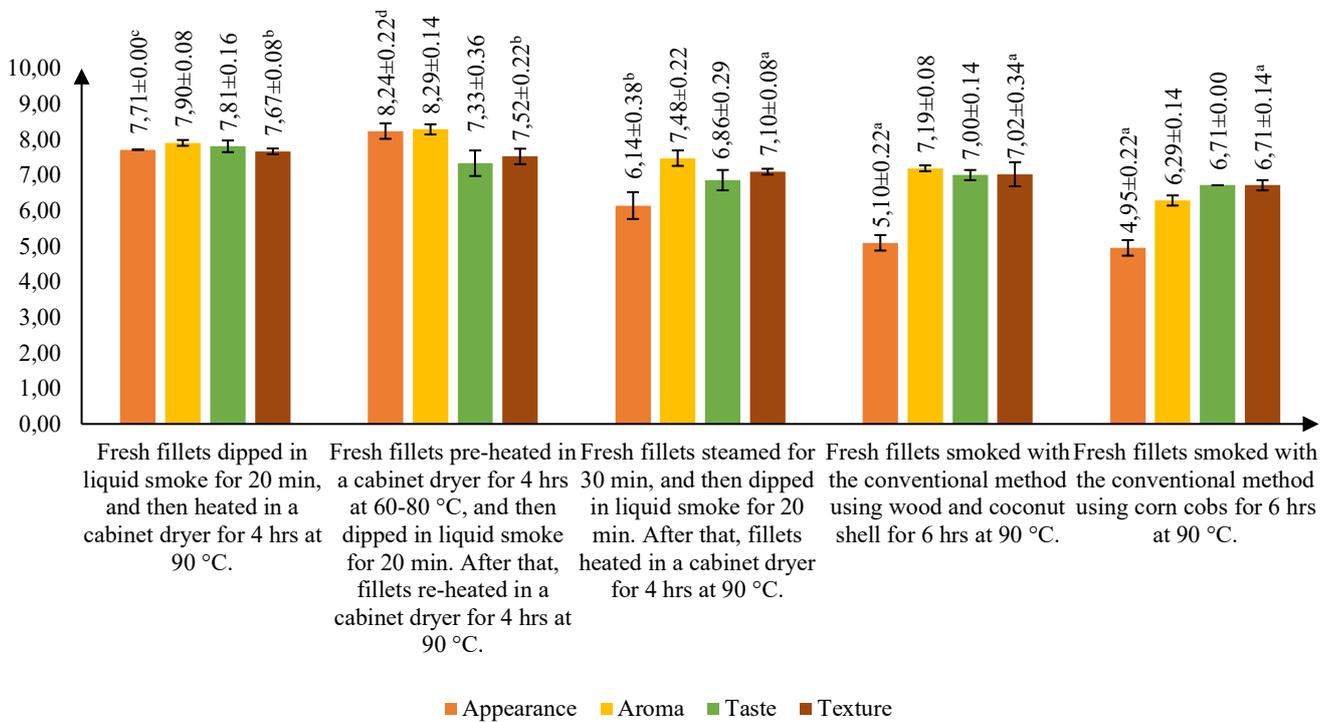
346
 347 Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian
 348 National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia
 349 Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the
 350 Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported
 351 benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about
 352 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout
 353 ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et*
 354 *al.*, 2010). Berhimpion *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25
 355 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg,
 356 benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg,
 357 and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

358 High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking
 359 process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21%
 360 (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut
 361 shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on
 362 a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH
 363 compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification
 364 processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds
 365 (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using
 366 corncobs are lower than those smoked with shells and coconut wood.

367
 368 **Sensory assessment**

369 A sensory assessment is carried out to evaluate the panelist's preference level, including appearance,
 370 aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product
 371 and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of
 372 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 373 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to

374 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 375 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 376 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 377 smoked fillet from each treatment can be seen in Fig. 7.
 378



379 **Fig. 7.** Sensory assesment of *julung julung* smoked fillet
 380
 381

382 **Appearance:** Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of
 383 smoked *julung julung* fish fillets with different smoking method treatments affecting the appearance of
 384 smoked fish ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from
 385 4.95 to 8.24, with the highest panelists' assessment in treatment B. Based on the requirements of the
 386 Indonesian National Standard, only treatments A and B met the minimum panelist assessment
 387 requirement of 7. The moisture content factor is thought to have influenced the panelists' assessment of
 388 the appearance of smoked fish, so panelists less favored treatment C with steaming. Moisture content
 389 can affect the physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*,
 390 2020a). Smoked fish with high moisture content will make the color of smoked fish look paler
 391 (Flick, 2010).

392 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 393 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 394 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another
 395 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the

396 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
397 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et al.*,
398 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
399 to the interaction of carbonyls with amino components on the surface of the meat. The color and
400 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
401 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
402 (Montazeri *et al.*, 2013).

403 **Aroma:** Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked
404 fish fillets *julung julung* with different smoking method treatments that did not affect the appearance of
405 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
406 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
407 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
408 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
409 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
410 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
411 hours in all treatments has not influenced the taste and aroma of smoked fish.

412 **Taste:** Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
413 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
414 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
415 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
416 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
417 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
418 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
419 fish (Sukowati *et al.*, 2021).

420 **Texture:** Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish
421 fillet *julung julung* with different smoking method treatments giving effect to the texture of smoked fish
422 ($p<0.05$). Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67,
423 with the highest panelist assessment in treatments A and B. Duncan's test analysis showed that
424 treatments A and B differed from treatments C, D, and E. This result was thought to be because the fish
425 fillets were dipped in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C
426 (fish fillets subjected to steaming), the texture of the smoked fillets was rather sticky and not solid.
427 Treatments D and E produced the texture of smoked fish fillets which were less dense and not compact.
428 The texture of smoked fish is negatively correlated with its moisture content. The higher the moisture
429 content in smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content
430 in smoked fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

431 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
432 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
433 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
434 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
435 the mouth when chewed (Ticoalu *et al.*, 2019).

436

437 **Conclusion**

438 Based on the findings of this study, it can be concluded that treatment B (Fresh fillets pre-heated in a
439 cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the
440 fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.), when compared to the conventional
441 smoking treatment based on total volatile bases, moisture content, water activity, pH value, phenol level,
442 polycyclic aromatic hydrocarbon content, and sensory assessment. In general, fish smoking dipped in
443 liquid smoke from corn cob produced a better quality of smoked fish than the conventional smoking
444 method. It is necessary to evaluate different smoking times on smoked fish fillets of *julung julung* with
445 liquid smoke method from corn cob.

446

447 **Acknowledgement (bold)**

448 **Author contributions**

449 **Conflicts of interest**

450 The authors declare that there is no conflict of interest.

451

452

453 **Highlights**

- 454 • Liquid smoke from corn cobs can increase total phenols. Fillets dried and soaked in liquid
455 smoke.

456

457

458 **References**

- 459 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
460 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 461 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
462 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
463 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 464 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
465 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*
466 *T1-T2-2020)*, 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>

- 467 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
468 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
469 <https://doi.org/10.21767/2572-5459.100026>
- 470 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
471 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 472
- 473 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
474 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 475 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
476 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 477 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
478 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 479 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
480 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
481 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 482 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
483 *Global Scientific Journal*, 1(2), 77–84.
- 484 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
485 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
486 <https://doi.org/10.1080/10498850.2020.1741752>
- 487 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
488 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
489 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 490 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
491 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
492 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 493 Baten, M. A., Won, N. E., Mohibullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
494 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
495 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 496 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
497 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
498 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 499 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
500 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 501 Berhimpon, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
502 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
503 1864–1869.
- 504 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
505 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
506 <https://doi.org/10.1007/s11694-019-00347-6>
- 507 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from [http://www.bccdc.ca/resource-](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
508 [gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)

- 509 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
510 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
511 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 512 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
513 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
514 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 515 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
516 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
517 <https://doi.org/10.2139/ssrn.3793663>
- 518 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
519 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
520 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 521 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
522 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
523 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 524 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
525 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 526 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
527 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
528 *Publications*, 3(3), 8–14.
- 529 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
530 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 531 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
532 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
533 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 534 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
535 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
536 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 537 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
538 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
539 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 540 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
541 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 542 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
543 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
544 <https://doi.org/10.4172/2572-4134.1000127>
- 545 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
546 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 547 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
548 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
549 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.
550 <https://doi.org/10.3390/foods11192938>

- 551 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
552 418, 31–32.
- 553 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
554 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
555 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
556 <https://doi.org/10.3390/fermentation8120704>
- 557 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
558 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 559 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
560 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 561 Hardianto, L., & Yuniarta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
562 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 563 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
564 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
565 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 566 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
567 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 568 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
569 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
571 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
573 Jakarta: Indonesia. (in Indonesia)
- 574 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
575 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 576 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
577 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
578 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 579 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
580 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
581 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
582 (in Indonesia)
- 583 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
584 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
585 <https://doi.org/10.1016/j.asej.2021.05.013>
- 586 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
587 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
588 Indonesia)
- 589 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
590 <https://doi.org/10.1007/s10086-016-1606-z>
- 591 Kiczorowska, B., Samolińska, W., Grela, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
592 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>

- 593 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
594 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. [https://doi.org/10.20474/japs-](https://doi.org/10.20474/japs-5.2.1)
595 5.2.1
- 596 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
597 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
598 Indonesia)
- 599 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
600 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 601 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
602 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
603 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 604 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
605 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 606 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
607 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 608 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
609 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
610 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 611 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
612 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
613 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 614 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
615 *Today*, 3(5), 409–412.
- 616 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
617 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
618 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 619 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
620 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 621 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
622 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
623 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 624 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
625 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
626 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 627 Nazmi, M. S., Dardak, R. A., Rani, R. A., & Rabu, M. R. (2021). *Benchmarking Indonesia for the development of the grain*
628 *corn industry in Malaysia*. FFTC Agricultural Policy Platform. Retrieved from <https://ap.ffc.org.tw/article/2782>
- 629 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
630 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
631 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 632 Nugroho, S., Soeparma, S., & Yuliaty, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
633 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
634 (in Indonesia)

- 635 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
636 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
637 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 638 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
639 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
640 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 641 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
642 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
643 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 644 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
645 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 646 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
647 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 648 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
649 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
650 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 651 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
652 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
653 180. <https://www.atlantis-pess.com/article/125938018.pdf>
- 654 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
655 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
656 <https://doi.org/10.2993/0278-0771-36.2.312>
- 657 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
658 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
659 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 660 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
661 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
662 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 663 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
664 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
665 [https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
666 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 667 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
668 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
669 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 670 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
671 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
672 *Riau*, 2(2), 1–6. (in Indonesia)
- 673 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
674 wax. *Animal Agriculture Journal*, 3(1), 34–40.
- 675 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
676 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in

- 677 Indonesia)
- 678 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
679 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
680 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 681 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
682 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
683 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 684 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
685 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
686 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 687 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
688 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 689 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
690 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
691 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 692 Stołyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
693 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 694 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
695 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 696 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
697 briquettes (corncob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
698 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 699 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
700 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
701 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 702 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
703 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
704 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 705 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
706 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 707 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
708 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 709 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
710 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 711 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
712 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 713 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
714 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 715 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
716 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*
717 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 718 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid

- 719 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
720 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 721 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
722 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
723 6(3), 281–286.
- 724 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
725 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
726 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 727 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
728 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 729 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
730 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
731 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 732 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
733 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 734 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
735 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
736 6379. <https://doi.org/10.1021/ef5013769>

Reviewer 1#

Detailed comments;

Line 179. Change Data analysis to Statistical analysis.

State replicates for all tests.

In figures just put Duncan's letters on the bars. There is no need to mention the numbers on the bars.

Provide the proper abbreviations for the treatments in figures, tables as well as the manuscript text.

Duncan's letters are misattributed, the first letters must show the biggest numbers. Also, Duncan's letters should be added in Table 2.

Sensory evaluation data should be present as a radar plot.

Delete methods from the conclusion section.

The last line of the abstract and conclusion should be revised and the best method mentioned.

1 **Characteristics of *Julung Julung* Smoked Fish Fillets (*Hemiramphus* sp.) using** 2 **Liquid Smoke from Corn Cobs Waste**

3 **Abstract**

4 Corn cobs can be utilized as a shell ingredient for liquid smoke. Liquid smoke can be used for the smoked fish
5 industry in North Sulawesi, Indonesia. However, the utilization of liquid smoke for the smoked fish industry has
6 yet to be optimal. This study aimed to obtain the best smoking method for *julung julung* fish fillets (*Hemiramphus*
7 sp.) using liquid smoke from corn cob waste. The treatment in this study was to apply liquid smoke from corn cob
8 waste in the smoking process, which was compared with the conventional method (using shell, coconut wood, and
9 corn cob). Parameters to determine the quality of smoked fish were total volatile bases (TVB), moisture, water
10 activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed
11 that the TVB of smoked *julung julung* fish fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged
12 from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged
13 from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard.
14 Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these results,
15 it can be concluded that the best treatment is fresh fillets preheated in a cabinet dryer for 4 hours at 60 – 80 °C and
16 then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90
17 °C.

18 **Keywords:** Coconut, Indonesia, Shell, North Sulawesi, Wood

Commented [u1]: Corn cobs
Liquid smoke

20 **Introduction**

21 Corn is the second most widely grown crop in Indonesia after rice. Indonesia is the 7th corn producer in
22 the world, with more than 12 million tons of corn produced in 2020 (Nazmi *et al.*, 2021). North Sulawesi
23 is one of the contributing regions that produce corn in Indonesia. Considerable corn production will also
24 produce waste, especially corn cobs, which are generally thrown away and burned by most Indonesians
25 (Cahyadi *et al.*, 2021).

26 One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can
27 produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from
28 corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs
29 affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*,
30 2018). Another study reported a phenolic content of 335 mg/L in liquid smoke produced from corn cobs
31 (Swastawati *et al.*, 2007).

32 Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et*
33 *al.*, 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without
34 the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save
35 time, energy, and labor and reduce production costs (Krah *et al.*, 2019). In addition, using liquid smoke
36 in food can speed up and standardize the smoking process, adding flavor and microbiological safety

37 while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used
38 to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced may
39 vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
40 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
41 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

42 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
43 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
44 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
45 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
46 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
47 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
48 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
49 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
50 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
51 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
52 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
53 (Azis & Akolo, 2020).

54 The study's reported that the conventional smoking process has disadvantages such as smoking time,
55 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
56 2020). Conventional smoking of food products has been shown to produce carcinogenic components
57 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
58 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
59 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
60 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

61 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
62 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
63 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
64 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
65 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
66 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
67 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

68 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
69 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*
70 *et al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
71 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on

72 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
73 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed
74 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
75 (Berhimpon *et al.*, 2018). ~~The results of these studies indicate that liquid smoke is good to apply to~~
76 ~~smoked fish products.~~ This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
77 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
78 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
79 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
80 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
81 polycyclic aromatic hydrocarbon content, and sensory assessment.

82

83 Materials and methods

84 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
85 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
86 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
87 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
88 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
89 (Mishra *et al.*, 2021). Then, the fish was washed, weeded, and filleted. The cleaned fillets were dipped
90 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
91 (Berhimpon *et al.*, 2018).

92

Commented [u2]: Why used this concentration??



93

94

95

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

96 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
97 of *julung julung* fish fillets, which was compared with the conventional method (using coconut wood,
98 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then heated in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets pre-heated in a cabinet dryer for 4 hours at 60 – 80 °C, and then dipped in liquid smoke for 20 minutes. After that, fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes and then dipped in liquid smoke for 20 minutes. After that, fillets were heated in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

Commented [u3]: Refrences?

Commented [u4]: Refrences?

99

100 Liquid smoke manufacturing process

101 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
102 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
103 cobs were gradually burned into the combustion furnace. The furnace was closed to prevent smoke from
104 escaping from the tank. The smoke generated from the combustion flows through a pipe connected to a
105 storage tank covered with ice cubes. The smoke that passes through the pipe will become cold, so
106 condensation occurs, turning the smoke into liquid. The smoke that has been formed is collected into a
107 container attached to the end of the pipe. The liquid smoke obtained is then allowed to settle the tar
108 formed for three weeks and filtered to obtain clear liquid smoke.

Commented [u5]: Temperature?

Commented [u6]: Reference?

Commented [u7]: How?? To separate what?? how about benzopyrene?

109

110 Total volatile bases assay

111 Total volatile base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
112 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
113 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
114 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
115 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
116 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
117 TVB levels in the smoked fish meat were expressed as mg N/100g.

Commented [u8]: Volatile Base

118

$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times dilution \times 100}{sample\ weight\ (g)}$$

119

120 **Moisture content assay**

121 The moisture content by method of Indonesia National Standard (Indonesia Standardization Agency,
122 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a porcelain
123 cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples were
124 then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content was
125 expressed as %.

126
$$\text{Moisture (\%)} = \frac{B (g) - C (g)}{B(g) - A (g)} \times 100\%$$

127

128 **Water activity (Aw) assay**

129 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
130 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
131 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
132 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
133 (Saputra *et al.*, 2014).

134

135 **pH assay**

136 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28°C . The sample
137 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
138 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
139 HI99192) (Lekahena & Jamin, 2018).

140

141 **Phenol level assay**

142 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
143 50%, homogenized, and allowed to stand for 5 minutes. Then added, 1 mL of 5% Na_2CO_3 and left in
144 the dark for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a
145 spectrophotometer (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were
146 expressed as mg/g (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

147
$$\text{Total Phenol } \left(\frac{\text{mg}}{\text{g}}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{\text{mg}}{\text{L}}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

148

149 **Polycyclic aromatic hydrocarbon (PAH) assay**

150 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
151 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL

152 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,
153 the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel
154 and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained
155 and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1)
156 and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase
157 was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract
158 was dried under nitrogen gas.

159 After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and
160 transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was
161 added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane.
162 A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and
163 stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible
164 light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH
165 compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector.
166 The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20%
167 water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was
168 used for PAH concentration calculation.

169

170 Sensory assessment assay

171 Sensory assessment assay refers to Indonesia National Standard (Indonesia Standardization Agency,
172 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were
173 placed on a plastic plate with a glass of water, coded, and presented to 30 panelists randomly under
174 light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance
175 of the samples on a scale of 1 – 9.

176

177

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

178

Commented [u9]: Without any preparation??

179 **Data analysis**

180 Data analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test.

184 **Results and discussion**

185 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
186 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
187 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
188 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
189 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
190 and sensory assessment.

192 **Total volatile bases**

193 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
194 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
195 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
196 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
197 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
198 products and is emerging as the most commonly used chemical parameter to assess the palatability of
199 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
200 *julung* are presented in Fig. 2.

201

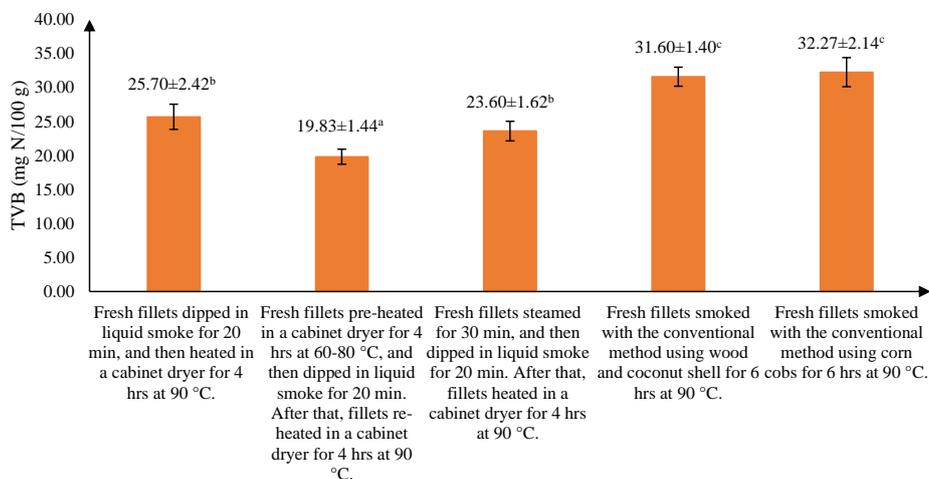


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018). Duncan's analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). Duncan's analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

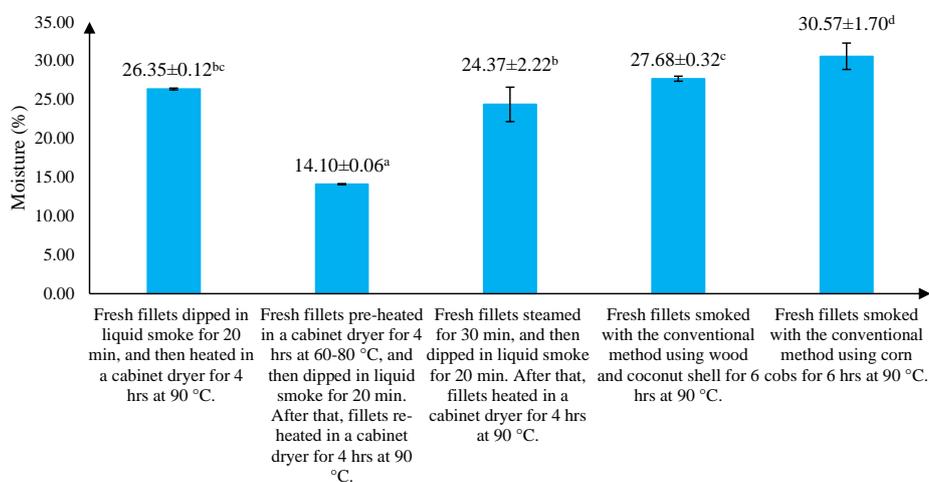
224 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 225 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 226 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 227 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 228 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 229 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 230 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 231 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 232 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

233

234 **Moisture content**

235 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 236 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 237 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 238 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 239 content of smoked fish fillets is presented in Fig. 3.

240



241

242

Fig. 3. Moisture content of *julung julung* smoked fillet

243

244 Fig. 3 shows the analysis of the variance of smoked *julung julung* fish fillets with different smoking
 245 methods treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung*
 246 *julung* fish fillets ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The

247 moisture content value in smoked fish products from all treatments still meets the Indonesian National
248 Standard No. 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization
249 Agency, 2013). Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content
250 of fish to below 40%, which can help preserve it longer. The treatment of the smoking method with
251 liquid smoke with corn cob (Treatment A, B, C) has a lower moisture content when compared to the
252 treatment of the conventional smoking method (Treatment D and E). This result is because the smoking
253 chamber is not fully enclosed in the conventional smoking method, so the heat generated could be more
254 optimal. Suboptimal heat can increase moisture content and cause the moisture content of smoked fish
255 to decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
256 temperature and humidity can be controlled better so that the moisture content of the product can be
257 reduced efficiently (Salindeho & Lumoindong, 2017).

258 Duncan's analysis showed a difference between treatment B, treatment A – C, and treatment D – E on
259 the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
260 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
261 content. This study's results are from previous research, which also reported a significant decrease in
262 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021).
263 Duncan's analysis also showed that treatments A and C were not different because steaming in treatment
264 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
265 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
266 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

268 **Water activity (Aw)**

269 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
270 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
271 whether water tends to move from the food product into the cells of microorganisms that may be present.
272 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
273 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
274 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
275 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
276 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
277 fillets can be seen in Fig. 4.

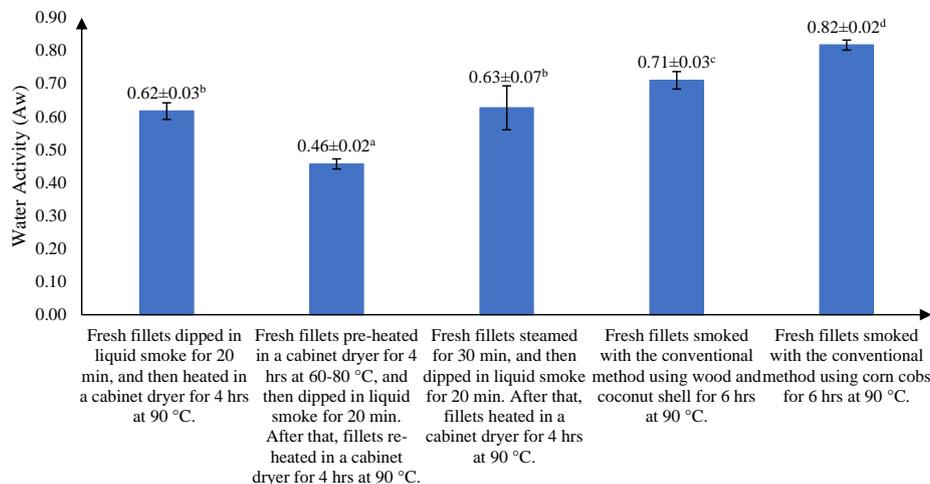


Fig. 4. Water activity of *julung julung* smoked fillet

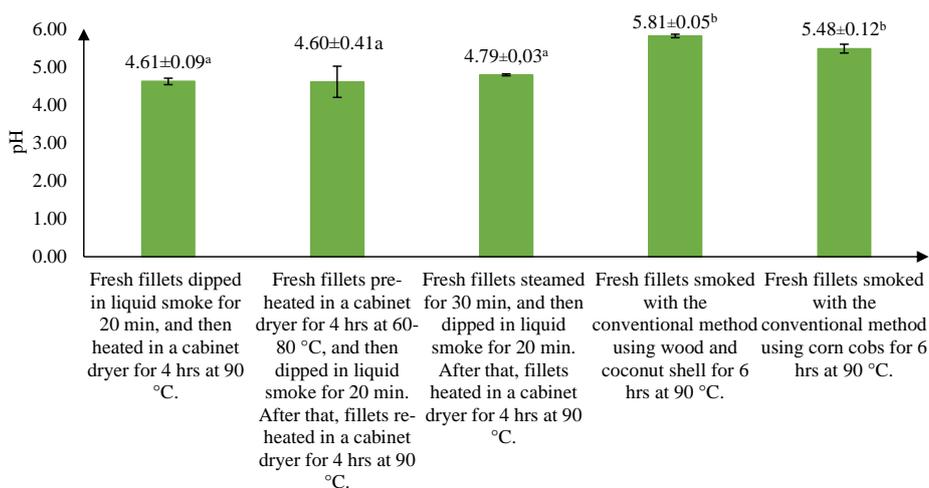
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

302 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 303 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 304 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 305 causes a decrease in pH (Berhimpon *et al.*, 2018).
 306



307 **Fig. 5.** pH of *julung julung* smoked fillet

308 **Phenol level**

309 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 310 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 311 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 312 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 313 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 314 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 315 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 316 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 317 conventional smoking method (treatments D and E).
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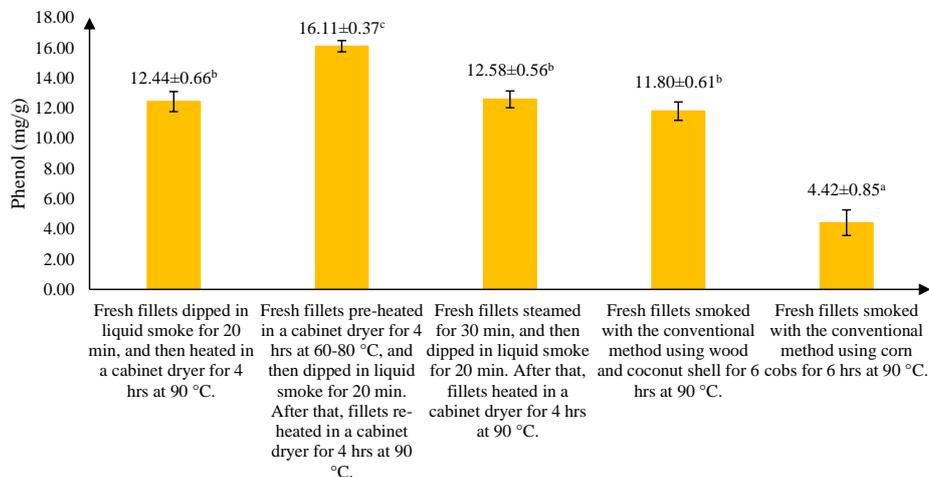


Fig. 6. Phenol level of *julung julung* smoked fillet

Duncan's analysis showed phenol levels in treatments A, C, and D were not different. Previous research reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there is less smoke condensation than products smoked at lower temperatures. The results of this study indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*, 2019).

The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*, 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

Polycyclic aromatic hydrocarbon (PAH) levels

Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion, such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic marker in smoked fish products (Stolyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH) levels in smoked fish fillets can be seen in Table 2.

344 **Table 2.** Polycyclic aromatic hydrocarbon levels in *Julung Julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8% (µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

345 nd = not detected

346

347 Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian
 348 National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia
 349 Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the
 350 Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported
 351 benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about
 352 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout
 353 ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*,
 354 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25
 355 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg,
 356 benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg,
 357 and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

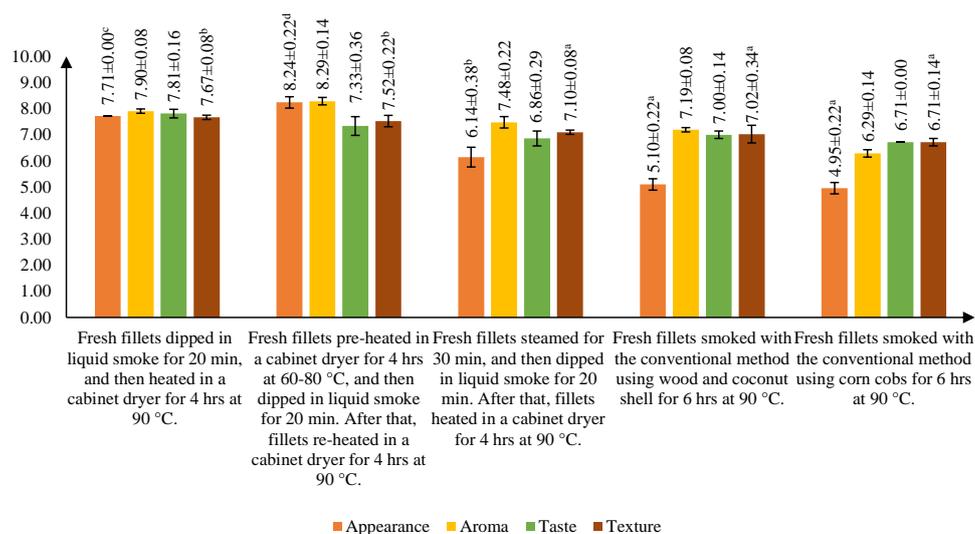
358 High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking
 359 process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21%
 360 (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut
 361 shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on
 362 a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH
 363 compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification
 364 processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds
 365 (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using
 366 corncobs are lower than those smoked with shells and coconut wood.

367

368 **Sensory assessment**

369 A sensory assessment is carried out to evaluate the panelist's preference level, including appearance,
 370 aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product
 371 and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of
 372 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 373 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to

374 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 375 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 376 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 377 smoked fillet from each treatment can be seen in Fig. 7.
 378



379
 380 **Fig. 7.** Sensory assesment of *julung julung* smoked fillet
 381

382 **Appearance:** Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of
 383 smoked *julung julung* fish fillets with different smoking method treatments affecting the appearance of
 384 smoked fish ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from
 385 4.95 to 8.24, with the highest panelists' assessment in treatment B. Based on the requirements of the
 386 Indonesian National Standard, only treatments A and B met the minimum panelist assessment
 387 requirement of 7. The moisture content factor is thought to have influenced the panelists' assessment of
 388 the appearance of smoked fish, so panelists less favored treatment C with steaming. Moisture content
 389 can affect the physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*,
 390 2020a). Smoked fish with high moisture content will make the color of smoked fish look paler
 391 (Flick, 2010).
 392 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 393 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 394 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another
 395 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the

396 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
397 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
398 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
399 to the interaction of carbonyls with amino components on the surface of the meat. The color and
400 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
401 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
402 (Montazeri *et al.*, 2013).

403 **Aroma:** Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked
404 fish fillets *julung julung* with different smoking method treatments that did not affect the appearance of
405 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
406 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
407 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
408 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
409 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
410 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
411 hours in all treatments has not influenced the taste and aroma of smoked fish.

412 **Taste:** Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
413 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
414 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
415 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
416 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
417 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
418 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
419 fish (Sukowati *et al.*, 2021).

420 **Texture:** Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish
421 fillet *julung julung* with different smoking method treatments giving effect to the texture of smoked fish
422 ($p<0.05$). Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67,
423 with the highest panelist assessment in treatments A and B. Duncan's test analysis showed that
424 treatments A and B differed from treatments C, D, and E. This result was thought to be because the fish
425 fillets were dipped in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C
426 (fish fillets subjected to steaming), the texture of the smoked fillets was rather sticky and not solid.
427 Treatments D and E produced the texture of smoked fish fillets which were less dense and not compact.
428 The texture of smoked fish is negatively correlated with its moisture content. The higher the moisture
429 content in smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content
430 in smoked fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

431 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
432 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
433 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
434 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
435 the mouth when chewed (Ticoalu *et al.*, 2019).

437 **Conclusion**

438 Based on the findings of this study, it can be concluded that treatment B (Fresh fillets pre-heated in a
439 cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the
440 fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.), when compared to the conventional
441 smoking treatment based on total volatile bases, moisture content, water activity, pH value, phenol level,
442 polycyclic aromatic hydrocarbon content, and sensory assessment. In general, fish smoking dipped in
443 liquid smoke from corn cob produced a better quality of smoked fish than the conventional smoking
444 method. It is necessary to evaluate different smoking times on smoked fish fillets of *julung julung* with
445 liquid smoke method from corn cob.

447 **Acknowledgement (bold)**

448 **Author contributions**

449 **Conflicts of interest**

450 The authors declare that there is no conflict of interest.

453 **Highlights**

- 454 • Liquid smoke from corn cobs can increase total phenols. Fillets dried and soaked in liquid
455 smoke.

458 **References**

- 459 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
460 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 461 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
462 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
463 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 464 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
465 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*
466 *T1-T2-2020)*, 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>

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Research and Innovation in Food Science and Technology

- 467 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
468 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
469 <https://doi.org/10.21767/2572-5459.100026>
- 470 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
471 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 472
- 473 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
474 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 475 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
476 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 477 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
478 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 479 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
480 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
481 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 482 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
483 *Global Scientific Journal*, 1(2), 77–84.
- 484 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
485 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
486 <https://doi.org/10.1080/10498850.2020.1741752>
- 487 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
488 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
489 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 490 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
491 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
492 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 493 Baten, M. A., Won, N. E., Mohibullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
494 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
495 *Scoromorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 496 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
497 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
498 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 499 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
500 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 501 Berhimpion, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
502 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
503 1864–1869.
- 504 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
505 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
506 <https://doi.org/10.1007/s11694-019-00347-6>
- 507 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from [http://www.bccdc.ca/resource-](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
508 [gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)

Research and Innovation in Food Science and Technology

- 509 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
510 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
511 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 512 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
513 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
514 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 515 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
516 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
517 <https://doi.org/10.2139/ssrn.3793663>
- 518 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
519 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
520 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 521 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
522 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
523 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 524 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
525 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 526 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
527 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
528 *Publications*, 3(3), 8–14.
- 529 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
530 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 531 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
532 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
533 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 534 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
535 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
536 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 537 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
538 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
539 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 540 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
541 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 542 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
543 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
544 <https://doi.org/10.4172/2572-4134.1000127>
- 545 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
546 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 547 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
548 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
549 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.
550 <https://doi.org/10.3390/foods11192938>

Research and Innovation in Food Science and Technology

- 551 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
552 418, 31–32.
- 553 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
554 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
555 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
556 <https://doi.org/10.3390/fermentation8120704>
- 557 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
558 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 559 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
560 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 561 Hardianto, L., & Yunianta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
562 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 563 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
564 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
565 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 566 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
567 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 568 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
569 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
571 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
573 Jakarta: Indonesia. (in Indonesia)
- 574 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
575 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 576 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
577 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
578 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 579 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
580 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
581 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
582 (in Indonesia)
- 583 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
584 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
585 <https://doi.org/10.1016/j.asej.2021.05.013>
- 586 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
587 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
588 Indonesia)
- 589 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
590 <https://doi.org/10.1007/s10086-016-1606-z>
- 591 Kiczorowska, B., Samolińska, W., Greła, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
592 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>

Research and Innovation in Food Science and Technology

- 593 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
594 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. [https://doi.org/10.20474/japs-](https://doi.org/10.20474/japs-595)
595 5.2.1
- 596 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
597 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
598 Indonesia)
- 599 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
600 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 601 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
602 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
603 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 604 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
605 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 606 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
607 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 608 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
609 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
610 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 611 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
612 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
613 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 614 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
615 *Today*, 3(5), 409–412.
- 616 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
617 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
618 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 619 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
620 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 621 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
622 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
623 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 624 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
625 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
626 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 627 Nazmi, M. S., Dardak, R. A., Rani, R. A., & Rabu, M. R. (2021). *Benchmarking Indonesia for the development of the grain*
628 *corn industry in Malaysia*. FFTC Agricultural Policy Platform. Retrieved from <https://ap.fttc.org.tw/article/2782>
- 629 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
630 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
631 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 632 Nugroho, S., Soeparma, S., & Yuliati, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
633 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
634 (in Indonesia)

Research and Innovation in Food Science and Technology

- 635 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
636 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
637 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 638 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
639 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
640 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 641 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
642 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
643 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 644 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
645 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 646 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
647 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 648 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
649 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
650 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 651 Rasulu, H., Praseptiangga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
652 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
653 180. <https://www.atlantis-press.com/article/125938018.pdf>
- 654 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
655 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
656 <https://doi.org/10.2993/0278-0771-36.2.312>
- 657 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
658 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
659 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 660 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
661 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
662 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 663 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
664 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
665 [https://scholar.archive.org/work/oconb3bhjzf3xl5lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl5lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
666 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 667 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
668 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
669 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 670 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
671 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
672 *Riau*, 2(2), 1–6. (in Indonesia)
- 673 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
674 wax. *Animal Agriculture Journal*, 3(1), 34–40.
- 675 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
676 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in

- 677 Indonesia)
- 678 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
679 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
680 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 681 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
682 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
683 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 684 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
685 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
686 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 687 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
688 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 689 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
690 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
691 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 692 Stołyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
693 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 694 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
695 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 696 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
697 briquettes (corn cob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
698 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 699 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
700 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
701 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 702 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
703 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
704 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 705 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
706 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 707 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
708 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 709 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
710 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 711 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
712 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 713 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
714 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 715 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
716 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*
717 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 718 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid

Research and Innovation in Food Science and Technology

- 719 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
720 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 721 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
722 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
723 6(3), 281–286.
- 724 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
725 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
726 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 727 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
728 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 729 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
730 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
731 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 732 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
733 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 734 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
735 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
736 6379. <https://doi.org/10.1021/ef5013769>

Characteristics of *Julung Julung* Smoked Fish-Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs Waste

Abstract

Corn cobs can be utilized as a shell ingredient for liquid smoke. Liquid smoke can be used for the smoked fish industry in North Sulawesi, Indonesia. However, the utilization of liquid smoke for the smoked fish industry has yet to be optimal. This study aimed to obtain the best smoking method for *Julung Julung* fillets (*Hemiramphus* sp.) using liquid smoke from corn cob waste. The treatment in this study was to apply liquid smoke from corn cob waste in the smoking process, which was compared with the conventional method (using shell, coconut wood, and corn cob). Parameters to determine the quality of smoked fish were total volatile bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed that the TVB of smoked *Julung Julung* fish fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these results, it can be concluded that the best treatment is fresh fillets preheated in a cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.

Keywords: Coconut, Indonesia, Shell, North Sulawesi, Wood

Introduction

Corn is the second most widely grown crop in Indonesia after rice. Indonesia is the 7th corn producer in the world, with more than 12 million tons of corn produced in 2020 (Nazmi *et al.*, 2021). North Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production will also produce waste, especially corn cobs, which are generally thrown away and burned by most Indonesians (Cahyadi *et al.*, 2021).

One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*, 2018). Another study reported a phenolic content of 335 mg/L in liquid smoke produced from corn cobs (Swastawati *et al.*, 2007).

Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*, 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save time, energy, and labor and reduce production costs (Krah *et al.*, 2019). In addition, using liquid smoke in food can speed up and standardize the smoking process, adding flavor and microbiological safety

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37 while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used
38 to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced may
39 vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
40 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
41 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

42 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
43 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
44 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
45 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
46 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
47 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
48 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
49 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
50 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
51 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
52 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
53 (Azis & Akolo, 2020).

54 The study's reported that the conventional smoking process has disadvantages such as smoking time,
55 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
56 2020). Conventional smoking of food products has been shown to produce carcinogenic components
57 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
58 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
59 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
60 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

61 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
62 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
63 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
64 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
65 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
66 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
67 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

68 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
69 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*
70 *et al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
71 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on

72 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
73 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed
74 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
75 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
76 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
77 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
78 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
79 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
80 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
81 polycyclic aromatic hydrocarbon content, and sensory assessment.

82

83 Materials and methods

84 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
85 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
86 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
87 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
88 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
89 (Mishra *et al.*, 2021). Then, the fish was washed, weeded, and filleted. The cleaned fillets were dipped
90 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
91 (Berhimpon *et al.*, 2018).

92



93

94

95

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

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96 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
97 of *julung julung* fish fillets, which was compared with the conventional method (using coconut wood,
98 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then heated in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets pre-heated in a cabinet dryer for 4 hours at 60 – 80 °C, and then dipped in liquid smoke for 20 minutes. After that, fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes and then dipped in liquid smoke for 20 minutes. After that, fillets were heated in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

99

100 **Liquid smoke manufacturing process**

101 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
102 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
103 cobs were gradually burned into the combustion furnace. The furnace was closed to prevent smoke from
104 escaping from the tank. The smoke generated from the combustion flows through a pipe connected to a
105 storage tank covered with ice cubes. The smoke that passes through the pipe will become cold, so
106 condensation occurs, turning the smoke into liquid. The smoke that has been formed is collected into a
107 container attached to the end of the pipe. The liquid smoke obtained is then allowed to settle the tar
108 formed for three weeks and filtered to obtain clear liquid smoke.

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110 **Total volatile bases assay**

111 Total volatile base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
112 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
113 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
114 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
115 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
116 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
117 TVB levels in the smoked fish meat were expressed as mg N/100g.

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$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times \text{dilution} \times 100}{\text{sample weight (g)}}$$

118

119

120 **Moisture content assay**

121 The moisture content by method of Indonesia National Standard (Indonesia Standardization Agency,
122 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a porcelain
123 cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples were
124 then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content was
125 expressed as %.

126
$$\text{Moisture (\%)} = \frac{B (g) - C (g)}{B(g) - A (g)} \times 100\%$$

127

128 **Water activity (Aw) assay**

129 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
130 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
131 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
132 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
133 (Saputra *et al.*, 2014).

134

135 **pH assay**

136 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28°C . The sample
137 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
138 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
139 HI99192) (Lekahena & Jamin, 2018).

140

141 **Phenol level assay**

142 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
143 50%, homogenized, and allowed to stand for 5 minutes. Then added, 1 mL of 5% Na_2CO_3 and left in
144 the dark for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a
145 spectrophotometer (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were
146 expressed as mg/g (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

147
$$\text{Total Phenol } \left(\frac{\text{mg}}{\text{g}}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{\text{mg}}{\text{L}}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

148

149 **Polycyclic aromatic hydrocarbon (PAH) assay**

150 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
151 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL

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152 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,
153 the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel
154 and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained
155 and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1)
156 and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase
157 was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract
158 was dried under nitrogen gas.

159 After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and
160 transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was
161 added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane.
162 A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and
163 stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible
164 light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH
165 compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector.
166 The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20%
167 water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was
168 used for PAH concentration calculation.

169

170 Sensory assessment assay

171 Sensory assessment assay refers to Indonesia National Standard (Indonesia Standardization Agency,
172 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were
173 placed on a plastic plate with a glass of water, coded, and presented to 30 panelists randomly under
174 light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance
175 of the samples on a scale of 1 – 9.

176

177

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

178

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179 **Data analysis**

180 Data analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test.

183

184 **Results and discussion**

185 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
186 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
187 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
188 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
189 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
190 and sensory assessment.

191

192 **Total volatile bases**

193 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
194 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
195 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
196 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
197 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
198 products and is emerging as the most commonly used chemical parameter to assess the palatability of
199 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
200 *julung* are presented in Fig. 2.

201

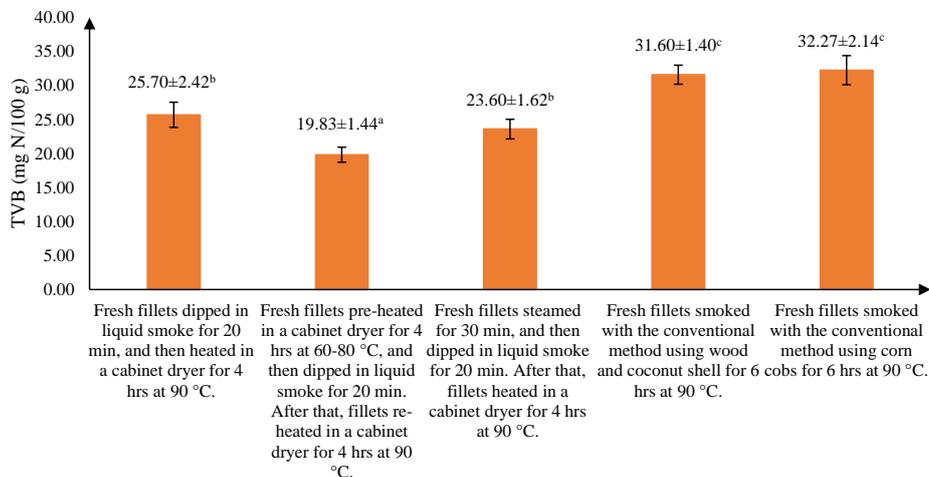


Fig. 2. Total volatile bases of *Julung Julung* smoked fillet

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Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018).

Duncan's analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). Duncan's analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

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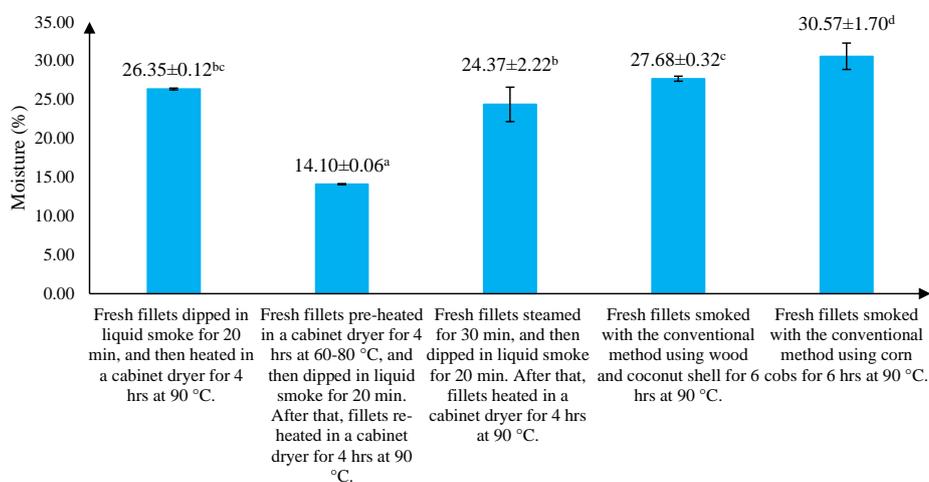
224 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 225 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 226 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 227 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 228 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 229 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 230 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 231 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 232 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

233

234 **Moisture content**

235 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 236 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 237 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 238 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 239 content of smoked fish fillets is presented in Fig. 3.

240



241

242

Fig. 3. Moisture content of *julung julung* smoked fillet

243

244 Fig. 3 shows the analysis of the variance of smoked *julung julung* fish fillets with different smoking
 245 methods treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung*
 246 *julung* fish fillets ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The

247 moisture content value in smoked fish products from all treatments still meets the Indonesian National
248 Standard No. 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization
249 Agency, 2013). Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content
250 of fish to below 40%, which can help preserve it longer. The treatment of the smoking method with
251 liquid smoke with corn cob (Treatment A, B, C) has a lower moisture content when compared to the
252 treatment of the conventional smoking method (Treatment D and E). This result is because the smoking
253 chamber is not fully enclosed in the conventional smoking method, so the heat generated could be more
254 optimal. Suboptimal heat can increase moisture content and cause the moisture content of smoked fish
255 to decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
256 temperature and humidity can be controlled better so that the moisture content of the product can be
257 reduced efficiently (Salindeho & Lumoindong, 2017).

258 Duncan's analysis showed a difference between treatment B, treatment A – C, and treatment D – E on
259 the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
260 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
261 content. This study's results are from previous research, which also reported a significant decrease in
262 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021).
263 Duncan's analysis also showed that treatments A and C were not different because steaming in treatment
264 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
265 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
266 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

268 **Water activity (Aw)**

269 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
270 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
271 whether water tends to move from the food product into the cells of microorganisms that may be present.
272 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
273 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
274 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
275 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
276 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
277 fillets can be seen in Fig. 4.

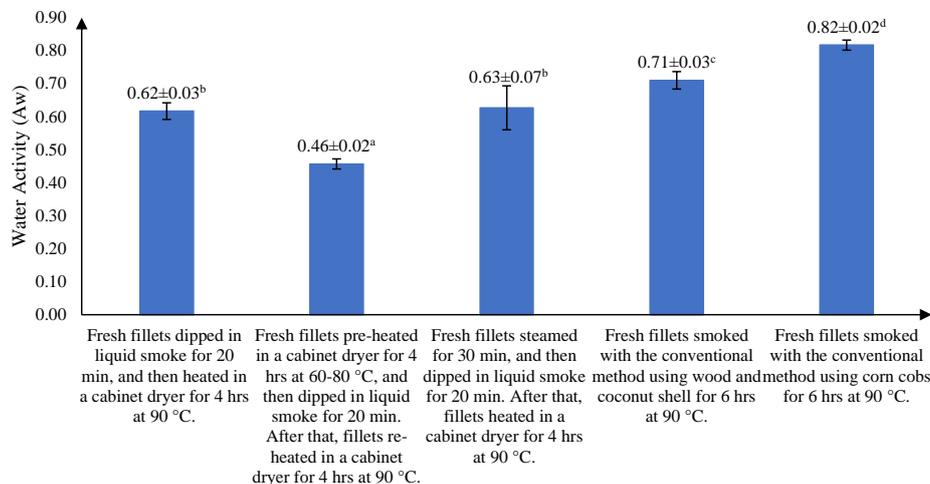


Fig. 4. Water activity of *julung julung* smoked fillet

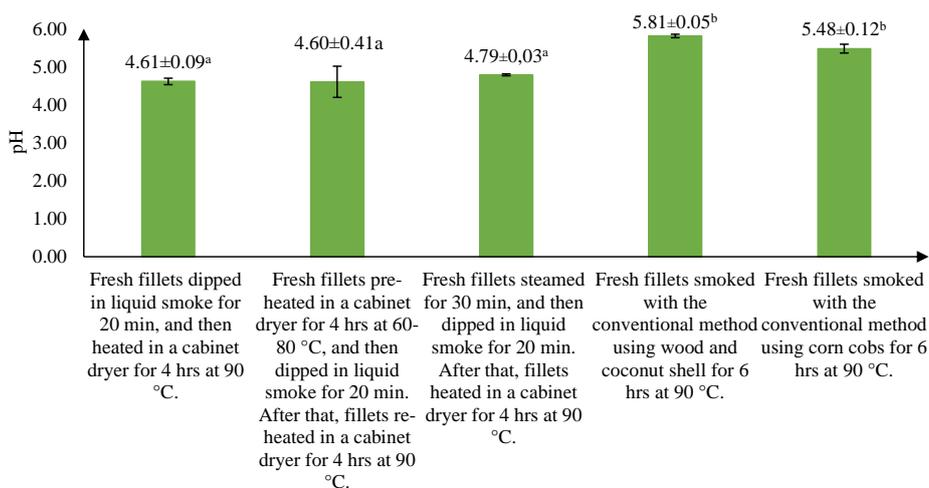
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

302 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 303 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 304 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 305 causes a decrease in pH (Berhimpon *et al.*, 2018).
 306



307 **Fig. 5.** pH of *julung julung* smoked fillet

308
 309
 310 **Phenol level**

311 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 312 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 313 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 314 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 315 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 316 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 317 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 318 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 319 conventional smoking method (treatments D and E).
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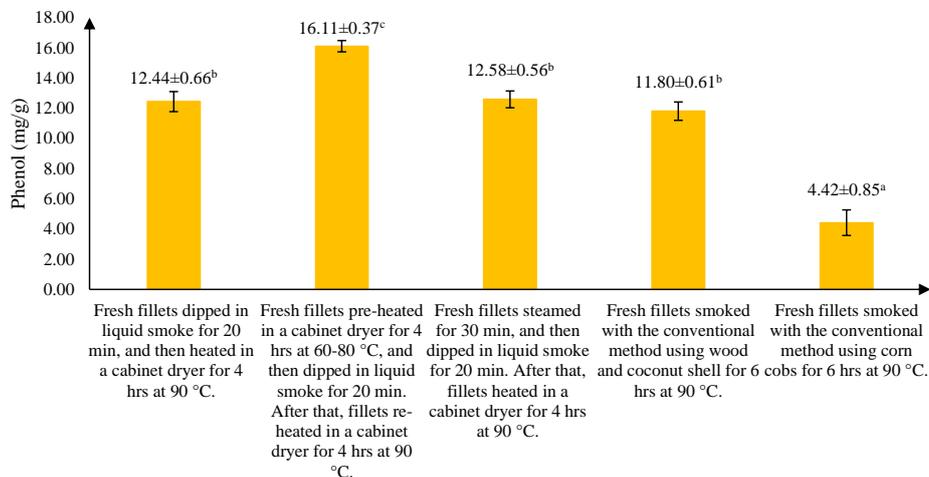


Fig. 6. Phenol level of *julung julung* smoked fillet

321

322

323

324 Duncan's analysis showed phenol levels in treatments A, C, and D were not different. Previous research
 325 reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products
 326 (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated
 327 process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a
 328 large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there
 329 is less smoke condensation than products smoked at lower temperatures. The results of this study
 330 indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*,
 331 2019).

332 The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*,
 333 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional
 334 method of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol
 335 content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol
 336 content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

337

338 **Polycyclic aromatic hydrocarbon (PAH) levels**

339 Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion,
 340 such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of
 341 smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic
 342 marker in smoked fish products (Stolyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH)
 343 levels in smoked fish fillets can be seen in Table 2.

344 **Table 2.** Polycyclic aromatic hydrocarbon levels in *Julung Julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8% (µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

345 nd = not detected

346

347 Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian
 348 National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia
 349 Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the
 350 Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported
 351 benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about
 352 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout
 353 ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*,
 354 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25
 355 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg,
 356 benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg,
 357 and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

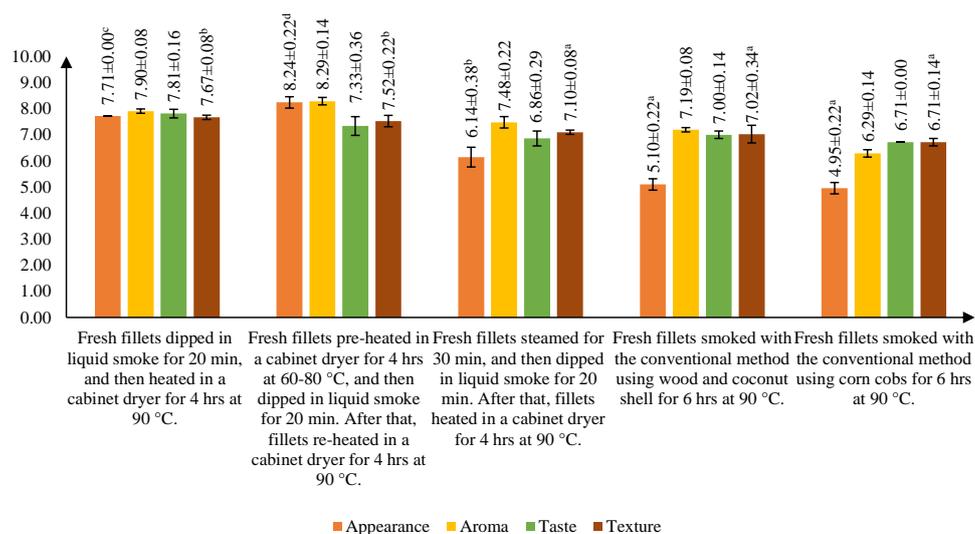
358 High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking
 359 process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21%
 360 (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut
 361 shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on
 362 a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH
 363 compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification
 364 processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds
 365 (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using
 366 corncobs are lower than those smoked with shells and coconut wood.

367

368 **Sensory assessment**

369 A sensory assessment is carried out to evaluate the panelist's preference level, including appearance,
 370 aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product
 371 and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of
 372 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 373 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to

374 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 375 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 376 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 377 smoked fillet from each treatment can be seen in Fig. 7.
 378



379
 380 **Fig. 7.** Sensory assesment of *julung julung* smoked fillet
 381

382 **Appearance:** Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of
 383 smoked *julung julung* fish fillets with different smoking method treatments affecting the appearance of
 384 smoked fish ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from
 385 4.95 to 8.24, with the highest panelists' assessment in treatment B. Based on the requirements of the
 386 Indonesian National Standard, only treatments A and B met the minimum panelist assessment
 387 requirement of 7. The moisture content factor is thought to have influenced the panelists' assessment of
 388 the appearance of smoked fish, so panelists less favored treatment C with steaming. Moisture content
 389 can affect the physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*,
 390 2020a). Smoked fish with high moisture content will make the color of smoked fish look paler
 391 (Flick, 2010).
 392 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 393 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 394 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another
 395 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the

396 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
397 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
398 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
399 to the interaction of carbonyls with amino components on the surface of the meat. The color and
400 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
401 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
402 (Montazeri *et al.*, 2013).

403 **Aroma:** Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked
404 fish fillets *julung julung* with different smoking method treatments that did not affect the appearance of
405 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
406 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
407 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
408 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
409 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
410 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
411 hours in all treatments has not influenced the taste and aroma of smoked fish.

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412 **Taste:** Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
413 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
414 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
415 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
416 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
417 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
418 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
419 fish (Sukowati *et al.*, 2021).

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420 **Texture:** Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish
421 fillet *julung julung* with different smoking method treatments giving effect to the texture of smoked fish
422 ($p<0.05$). Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67,
423 with the highest panelist assessment in treatments A and B. Duncan's test analysis showed that
424 treatments A and B differed from treatments C, D, and E. This result was thought to be because the fish
425 fillets were dipped in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C
426 (fish fillets subjected to steaming), the texture of the smoked fillets was rather sticky and not solid.
427 Treatments D and E produced the texture of smoked fish fillets which were less dense and not compact.
428 The texture of smoked fish is negatively correlated with its moisture content. The higher the moisture
429 content in smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content
430 in smoked fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021). The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in the mouth when chewed (Ticoalu *et al.*, 2019).

Conclusion

Based on the findings of this study, it can be concluded that treatment B (Fresh fillets pre-heated in a cabinet dryer for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes). After that, the fillets were re-heated in a cabinet dryer for 4 hours at 90 °C.), when compared to the conventional smoking treatment based on total volatile bases, moisture content, water activity, pH value, phenol level, polycyclic aromatic hydrocarbon content, and sensory assessment. In general, fish smoking dipped in liquid smoke from corn cob produced a better quality of smoked fish than the conventional smoking method. It is necessary to evaluate different smoking times on smoked fish fillets of *julung julung* with liquid smoke method from corn cob.

Acknowledgement (bold)

Author contributions

Conflicts of interest

The authors declare that there is no conflict of interest.

Highlights

- Liquid smoke from corn cobs can increase total phenols. Fillets dried and soaked in liquid smoke.

References

- Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. <https://doi.org/10.1088/1742-6596/1500/1/012064>
- Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-T1-T2-2020)*, 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>

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- 467 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
468 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
469 <https://doi.org/10.21767/2572-5459.100026>
- 470 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
471 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 472
- 473 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
474 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 475 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
476 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 477 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
478 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 479 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
480 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
481 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 482 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
483 *Global Scientific Journal*, 1(2), 77–84.
- 484 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
485 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
486 <https://doi.org/10.1080/10498850.2020.1741752>
- 487 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
488 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
489 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 490 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
491 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
492 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 493 Baten, M. A., Won, N. E., Mohibbullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
494 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
495 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 496 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibbullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
497 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
498 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 499 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
500 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 501 Berhimpion, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
502 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
503 1864–1869.
- 504 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
505 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
506 <https://doi.org/10.1007/s11694-019-00347-6>
- 507 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from [http://www.bccdc.ca/resource-](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
508 [gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)

Research and Innovation in Food Science and Technology

- 509 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
510 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
511 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 512 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
513 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
514 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 515 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
516 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
517 <https://doi.org/10.2139/ssrn.3793663>
- 518 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
519 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
520 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 521 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
522 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
523 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 524 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
525 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 526 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
527 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
528 *Publications*, 3(3), 8–14.
- 529 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
530 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 531 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
532 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
533 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 534 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
535 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
536 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 537 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
538 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
539 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 540 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
541 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 542 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
543 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
544 <https://doi.org/10.4172/2572-4134.1000127>
- 545 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
546 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 547 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
548 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
549 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.
550 <https://doi.org/10.3390/foods11192938>

Research and Innovation in Food Science and Technology

- 551 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
552 418, 31–32.
- 553 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
554 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
555 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
556 <https://doi.org/10.3390/fermentation8120704>
- 557 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
558 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 559 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
560 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 561 Hardianto, L., & Yunianta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
562 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 563 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
564 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
565 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 566 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
567 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 568 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
569 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
571 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
573 Jakarta: Indonesia. (in Indonesia)
- 574 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
575 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 576 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
577 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
578 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 579 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
580 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
581 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
582 (in Indonesia)
- 583 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
584 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
585 <https://doi.org/10.1016/j.asej.2021.05.013>
- 586 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
587 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
588 Indonesia)
- 589 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
590 <https://doi.org/10.1007/s10086-016-1606-z>
- 591 Kiczorowska, B., Samolińska, W., Greła, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
592 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>

Research and Innovation in Food Science and Technology

- 593 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
594 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. [https://doi.org/10.20474/japs-](https://doi.org/10.20474/japs-595)
595 5.2.1
- 596 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
597 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
598 Indonesia)
- 599 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
600 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 601 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
602 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
603 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 604 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
605 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 606 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
607 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 608 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
609 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
610 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 611 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
612 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
613 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 614 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
615 *Today*, 3(5), 409–412.
- 616 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
617 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
618 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 619 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
620 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 621 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
622 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
623 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 624 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
625 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
626 *(JKPT)*, 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 627 Nazmi, M. S., Dardak, R. A., Rani, R. A., & Rabu, M. R. (2021). *Benchmarking Indonesia for the development of the grain*
628 *corn industry in Malaysia*. FFTC Agricultural Policy Platform. Retrieved from <https://ap.fttc.org.tw/article/2782>
- 629 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
630 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
631 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 632 Nugroho, S., Soeparma, S., & Yuliati, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
633 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
634 (in Indonesia)

Research and Innovation in Food Science and Technology

- 635 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
636 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
637 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 638 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
639 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
640 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 641 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
642 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
643 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 644 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
645 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 646 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
647 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 648 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
649 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
650 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 651 Rasulu, H., Praseptiangga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
652 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
653 180. <https://www.atlantis-press.com/article/125938018.pdf>
- 654 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
655 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
656 <https://doi.org/10.2993/0278-0771-36.2.312>
- 657 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
658 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
659 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 660 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
661 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
662 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 663 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
664 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
665 [https://scholar.archive.org/work/oconb3bhjzf3xl5lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl5lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
666 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 667 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
668 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
669 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 670 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
671 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
672 *Riau*, 2(2), 1–6. (in Indonesia)
- 673 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
674 wax. *Animal Agriculture Journal*, 3(1), 34–40.
- 675 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
676 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in

- 677 Indonesia)
- 678 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
679 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
680 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 681 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
682 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
683 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 684 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
685 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
686 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 687 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
688 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 689 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
690 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
691 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 692 Stołyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
693 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 694 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corn cob Charcoal) on the
695 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 696 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
697 briquettes (corn cob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
698 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 699 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
700 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
701 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 702 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
703 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
704 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 705 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
706 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 707 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
708 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 709 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
710 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 711 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
712 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 713 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
714 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 715 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corn cob via combined hydrodynamic
716 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*
717 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 718 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid

Research and Innovation in Food Science and Technology

- 719 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
720 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 721 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
722 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
723 6(3), 281–286.
- 724 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
725 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
726 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 727 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
728 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 729 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
730 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
731 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 732 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
733 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 734 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
735 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
736 6379. <https://doi.org/10.1021/ef5013769>

3. Bukti respons kepada reviewer terkait revisi manuskrip

1 Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) using Liquid 2 Smoke from Corn Cobs Waste

3 Abstract

4 This study aimed to obtain the best smoking method for *Julung Julung* fillets (*Hemiramphus* sp.) using liquid
5 smoke from corn cob waste. This study used three different fillet treatment methods (dried and steamed) before
6 liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional
7 methods (using shell, coconut wood, and corn cob). The parameters to determine the quality of smoked fish were
8 Total Volatile Bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH),
9 and sensory assessment. The results showed that the TVB of smoked *Julung Julung* fillets ranged from 19.83 –
10 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged
11 from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required
12 in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture
13 of smoked fish. From these research, it can be concluded that treatment B is the best treatment, namely fresh fillets
14 are first heated for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were
15 reheated for 4 hours at 90 °C.

16 **Keywords:** Corn cobs, Indonesia, Liquid smoke, North Sulawesi, Wood

18 Introduction

19 Corn is the second most widely grown crop in Indonesia after rice. Indonesia's maize production in 2023
20 is 14.46 million tons, ranking 9th in the world. (Indonesia Center of Statistic Agency, 2023). North
21 Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production
22 will also produce waste, especially corn cobs, which are generally thrown away and burned by most
23 Indonesians (Cahyadi *et al.*, 2021).

24 One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can
25 produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from
26 corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs
27 affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*,
28 2018). Swastawati *et al.* (2007) reported the phenolic content in liquid smoke produced from 335 mg/L
29 corn cobs.

30 Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*,
31 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without
32 the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save
33 time, energy, and labor, so that can reduce production costs (Krah *et al.*, 2019). In addition, using liquid
34 smoke in food can speed up and standardize the smoking process, adding flavor and microbiological
35 safety while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were
36 used to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced

37 may vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
38 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
39 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

40 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
41 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
42 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
43 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
44 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
45 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
46 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
47 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
48 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
49 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
50 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
51 (Azis & Akolo, 2020).

52 The study's reported that the conventional smoking process has disadvantages such as smoking time,
53 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
54 2020). Conventional smoking of food products has been shown to produce carcinogenic components
55 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
56 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
57 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
58 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

59 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
60 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
61 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
62 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
63 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
64 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
65 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

66 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
67 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et*
68 *al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
69 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on
70 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
71 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed

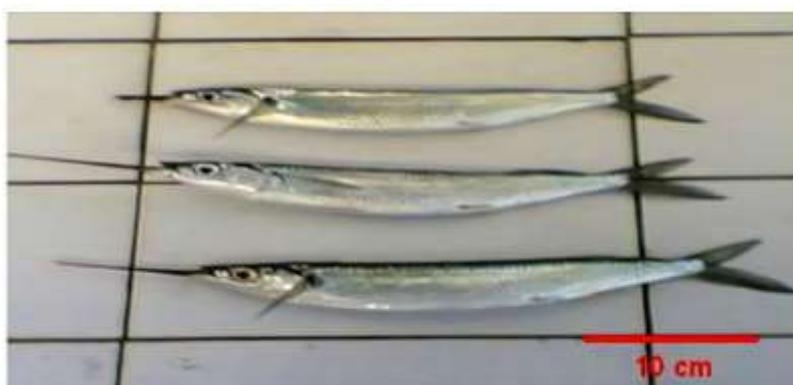
72 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
73 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
74 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
75 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
76 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
77 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
78 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
79 polycyclic aromatic hydrocarbon content, and sensory assessment.

80

81 **Materials and methods**

82 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
83 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
84 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
85 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
86 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
87 (Mishra *et al.*, 2021). Then, the fish was washed, cleaned, and filleted. The cleaned fillets were dipped
88 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0,8%
89 (Berhimpon *et al.*, 2018).

90



91

92

93

94 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
95 of *julung julung* fillets, which was compared with the conventional method (using coconut wood,
96 coconut shells, and corn cobs).

Commented [WT1]: Because based on the results of Berhimpon *et al.*, 2018, the best concentration of liquid acid from corn cobs for fish smoking is at a concentration of 0.8%.

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then dried in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets were preheated in a cabinet dryer for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes, then dipped in liquid smoke for 20 minutes. After that, the fillets were dried in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

Commented [WT2]: The treatment in this study was based on the results of Berhimpon et al. (2018) with some modifications, namely smoking fish without liquid smoke (using wood, head, coconut shell, and corn cobs).

97

98 Liquid smoke manufacturing process

99 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
100 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
101 cobs are gradually burned into the combustion furnace, at 400 °C and have a pyrolysis time of about
102 120 minutes. The furnace was closed to prevent smoke from escaping from the tank. The smoke
103 generated from the combustion flows through a pipe connected to a storage tank covered with ice cubes.
104 The smoke that passes through the pipe will become cold, so condensation occurs, turning the smoke
105 into liquid. The smoke that has been formed is collected into a container attached to the end of the pipe.
106 The liquid smoke obtained is then allowed to settle the tar formed for three weeks and filtered (using
107 Whatman filter paper No. 10) to obtain clear liquid smoke.

Commented [WT3]: Based Aladin *et al.*, 2018

Commented [WT4]: charcoal formed from the pyrolysis process

Commented [WT5]: Based Aladin *et al.*, 2018

Commented [WT6]: The level of benzopyrene from liquid smoke was evaluated by HPLC. And the benzopyrene in liquid smoke was about 0.5 µg/kg.

108 Total volatile bases assay

109 Total Volatile Base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
110 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
111 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
112 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
113 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
114 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
115 TVB levels in the smoked fish meat were expressed as mg N/100g.

$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times dilution \times 100}{sample\ weight\ (g)}$$

117

118

119 **Moisture content assay**

120 The moisture content is determined by the Indonesia National Standard (Indonesia Standardization
121 Agency, 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a
122 porcelain cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples
123 were then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content
124 was expressed as %.

$$125 \quad \text{Moisture (\%)} = \frac{B (g) - C (g)}{B (g) - A (g)} \times 100\%$$

126
127 **Water activity (Aw) assay**

128 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
129 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
130 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
131 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
132 (Saputra *et al.*, 2014).

133
134 **pH assay**

135 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28 °C. The sample
136 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
137 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
138 HI99192) (Lekahena & Jamin, 2018).

139
140 **Phenol level assay**

141 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
142 50%, homogenized, and allowed to stand for 5 minutes. Then, 1 mL of 5% Na₂CO₃ and left in the dark
143 for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a spectrophotometer
144 (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were expressed as mg/g
145 (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

$$146 \quad \text{Total Phenol } \left(\frac{mg}{g}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{mg}{L}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

147
148 **Polycyclic aromatic hydrocarbon (PAH) assay**

149 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
150 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL
151 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,

the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1) and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract was dried under nitrogen gas.

After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane. A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector. The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20% water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was used for PAH concentration calculation.

Sensory assessment assay

Sensory assessment assay refers to the Indonesia National Standard (Indonesia Standardization Agency, 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were placed on a plastic plate with a glass of water, coded, and presented to 30 randomly selected semi-trained panelists (university students who had studied sensory assessment techniques), and the assessment process was carried out under light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance of the samples on a scale of 1 – 9.

Commented [WT7]: Without preparation, karena sampel ikan asap yang digunakan masih layak dikonsumsi (dibawah 24 jam sejak pengasapan)

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

179 **Statistical analysis**

180 **Statistical analysis** was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test. **The**
183 **TVB, total phenol, pH, moisture, water activity, and sensory assessment parameters were evaluated**
184 **with three replicates.**

185
186 **Results and discussion**

187 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
188 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
189 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
190 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
191 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
192 and sensory assessment.

193
194 **Total volatile bases**

195 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
196 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
197 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
198 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
199 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
200 products and is emerging as the most commonly used chemical parameter to assess the palatability of
201 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
202 *julung* are presented in Fig. 2.

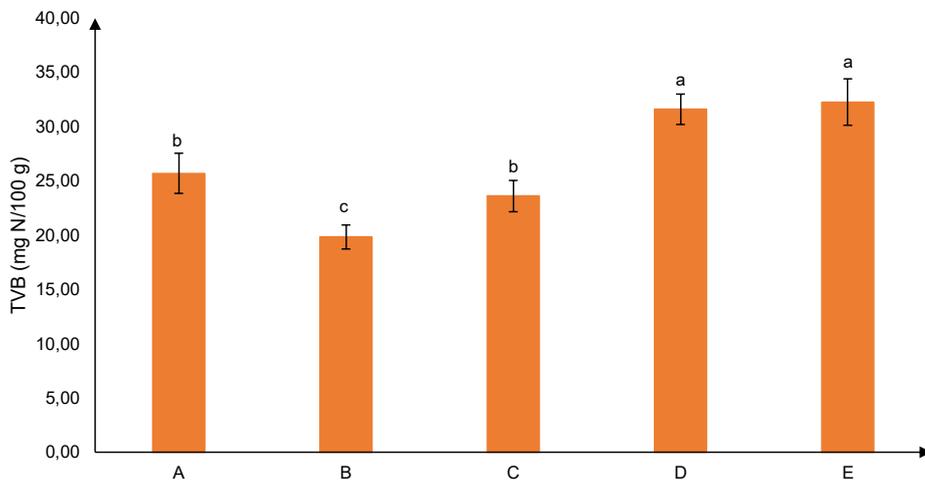


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yuniarta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018).

The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013).

The statistical analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

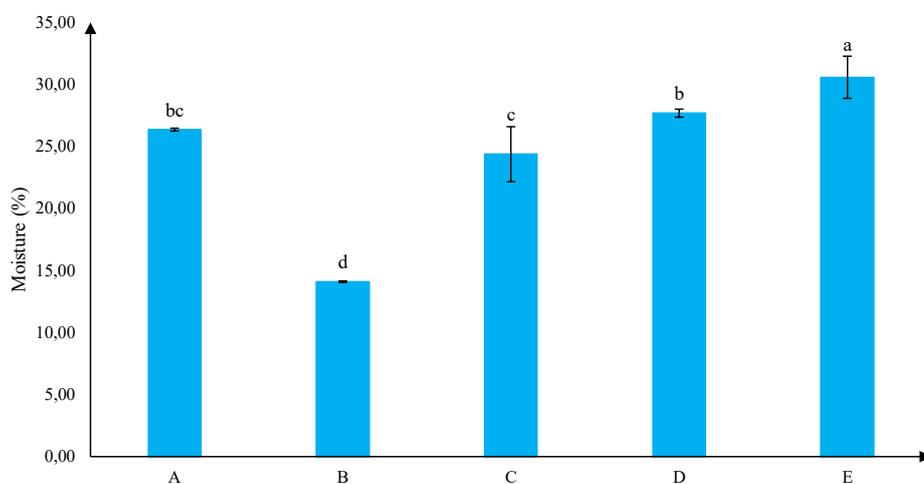
226 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 227 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 228 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 229 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 230 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 231 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 232 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 233 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 234 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

235

236 **Moisture content**

237 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 238 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 239 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 240 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 241 content of smoked fish fillets is presented in Fig. 3.

242



243

244 **Fig. 3. Moisture content of julung julung smoked fillet**

245

246 Fig. 3 shows the analysis of the variance of smoked *julung julung* fillets with different smoking methods
 247 treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung julung* fillets
 248 ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The moisture content

249 value in smoked fish products from all treatments still meets the Indonesian National Standard No.
250 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization Agency, 2013).
251 Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content of fish to below
252 40%, which can help preserve it longer. The treatment of the smoking method with liquid smoke with
253 corn cob (Treatment A, B, C) has a lower moisture content when compared to the treatment of the
254 conventional smoking method (Treatment D and E). This result is because the smoking chamber is not
255 fully enclosed in the conventional smoking method, so the heat generated could be more optimal.
256 Suboptimal heat can increase moisture content and cause the moisture content of smoked fish to
257 decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
258 temperature and humidity can be controlled better so that the moisture content of the product can be
259 reduced efficiently (Salindeho & Lumoindong, 2017).

260 **The statistical analysis** showed a difference between treatments B, A – C, and D – E on the TVB value
261 of smoked fish fillets showed a difference between treatment B, treatment A – C, and treatment D – E
262 on the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
263 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
264 content. This study's results are from previous research, which also reported a significant decrease in
265 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021). The
266 statistical analysis also showed that treatments A and C were not different because steaming in treatment
267 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
268 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
269 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

270

271 **Water activity (Aw)**

272 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
273 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
274 whether water tends to move from the food product into the cells of microorganisms that may be present.
275 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
276 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
277 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
278 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
279 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
280 fillets can be seen in Fig. 4.

281

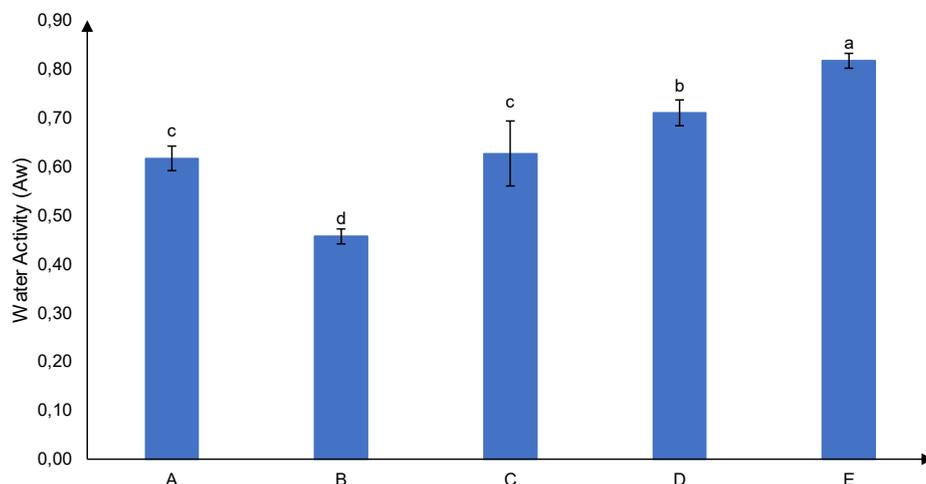


Fig. 4. Water activity of *julung julung* smoked fillet

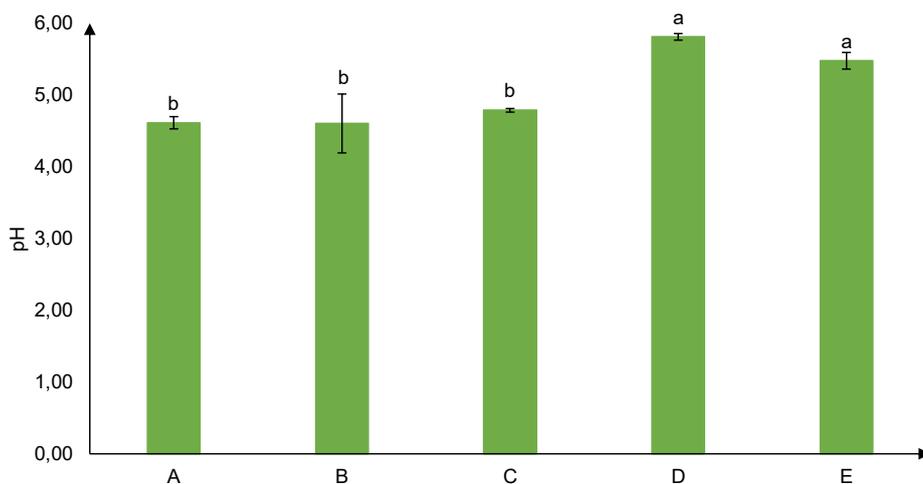
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

305 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 306 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 307 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 308 causes a decrease in pH (Berhimpon *et al.*, 2018).
 309



310
 311 **Fig. 5. pH of julung julung smoked fillet**
 312

313 **Phenol level**

314 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 315 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 316 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 317 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 318 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets julung
 319 julung with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 320 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 321 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 322 conventional smoking method (treatments D and E).
 323

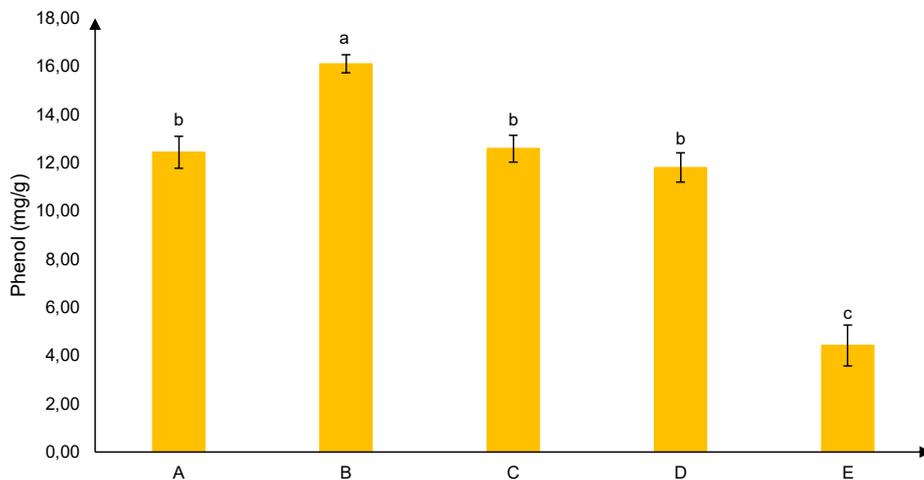


Fig. 6. Phenol level of *julung julung* smoked fillet

The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets showed phenol levels in treatments A, C, and D were not different. Previous research reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there is less smoke condensation than products smoked at lower temperatures. The results of this study indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*, 2019).

The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*, 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

Polycyclic aromatic hydrocarbon (PAH) levels

Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion, such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic

marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH) levels in smoked fish fillets can be seen in Table 2.

Table 2. Polycyclic aromatic hydrocarbon levels in *Julung Julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8%(µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

nd = not detected

Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*, 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg, benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg, and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21% (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using corncobs are lower than those smoked with shells and coconut wood.

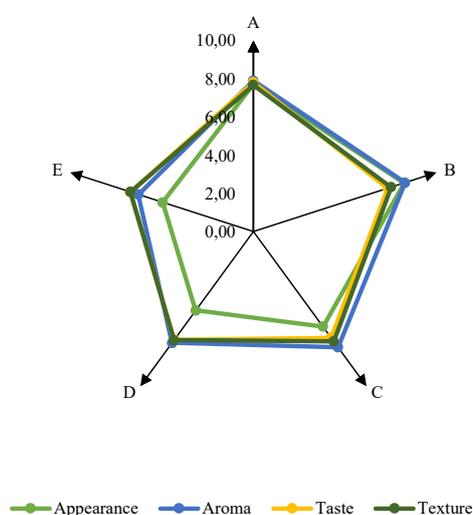
Sensory assessment

A sensory assessment is carried out to evaluate the panelist's preference level, including appearance, aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of

Commented [WT8]: PAH testing is not replicated because because it uses the HPLC method

376 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 377 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to
 378 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 379 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 380 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 381 smoked fillet from each treatment can be seen in Fig. 7.

382



383

384

385

Fig. 7. Sensory assesment of *julung julung* smoked fillet

386 Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of smoked *julung*
 387 *julung fillets* with different smoking method treatments affecting the appearance of smoked fish
 388 ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from 4.95 to 8.24,
 389 with the highest panelists' assessment in treatment B. Based on the requirements of the Indonesian
 390 National Standard, only treatments A and B met the minimum panelist assessment requirement of 7.
 391 The moisture content factor is thought to have influenced the panelists' assessment of the appearance of
 392 smoked fish, so panelists less favored treatment C with steaming. Moisture content can affect the
 393 physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*, 2020a).
 394 Smoked fish with high moisture content will make the color of smoked fish look paler (Flick, 2010).
 395 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 396 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 397 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another

398 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the
399 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
400 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
401 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
402 to the interaction of carbonyls with amino components on the surface of the meat. The color and
403 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
404 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
405 (Montazeri *et al.*, 2013).

406 Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked fish
407 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
408 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
409 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
410 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
411 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
412 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
413 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
414 hours in all treatments has not influenced the taste and aroma of smoked fish.

415 Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
416 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
417 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
418 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
419 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
420 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
421 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
422 fish (Sukowati *et al.*, 2021).

423 Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish fillet *julung*
424 *julung* with different smoking method treatments giving effect to the texture of smoked fish ($p<0.05$).
425 Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67, with the
426 highest panelist assessment in treatments A and B. The statistical analysis showed that treatments A and
427 B differed from treatments C, D, and E. This result was thought to be because the fish fillets were dipped
428 in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C (fish fillets subjected
429 to steaming), the texture of the smoked fillets was rather sticky and not solid. Treatments D and E
430 produced the texture of smoked fish fillets which were less dense and not compact. The texture of
431 smoked fish is negatively correlated with its moisture content. The higher the moisture content in

432 smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content in smoked
433 fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

434 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
435 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
436 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
437 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
438 the mouth when chewed (Ticoalu *et al.*, 2019).

439 440 **Conclusion**

441 Based on the evaluation of the parameters of total volatile bases, moisture content, water activity, pH,
442 phenol content, polycyclic aromatic hydrocarbon content, and sensory assessment of smoked *julung*
443 *julung* fillets, it can be concluded that treatment B is the best treatment, i.e. the fillets were preheated
444 for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated
445 for 4 hours at 90 °C. In general, the characteristics of smoked fillets using liquid smoke were better
446 when compared to the conventional smoking treatment. It is necessary to evaluate different smoking
447 times on smoked *julung julung* fillets with corn cob liquid smoke method.

448 449 **Acknowledgment**

450 451 **Author contributions**

452 453 **Conflicts of interest**

454 The authors declare that there is no conflict of interest.

455 456 **Highlights**

457 Effectiveness of using liquid smoke derived from corn cob waste in the smoking process of *julung*
458 *julung* fillets

459 460 **References**

- 461 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
462 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 463 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
464 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
465 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 466 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
467 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*

- 468 T1-T2-2020), 7, 328–338. <https://doi.org/10.2991/ahc.k.210205.055>
- 469 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
470 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
471 <https://doi.org/10.21767/2572-5459.100026>
- 472 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
473 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 474
- 475 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
476 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 477 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
478 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 479 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
480 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 481 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
482 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
483 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 484 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
485 *Global Scientific Journal*, 1(2), 77–84.
- 486 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
487 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
488 <https://doi.org/10.1080/10498850.2020.1741752>
- 489 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
490 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
491 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 492 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
493 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
494 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 495 Baten, M. A., Won, N. E., Mohibbullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
496 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
497 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 498 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibbullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
499 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
500 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 501 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
502 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 503 Berhimpion, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
504 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
505 1864–1869.
- 506 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
507 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
508 <https://doi.org/10.1007/s11694-019-00347-6>
- 509 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from <http://www.bccdc.ca/resource->

Research and Innovation in Food Science and Technology

- 510 gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf
- 511 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
512 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
513 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 514 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
515 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
516 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 517 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
518 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
519 <https://doi.org/10.2139/ssrn.3793663>
- 520 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
521 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
522 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 523 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
524 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
525 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 526 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
527 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 528 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
529 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
530 *Publications*, 3(3), 8–14.
- 531 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
532 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 533 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
534 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
535 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 536 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
537 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
538 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 539 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
540 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
541 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 542 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
543 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 544 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
545 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
546 <https://doi.org/10.4172/2572-4134.1000127>
- 547 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
548 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 549 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
550 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
551 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.

- 552 <https://doi.org/10.3390/foods11192938>
- 553 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
554 418, 31–32.
- 555 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
556 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
557 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
558 <https://doi.org/10.3390/fermentation8120704>
- 559 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
560 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 561 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
562 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 563 Hardianto, L., & Yuniarta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
564 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 565 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
566 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
567 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 568 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
569 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
571 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2006b). *Indonesia National Standard - instructions for organoleptic and or sensor*
573 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 574 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
575 Jakarta: Indonesia. (in Indonesia)
- 576 Indonesia Center of Statistic Agency. (2023). Maize Harvested Area and Production in Indonesia 2023. Retrieved from
577 <https://www.bps.go.id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-sementara-.html>. (in Indonesia)
- 578
- 579 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
580 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 581 Jinadasa, B. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
582 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
583 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 584 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
585 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
586 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
587 (in Indonesia)
- 588 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
589 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
590 <https://doi.org/10.1016/j.asej.2021.05.013>
- 591 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
592 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
593 Indonesia)

Research and Innovation in Food Science and Technology

- 594 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
595 <https://doi.org/10.1007/s10086-016-1606-z>
- 596 Kiczorowska, B., Samolińska, W., Grela, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
597 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>
- 598 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
599 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. <https://doi.org/10.20474/japs-600-5.2.1>
- 601 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
602 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
603 Indonesia)
- 604 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 605 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
606 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
607 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 608 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 609 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
610 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 611 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
612 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
613 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 614 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
615 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
616 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 617 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research Today*, 3(5), 409–412.
- 618 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
619 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
620 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 621 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
622 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 623 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
624 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
625 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 626 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
627 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
628 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 629 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
630 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
631 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 632 Nugroho, S., Soeparma, S., & Yulianti, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
633

Research and Innovation in Food Science and Technology

- 636 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
637 (in Indonesia)
- 638 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
639 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
640 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 641 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
642 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
643 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 644 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
645 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
646 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 647 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
648 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 649 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
650 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 651 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
652 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
653 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 654 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
655 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
656 180. <https://www.atlantis-press.com/article/125938018.pdf>
- 657 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
658 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
659 <https://doi.org/10.2993/0278-0771-36.2.312>
- 660 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
661 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
662 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 663 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
664 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
665 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 666 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
667 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
668 [https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl55lpgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
669 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 670 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
671 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
672 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 673 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
674 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
675 *Riau*, 2(2), 1–6. (in Indonesia)
- 676 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
677 wax. *Animal Agriculture Journal*, 3(1), 34–40.

Research and Innovation in Food Science and Technology

- 678 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
679 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in
680 Indonesia)
- 681 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
682 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
683 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 684 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
685 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
686 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 687 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
688 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
689 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 690 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
691 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 692 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
693 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
694 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 695 Stolyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
696 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 697 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
698 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 699 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
700 briquettes (corncob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
701 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 702 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
703 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
704 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 705 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
706 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
707 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 708 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
709 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 710 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiapatni, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
711 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 712 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
713 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 714 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
715 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 716 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
717 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 718 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
719 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*

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- 720 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 721 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid
722 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
723 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 724 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
725 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
726 6(3), 281–286.
- 727 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
728 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
729 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 730 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
731 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 732 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
733 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
734 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 735 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
736 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 737 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
738 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
739 6379. <https://doi.org/10.1021/ef5013769>

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Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs Waste

Abstract

This study aimed to obtain the best smoking method for *Julung Julung* fillets (*Hemiramphus* sp.) using liquid smoke from corn cob waste. This study used three different fillet treatment methods (dried and steamed) before liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional methods (using shell, coconut wood, and corn cob). The parameters to determine the quality of smoked fish were Total Volatile Bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed that the TVB of smoked *Julung Julung* fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these research, it can be concluded that treatment B is the best treatment, namely fresh fillets are first heated for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated for 4 hours at 90 °C.

Keywords: Corn cobs, Indonesia, Liquid smoke, North Sulawesi, Wood

Introduction

Corn is the second most widely grown crop in Indonesia after rice. Indonesia's maize production in 2023 is 14.46 million tons, ranking 9th in the world. (Indonesia Center of Statistic Agency, 2023). North Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production will also produce waste, especially corn cobs, which are generally thrown away and burned by most Indonesians (Cahyadi *et al.*, 2021).

One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*, 2018). Swastawati *et al.* (2007) reported the phenolic content in liquid smoke produced from 335 mg/L corn cobs.

Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*, 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save time, energy, and labor, so that can reduce production costs (Krah *et al.*, 2019). In addition, using liquid smoke in food can speed up and standardize the smoking process, adding flavor and microbiological safety while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced

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Reviewer comment for author

- 1-The responses to reviewers comments should be attached (Reviewers 1, 2 and 3), (Necessary)
- 2-The responses to final reviewer comments should be attached (Necessary).
- 3-The radar plot is drawn incorrectly and needs to be corrected. Attributes must be at the vertices of the polygon.

37 may vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
38 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
39 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

40 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
41 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
42 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
43 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
44 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
45 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
46 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
47 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
48 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
49 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
50 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
51 (Azis & Akolo, 2020).

52 The study's reported that the conventional smoking process has disadvantages such as smoking time,
53 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
54 2020). Conventional smoking of food products has been shown to produce carcinogenic components
55 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
56 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
57 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
58 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

59 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
60 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
61 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
62 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
63 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
64 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
65 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

66 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
67 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*,
68 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
69 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on
70 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
71 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed

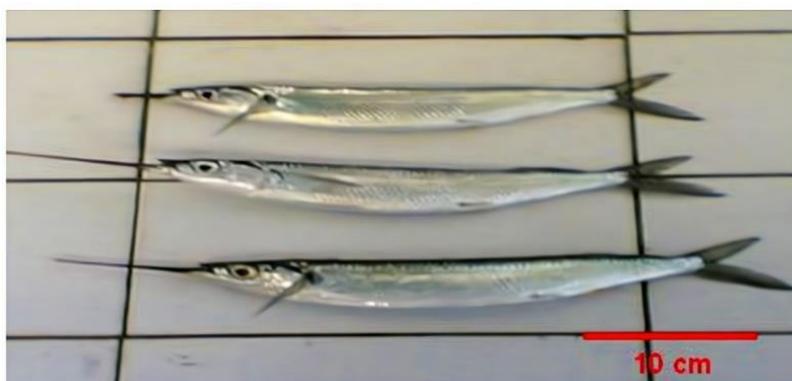
72 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
73 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
74 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
75 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
76 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
77 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
78 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
79 polycyclic aromatic hydrocarbon content, and sensory assessment.

80

81 **Materials and methods**

82 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
83 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
84 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
85 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
86 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
87 (Mishra *et al.*, 2021). Then, the fish was washed, cleaned, and filleted. The cleaned fillets were dipped
88 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
89 (Berhimpon *et al.*, 2018).

90



91

92

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

93

94 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
95 of *julung julung* fillets, which was compared with the conventional method (using coconut wood,
96 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then dried in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets were preheated in a cabinet dryer for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes, then dipped in liquid smoke for 20 minutes. After that, the fillets were dried in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

97

98 **Liquid smoke manufacturing process**

99 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
100 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
101 cobs are gradually burned into the combustion furnace, at 400 °C and have a pyrolysis time of about
102 120 minutes. The furnace was closed to prevent smoke from escaping from the tank. The smoke
103 generated from the combustion flows through a pipe connected to a storage tank covered with ice cubes.
104 The smoke that passes through the pipe will become cold, so condensation occurs, turning the smoke
105 into liquid. The smoke that has been formed is collected into a container attached to the end of the pipe.
106 The liquid smoke obtained is then allowed to settle the tar formed for three weeks and filtered (using
107 Whatman filter paper No. 10) to obtain clear liquid smoke.

108 **Total volatile bases assay**

109 Total Volatile Base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
110 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
111 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
112 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
113 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
114 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
115 TVB levels in the smoked fish meat were expressed as mg N/100g.

116
$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times \text{dilution} \times 100}{\text{sample weight (g)}}$$

117

118

119 **Moisture content assay**

120 The moisture content is determined by the Indonesia National Standard (Indonesia Standardization
121 Agency, 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a
122 porcelain cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples
123 were then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content
124 was expressed as %.

$$\text{Moisture (\%)} = \frac{B(g) - C(g)}{B(g) - A(g)} \times 100\%$$

127 **Water activity (Aw) assay**

128 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
129 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
130 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
131 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
132 (Saputra *et al.*, 2014).

134 **pH assay**

135 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28 °C. The sample
136 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
137 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
138 HI99192) (Lekahena & Jamin, 2018).

140 **Phenol level assay**

141 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
142 50%, homogenized, and allowed to stand for 5 minutes. Then, 1 mL of 5% Na₂CO₃ and left in the dark
143 for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a spectrophotometer
144 (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were expressed as mg/g
145 (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

$$\text{Total Phenol } \left(\frac{mg}{g}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{mg}{L}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

148 **Polycyclic aromatic hydrocarbon (PAH) assay**

149 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
150 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL
151 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,

the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1) and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract was dried under nitrogen gas.

After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane. A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector. The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20% water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was used for PAH concentration calculation.

Sensory assessment assay

Sensory assessment assay refers to the Indonesia National Standard (Indonesia Standardization Agency, 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were placed on a plastic plate with a glass of water, coded, and presented to 30 randomly selected semi-trained panelists (university students who had studied sensory assessment techniques), and the assessment process was carried out under light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance of the samples on a scale of 1 – 9.

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

179 **Statistical analysis**

180 Statistical analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test. The
183 TVB, total phenol, pH, moisture, water activity, and sensory assessment parameters were evaluated
184 with three replicates.

185
186 **Results and discussion**

187 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
188 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
189 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
190 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
191 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
192 and sensory assessment.

193
194 **Total volatile bases**

195 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
196 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
197 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
198 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
199 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
200 products and is emerging as the most commonly used chemical parameter to assess the palatability of
201 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
202 *julung* are presented in Fig. 2.

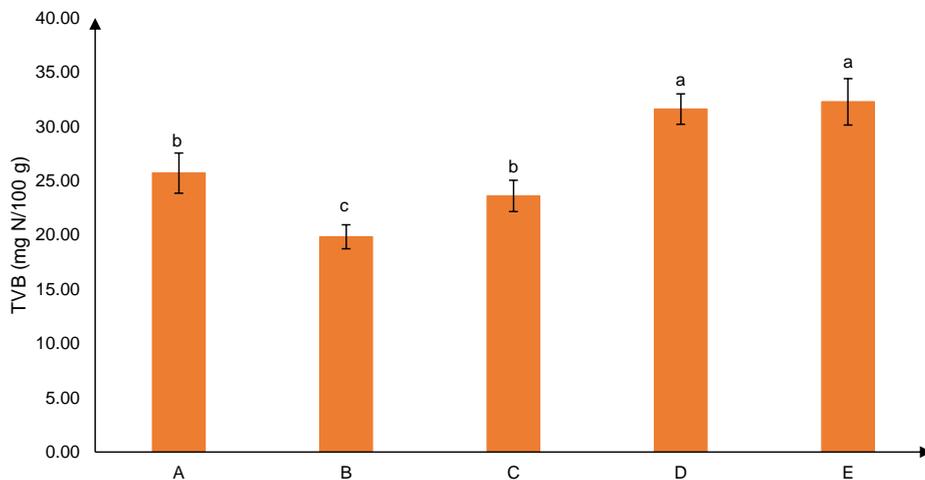


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018). The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). The statistical analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

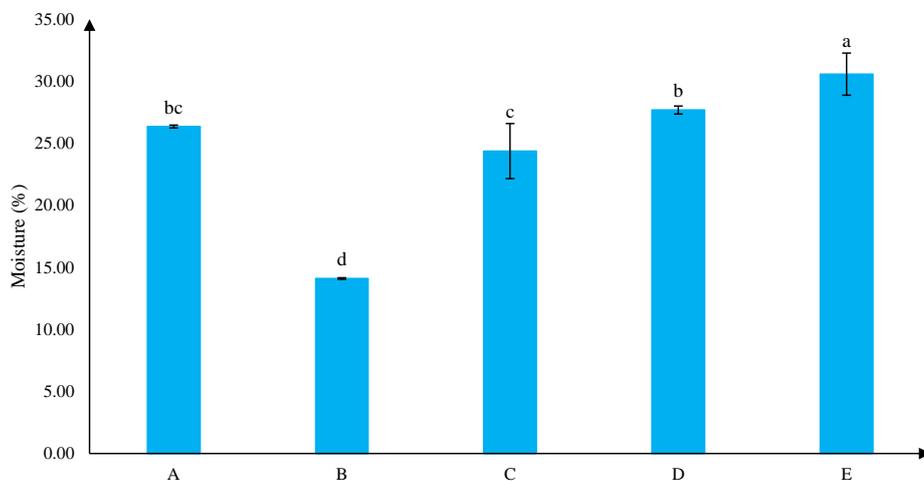
226 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 227 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 228 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 229 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 230 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 231 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 232 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 233 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 234 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

235

236 **Moisture content**

237 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 238 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 239 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 240 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 241 content of smoked fish fillets is presented in Fig. 3.

242



243

244 **Fig. 3.** Moisture content of *julung julung* smoked fillet

245

246 Fig. 3 shows the analysis of the variance of smoked *julung julung* fillets with different smoking methods
 247 treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung julung* fillets
 248 ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The moisture content

249 value in smoked fish products from all treatments still meets the Indonesian National Standard No.
250 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization Agency, 2013).
251 Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content of fish to below
252 40%, which can help preserve it longer. The treatment of the smoking method with liquid smoke with
253 corn cob (Treatment A, B, C) has a lower moisture content when compared to the treatment of the
254 conventional smoking method (Treatment D and E). This result is because the smoking chamber is not
255 fully enclosed in the conventional smoking method, so the heat generated could be more optimal.
256 Suboptimal heat can increase moisture content and cause the moisture content of smoked fish to
257 decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
258 temperature and humidity can be controlled better so that the moisture content of the product can be
259 reduced efficiently (Salindeho & Lumoindong, 2017).

260 The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value
261 of smoked fish fillets showed a difference between treatment B, treatment A – C, and treatment D – E
262 on the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
263 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
264 content. This study's results are from previous research, which also reported a significant decrease in
265 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021). The
266 statistical analysis also showed that treatments A and C were not different because steaming in treatment
267 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
268 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
269 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

270

271 **Water activity (Aw)**

272 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
273 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
274 whether water tends to move from the food product into the cells of microorganisms that may be present.
275 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
276 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
277 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
278 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
279 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
280 fillets can be seen in Fig. 4.

281

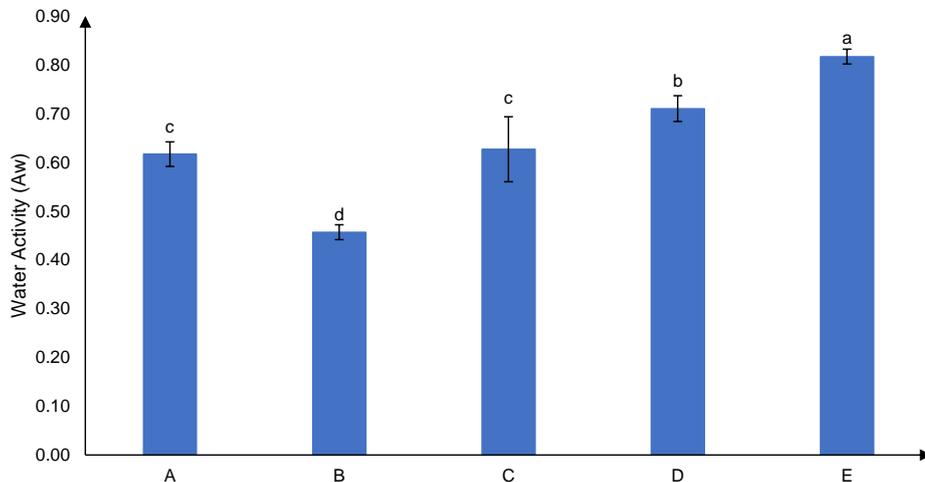


Fig. 4. Water activity of *julung julung* smoked fillet

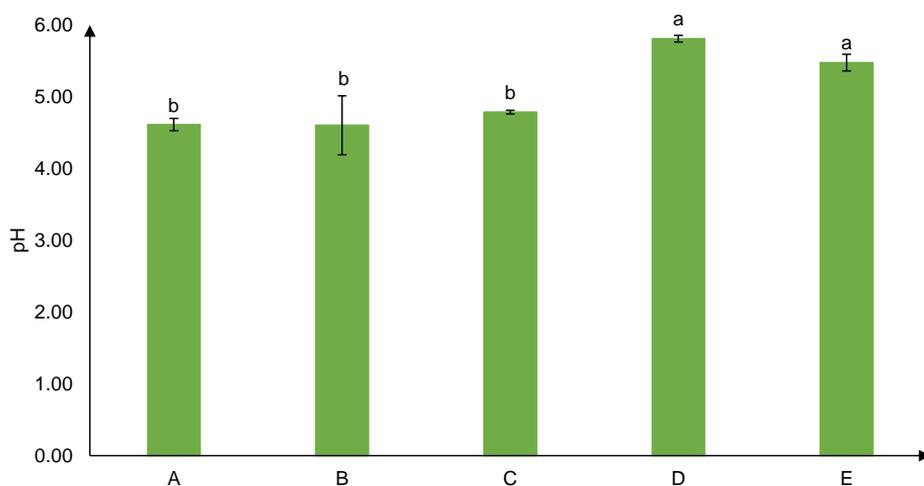
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

305 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 306 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 307 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 308 causes a decrease in pH (Berhimpon *et al.*, 2018).
 309



310
 311 **Fig. 5.** pH of *julung julung* smoked fillet
 312

313 **Phenol level**

314 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 315 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 316 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 317 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 318 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 319 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 320 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 321 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 322 conventional smoking method (treatments D and E).
 323

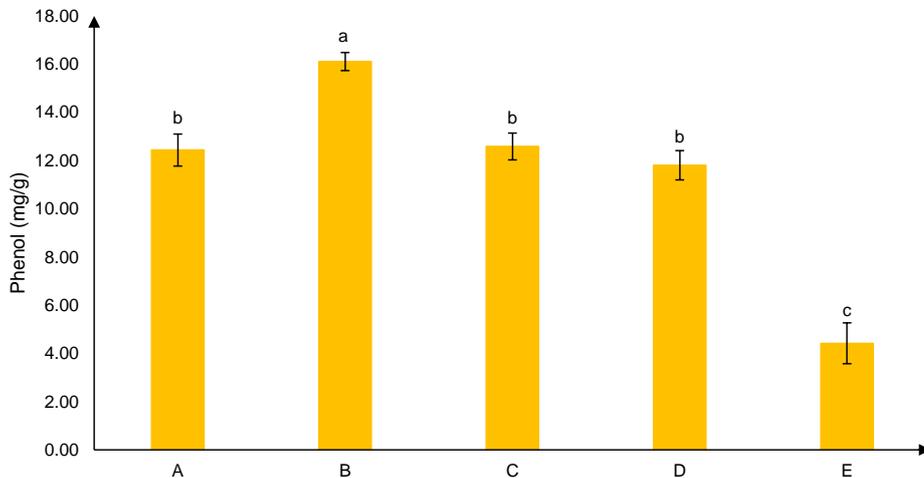


Fig. 6. Phenol level of *julung julung* smoked fillet

324
325
326

327 The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value
328 of smoked fish fillets showed phenol levels in treatments A, C, and D were not different. Previous
329 research reported that the drying treatment of fish meat can increase phenolic compounds in smoked
330 fish products (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the
331 pre-heated process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets
332 absorb a large amount of liquid smoke. Previous studies have reported that when the fish surface is
333 dried, there is less smoke condensation than products smoked at lower temperatures. The results of this
334 study indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et*
335 *al.*, 2019).

336 The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*,
337 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method
338 of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol
339 content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol
340 content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.
341

342 **Polycyclic aromatic hydrocarbon (PAH) levels**

343 Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion,
344 such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of
345 smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic

marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH) levels in smoked fish fillets can be seen in Table 2.

Table 2. Polycyclic aromatic hydrocarbon levels in *julung julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8% (µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

nd = not detected

Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*, 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg, benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg, and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

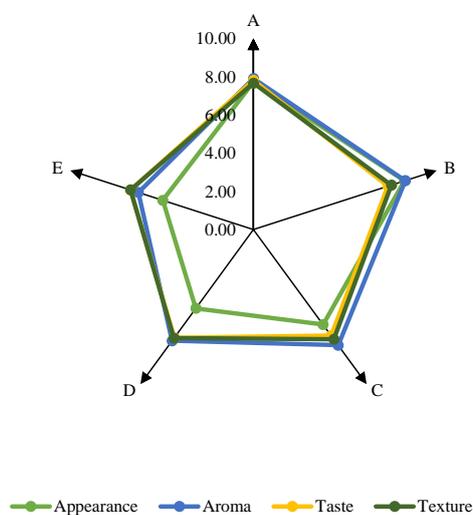
High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21% (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using corncobs are lower than those smoked with shells and coconut wood.

Sensory assessment

A sensory assessment is carried out to evaluate the panelist's preference level, including appearance, aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of

376 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 377 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to
 378 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 379 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 380 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 381 smoked fillet from each treatment can be seen in Fig. 7.

382



383

384

385

Fig. 7. Sensory assesment of *julung julung* smoked fillet

386 Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of smoked *julung*
 387 *julung* fillets with different smoking method treatments affecting the appearance of smoked fish
 388 ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from 4.95 to 8.24,
 389 with the highest panelists' assessment in treatment B. Based on the requirements of the Indonesian
 390 National Standard, only treatments A and B met the minimum panelist assessment requirement of 7.
 391 The moisture content factor is thought to have influenced the panelists' assessment of the appearance of
 392 smoked fish, so panelists less favored treatment C with steaming. Moisture content can affect the
 393 physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*, 2020a).
 394 Smoked fish with high moisture content will make the color of smoked fish look paler (Flick, 2010).
 395 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 396 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 397 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another

398 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the
399 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
400 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
401 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
402 to the interaction of carbonyls with amino components on the surface of the meat. The color and
403 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
404 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
405 (Montazeri *et al.*, 2013).

406 Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked fish
407 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
408 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
409 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
410 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
411 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
412 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
413 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
414 hours in all treatments has not influenced the taste and aroma of smoked fish.

415 Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
416 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
417 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
418 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
419 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
420 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
421 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
422 fish (Sukowati *et al.*, 2021).

423 Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish fillet *julung*
424 *julung* with different smoking method treatments giving effect to the texture of smoked fish ($p<0.05$).
425 Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67, with the
426 highest panelist assessment in treatments A and B. The statistical analysis showed that treatments A and
427 B differed from treatments C, D, and E. This result was thought to be because the fish fillets were dipped
428 in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C (fish fillets subjected
429 to steaming), the texture of the smoked fillets was rather sticky and not solid. Treatments D and E
430 produced the texture of smoked fish fillets which were less dense and not compact. The texture of
431 smoked fish is negatively correlated with its moisture content. The higher the moisture content in

432 smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content in smoked
433 fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

434 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
435 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
436 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
437 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
438 the mouth when chewed (Ticoalu *et al.*, 2019).

439

440 **Conclusion**

441 Based on the evaluation of the parameters of total volatile bases, moisture content, water activity, pH,
442 phenol content, polycyclic aromatic hydrocarbon content, and sensory assessment of smoked *julung*
443 *julung* fillets, it can be concluded that treatment B is the best treatment, i.e. the fillets were preheated
444 for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated
445 for 4 hours at 90 °C. In general, the characteristics of smoked fillets using liquid smoke were better
446 when compared to the conventional smoking treatment. It is necessary to evaluate different smoking
447 times on smoked *julung julung* fillets with corn cob liquid smoke method.

448

449 **Acknowledgment**

450

451 **Author contributions**

452

453 **Conflicts of interest**

454 The authors declare that there is no conflict of interest.

455

456 **Highlights**

457 Effectiveness of using liquid smoke derived from corn cob waste in the smoking process of *julung*
458 *julung* fillets

459

460 **References**

- 461 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
462 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 463 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
464 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
465 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 466 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
467 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*

Research and Innovation in Food Science and Technology

- 468 *T1-T2-2020*), 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>
- 469 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
470 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
471 <https://doi.org/10.21767/2572-5459.100026>
- 472 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
473 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 474
- 475 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
476 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 477 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
478 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 479 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
480 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 481 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
482 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
483 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 484 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
485 *Global Scientific Journal*, 1(2), 77–84.
- 486 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
487 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
488 <https://doi.org/10.1080/10498850.2020.1741752>
- 489 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
490 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
491 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 492 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
493 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
494 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 495 Baten, M. A., Won, N. E., Mohibbullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
496 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
497 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 498 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibbullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
499 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
500 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 501 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
502 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 503 Berhimon, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
504 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
505 1864–1869.
- 506 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
507 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
508 <https://doi.org/10.1007/s11694-019-00347-6>
- 509 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from <http://www.bccdc.ca/resource->

Research and Innovation in Food Science and Technology

- 510 gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf
- 511 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
512 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
513 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 514 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
515 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
516 1315/757/1/012053
- 517 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
518 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
519 <https://doi.org/10.2139/ssrn.3793663>
- 520 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
521 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
522 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 523 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
524 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
525 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 526 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
527 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 528 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
529 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
530 *Publications*, 3(3), 8–14.
- 531 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
532 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 533 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
534 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
535 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 536 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
537 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
538 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 539 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
540 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
541 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 542 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
543 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 544 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
545 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
546 <https://doi.org/10.4172/2572-4134.1000127>
- 547 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
548 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 549 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
550 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
551 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.

Research and Innovation in Food Science and Technology

- 552 <https://doi.org/10.3390/foods11192938>
- 553 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
554 418, 31–32.
- 555 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
556 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
557 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
558 <https://doi.org/10.3390/fermentation8120704>
- 559 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
560 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 561 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
562 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 563 Hardianto, L., & Yuniarta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
564 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 565 Indiarso, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
566 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
567 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 568 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
569 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
571 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
573 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 574 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
575 Jakarta: Indonesia. (in Indonesia)
- 576 Indonesia Center of Statistic Agency. (2023). Maize Harvested Area and Production in Indonesia 2023. Retrieved from
577 [https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-](https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-mentara-.html)
578 [sementara-.html](https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-mentara-.html). (in Indonesia)
- 579 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
580 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 581 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
582 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
583 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 584 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
585 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
586 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
587 (in Indonesia)
- 588 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
589 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
590 <https://doi.org/10.1016/j.asej.2021.05.013>
- 591 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
592 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
593 Indonesia)

Research and Innovation in Food Science and Technology

- 594 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
595 <https://doi.org/10.1007/s10086-016-1606-z>
- 596 Kiczorowska, B., Samolińska, W., Grela, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
597 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>
- 598 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
599 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. <https://doi.org/10.20474/japs->
600 5.2.1
- 601 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
602 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
603 Indonesia)
- 604 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
605 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 606 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
607 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
608 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 609 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
610 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 611 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
612 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 613 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
614 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
615 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 616 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
617 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
618 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 619 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
620 *Today*, 3(5), 409–412.
- 621 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
622 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
623 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 624 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
625 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 626 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
627 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
628 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 629 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
630 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
631 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 632 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
633 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
634 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 635 Nugroho, S., Soeparma, S., & Yuliati, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the

Research and Innovation in Food Science and Technology

- 636 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
637 (in Indonesia)
- 638 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
639 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
640 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 641 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
642 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
643 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 644 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
645 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
646 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 647 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
648 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 649 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
650 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 651 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
652 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
653 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 654 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
655 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
656 180. <https://www.atlantispress.com/article/125938018.pdf>
- 657 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
658 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
659 <https://doi.org/10.2993/0278-0771-36.2.312>
- 660 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
661 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
662 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 663 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
664 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
665 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 666 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
667 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
668 [https://scholar.archive.org/work/oconb3bhjzf3x1551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3x1551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
669 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 670 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
671 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
672 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 673 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
674 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
675 *Riau*, 2(2), 1–6. (in Indonesia)
- 676 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
677 wax. *Animal Agriculture Journal*, 3(1), 34–40.

Research and Innovation in Food Science and Technology

- 678 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
679 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in
680 Indonesia)
- 681 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
682 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
683 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 684 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
685 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
686 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 687 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
688 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
689 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 690 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
691 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 692 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
693 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
694 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 695 Stolyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
696 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 697 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
698 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 699 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
700 briquettes (corncob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
701 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 702 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
703 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
704 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 705 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
706 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
707 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 708 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
709 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 710 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
711 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 712 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
713 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 714 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
715 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 716 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
717 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 718 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
719 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*

Research and Innovation in Food Science and Technology

- 720 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 721 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid
722 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
723 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 724 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
725 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
726 6(3), 281–286.
- 727 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
728 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
729 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 730 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
731 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 732 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
733 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
734 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 735 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
736 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 737 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
738 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
739 6379. <https://doi.org/10.1021/ef5013769>

6. Bukti respons kepada reviewer terkait revisi manuskrip

1 Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) using Liquid 2 Smoke from Corn Cobs Waste

3 Abstract

4 This study aimed to obtain the best smoking method for *Julung Julung* fillets (*Hemiramphus* sp.) using liquid
5 smoke from corn cob waste. This study used three different fillet treatment methods (dried and steamed) before
6 liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional
7 methods (using shell, coconut wood, and corn cob). The parameters to determine the quality of smoked fish were
8 Total Volatile Bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH),
9 and sensory assessment. The results showed that the TVB of smoked *Julung Julung* fillets ranged from 19.83 –
10 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged
11 from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required
12 in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture
13 of smoked fish. From these research, it can be concluded that treatment B is the best treatment, namely fresh fillets
14 are first heated for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were
15 reheated for 4 hours at 90 °C.

16 **Keywords:** Corn cobs, Indonesia, Liquid smoke, North Sulawesi, Wood

18 Introduction

19 Corn is the second most widely grown crop in Indonesia after rice. Indonesia's maize production in 2023
20 is 14.46 million tons, ranking 9th in the world. (Indonesia Center of Statistic Agency, 2023). North
21 Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production
22 will also produce waste, especially corn cobs, which are generally thrown away and burned by most
23 Indonesians (Cahyadi *et al.*, 2021).

24 One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can
25 produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from
26 corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs
27 affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*,
28 2018). Swastawati *et al.* (2007) reported the phenolic content in liquid smoke produced from 335 mg/L
29 corn cobs.

30 Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*,
31 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without
32 the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save
33 time, energy, and labor, so that can reduce production costs (Krah *et al.*, 2019). In addition, using liquid
34 smoke in food can speed up and standardize the smoking process, adding flavor and microbiological
35 safety while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were
36 used to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced

37 may vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
38 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
39 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

40 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
41 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
42 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
43 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
44 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
45 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
46 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
47 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
48 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
49 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
50 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
51 (Azis & Akolo, 2020).

52 The study's reported that the conventional smoking process has disadvantages such as smoking time,
53 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
54 2020). Conventional smoking of food products has been shown to produce carcinogenic components
55 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
56 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
57 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
58 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

59 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
60 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
61 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
62 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
63 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
64 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
65 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

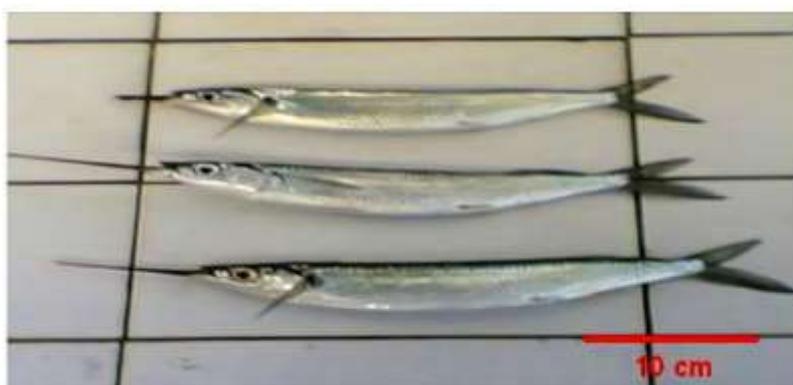
66 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
67 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et*
68 *al.*, 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
69 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on
70 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
71 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed

72 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
73 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
74 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
75 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
76 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
77 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
78 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
79 polycyclic aromatic hydrocarbon content, and sensory assessment.

81 Materials and methods

82 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
83 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
84 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
85 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
86 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
87 (Mishra *et al.*, 2021). Then, the fish was washed, cleaned, and filleted. The cleaned fillets were dipped
88 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0,8%
89 (Berhimpon *et al.*, 2018).

Commented [WT1]: Because based on the results of Berhimpon *et al.*, 2018, the best concentration of liquid acid from corn cobs for fish smoking is at a concentration of 0.8%.



91
92 **Fig. 1.** *Julung julung* (*Hemiramphus* sp.)

93
94 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
95 of *julung julung* fillets, which was compared with the conventional method (using coconut wood,
96 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then dried in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets were preheated in a cabinet dryer for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes, then dipped in liquid smoke for 20 minutes. After that, the fillets were dried in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

Commented [WT2]: The treatment in this study was based on the results of Berhimpon et al. (2018) with some modifications, namely smoking fish without liquid smoke (using wood, head, coconut shell, and corn cobs).

97

98 Liquid smoke manufacturing process

99 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
100 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
101 cobs are gradually burned into the combustion furnace, at 400 °C and have a pyrolysis time of about
102 120 minutes. The furnace was closed to prevent smoke from escaping from the tank. The smoke
103 generated from the combustion flows through a pipe connected to a storage tank covered with ice cubes.
104 The smoke that passes through the pipe will become cold, so condensation occurs, turning the smoke
105 into liquid. The smoke that has been formed is collected into a container attached to the end of the pipe.
106 The liquid smoke obtained is then allowed to settle the tar formed for three weeks and filtered (using
107 Whatman filter paper No. 10) to obtain clear liquid smoke.

Commented [WT3]: Based Aladin *et al.*, 2018

108 Total volatile bases assay

109 Total Volatile Base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
110 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
111 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
112 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
113 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
114 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
115 TVB levels in the smoked fish meat were expressed as mg N/100g.

Commented [WT4]: charcoal formed from the pyrolysis process

Commented [WT5]: Based Aladin *et al.*, 2018

Commented [WT6]: The level of benzopyrene from liquid smoke was evaluated by HPLC. And the benzopyrene in liquid smoke was about 0.5 µg/kg.

Commented [WT7]: The TVB testing method is based on the instructions of Tambunan and Chamidah (2021). We still include the complete work procedure, so that readers will get complete information.

$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times dilution \times 100}{sample\ weight\ (g)}$$

117

118

119 **Moisture content assay**

120 The moisture content is determined by the Indonesia National Standard (Indonesia Standardization
121 Agency, 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a
122 porcelain cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples
123 were then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content
124 was expressed as %.

$$125 \quad \text{Moisture (\%)} = \frac{B (g) - C (g)}{B (g) - A (g)} \times 100\%$$

126
127 **Water activity (Aw) assay**

128 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
129 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
130 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
131 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
132 (Saputra *et al.*, 2014).

133
134 **pH assay**

135 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28 °C. The sample
136 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
137 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
138 HI99192) (Lekahena & Jamin, 2018).

139
140 **Phenol level assay**

141 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
142 50%, homogenized, and allowed to stand for 5 minutes. Then, 1 mL of 5% Na₂CO₃ and left in the dark
143 for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a spectrophotometer
144 (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were expressed as mg/g
145 (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

$$146 \quad \text{Total Phenol } \left(\frac{mg}{g}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{mg}{L}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

147
148 **Polycyclic aromatic hydrocarbon (PAH) assay**

149 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
150 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL
151 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,

Commented [WT8]: Yes, using gallic acid as standar curve

the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1) and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract was dried under nitrogen gas.

After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane. A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector. The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20% water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was used for PAH concentration calculation.

Sensory assessment assay

Sensory assessment assay refers to the Indonesia National Standard (Indonesia Standardization Agency, 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were placed on a plastic plate with a glass of water, coded, and presented to 30 randomly selected semi-trained panelists (university students who had studied sensory assessment techniques), and the assessment process was carried out under light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance of the samples on a scale of 1 – 9.

Commented [WT9]: Without preparation, because the smoked fish samples used are still suitable for consumption (under 24 hours since smoking).

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

179 **Statistical analysis**

180 **Statistical analysis** was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test. **The**
183 **TVB, total phenol, pH, moisture, water activity, and sensory assessment parameters were evaluated**
184 **with three replicates.**

185
186 **Results and discussion**

187 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
188 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
189 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
190 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
191 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
192 and sensory assessment.

193
194 **Total volatile bases**

195 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
196 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
197 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
198 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
199 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
200 products and is emerging as the most commonly used chemical parameter to assess the palatability of
201 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
202 *julung* are presented in Fig. 2.

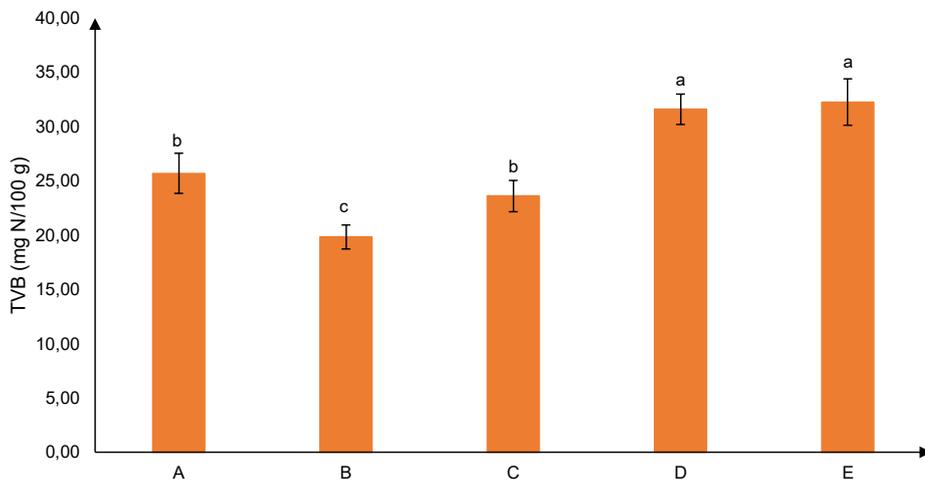


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yuniarta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018).

The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013).

The statistical analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

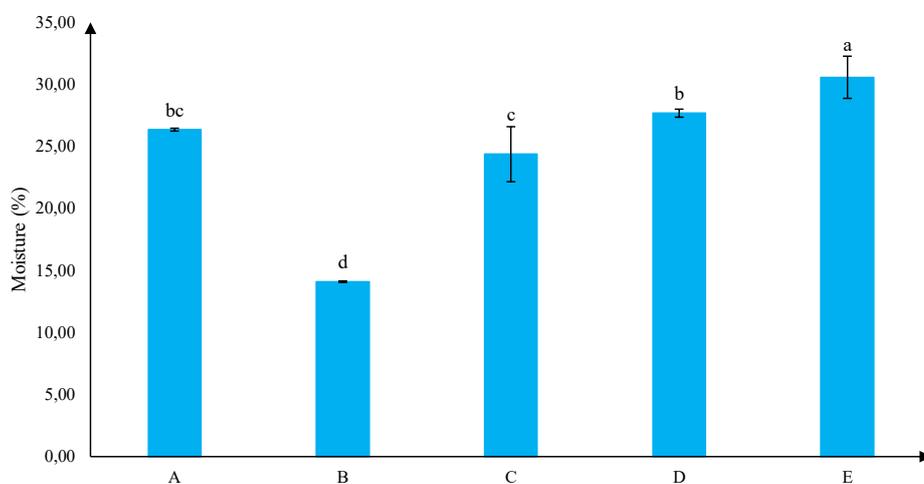
226 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 227 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 228 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 229 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 230 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 231 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 232 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 233 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 234 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

235

236 **Moisture content**

237 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 238 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 239 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 240 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 241 content of smoked fish fillets is presented in Fig. 3.

242



243

244

245

Fig. 3. Moisture content of julung julung smoked fillet

246 Fig. 3 shows the analysis of the variance of smoked *julung julung* fillets with different smoking methods
 247 treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung julung* fillets
 248 ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The moisture content

249 value in smoked fish products from all treatments still meets the Indonesian National Standard No.
250 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization Agency, 2013).
251 Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content of fish to below
252 40%, which can help preserve it longer. The treatment of the smoking method with liquid smoke with
253 corn cob (Treatment A, B, C) has a lower moisture content when compared to the treatment of the
254 conventional smoking method (Treatment D and E). This result is because the smoking chamber is not
255 fully enclosed in the conventional smoking method, so the heat generated could be more optimal.
256 Suboptimal heat can increase moisture content and cause the moisture content of smoked fish to
257 decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
258 temperature and humidity can be controlled better so that the moisture content of the product can be
259 reduced efficiently (Salindeho & Lumoindong, 2017).

260 **The statistical analysis** showed a difference between treatments B, A – C, and D – E on the TVB value
261 of smoked fish fillets showed a difference between treatment B, treatment A – C, and treatment D – E
262 on the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
263 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
264 content. This study's results are from previous research, which also reported a significant decrease in
265 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021). The
266 statistical analysis also showed that treatments A and C were not different because steaming in treatment
267 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
268 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
269 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

270

271 **Water activity (Aw)**

272 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
273 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
274 whether water tends to move from the food product into the cells of microorganisms that may be present.
275 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
276 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
277 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
278 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
279 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
280 fillets can be seen in Fig. 4.

281

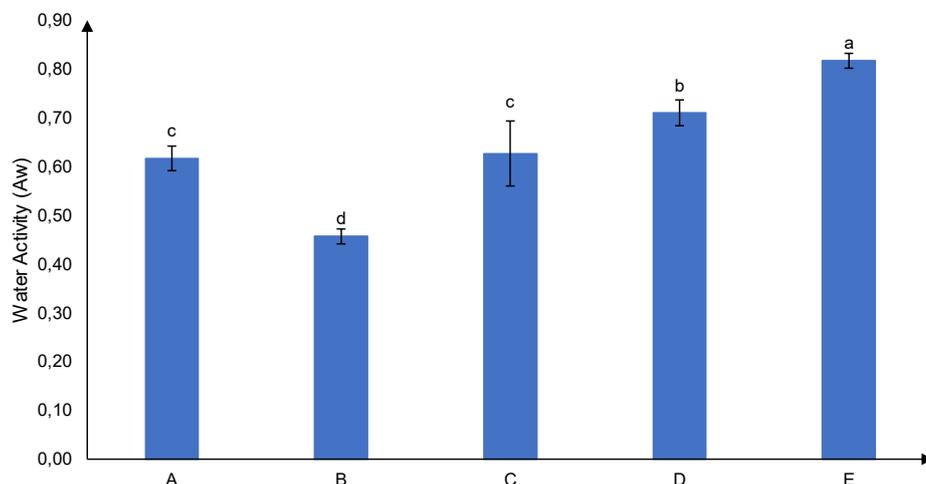


Fig. 4. Water activity of *julung julung* smoked fillet

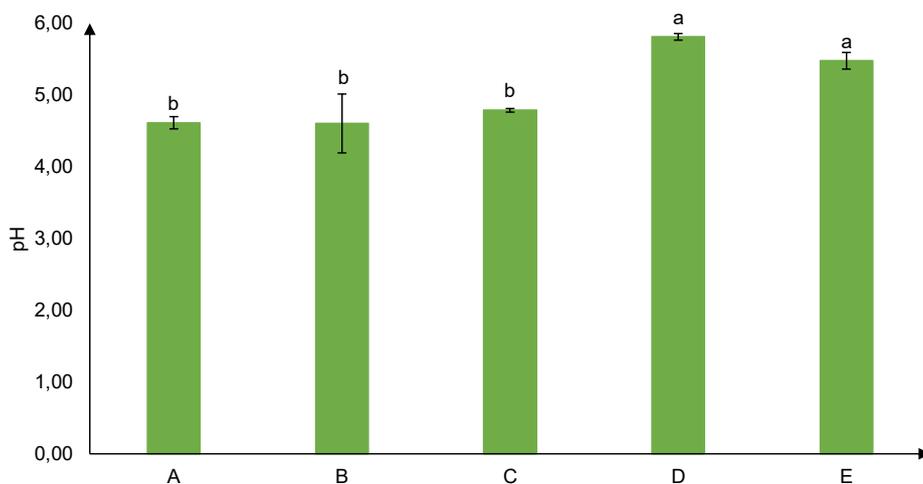
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

305 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 306 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 307 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 308 causes a decrease in pH (Berhimpon *et al.*, 2018).
 309



310
 311 **Fig. 5. pH of julung julung smoked fillet**
 312

313 **Phenol level**

314 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 315 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 316 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 317 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 318 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets julung
 319 julung with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 320 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 321 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 322 conventional smoking method (treatments D and E).
 323

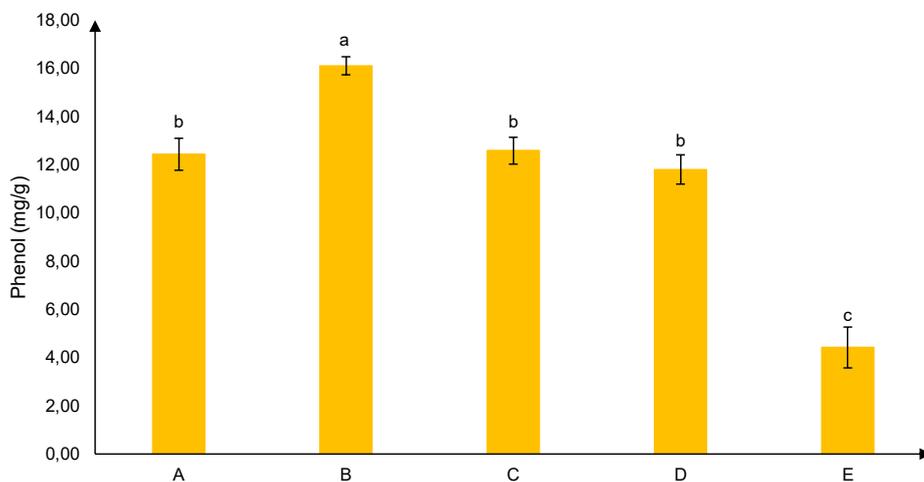


Fig. 6. Phenol level of *julung julung* smoked fillet

The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets showed phenol levels in treatments A, C, and D were not different. Previous research reported that the drying treatment of fish meat can increase phenolic compounds in smoked fish products (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the pre-heated process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets absorb a large amount of liquid smoke. Previous studies have reported that when the fish surface is dried, there is less smoke condensation than products smoked at lower temperatures. The results of this study indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et al.*, 2019).

The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*, 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.

Polycyclic aromatic hydrocarbon (PAH) levels

Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion, such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic

marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH) levels in smoked fish fillets can be seen in Table 2.

Table 2. Polycyclic aromatic hydrocarbon levels in *julung julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8%(µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

nd = not detected

Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*, 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg, benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg, and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

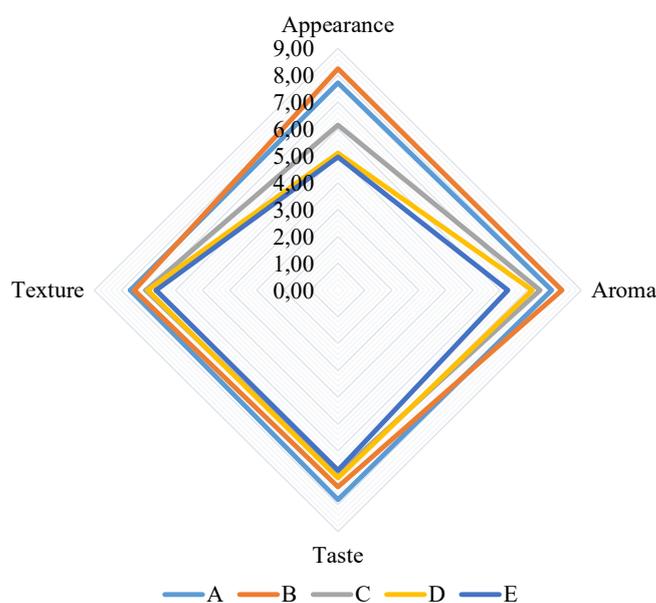
High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21% (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using corncobs are lower than those smoked with shells and coconut wood.

Sensory assessment

A sensory assessment is carried out to evaluate the panelist's preference level, including appearance, aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of

Commented [WT10]: PAH testing is not replicated because it uses the HPLC method

376 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 377 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to
 378 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 379 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 380 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 381 smoked fillet from each treatment can be seen in Fig. 7.



382 **Fig. 7. Sensory assesment of *julung julung* smoked fillet**

383
 384
 385 Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of smoked *julung*
 386 *julung fillets* with different smoking method treatments affecting the appearance of smoked fish
 387 ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from 4.95 to 8.24,
 388 with the highest panelists' assessment in treatment B. Based on the requirements of the Indonesian
 389 National Standard, only treatments A and B met the minimum panelist assessment requirement of 7.
 390 The moisture content factor is thought to have influenced the panelists' assessment of the appearance of
 391 smoked fish, so panelists less favored treatment C with steaming. Moisture content can affect the
 392 physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*, 2020a).
 393 Smoked fish with high moisture content will make the color of smoked fish look paler (Flick, 2010).
 394 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 395 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has

396 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another
397 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the
398 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
399 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
400 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
401 to the interaction of carbonyls with amino components on the surface of the meat. The color and
402 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
403 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
404 (Montazeri *et al.*, 2013).

405 Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked fish
406 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
407 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
408 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
409 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
410 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
411 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
412 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
413 hours in all treatments has not influenced the taste and aroma of smoked fish.

414 Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
415 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
416 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
417 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
418 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
419 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
420 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
421 fish (Sukowati *et al.*, 2021).

422 Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish fillet *julung*
423 *julung* with different smoking method treatments giving effect to the texture of smoked fish ($p<0.05$).
424 Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67, with the
425 highest panelist assessment in treatments A and B. The statistical analysis showed that treatments A and
426 B differed from treatments C, D, and E. This result was thought to be because the fish fillets were dipped
427 in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C (fish fillets subjected
428 to steaming), the texture of the smoked fillets was rather sticky and not solid. Treatments D and E
429 produced the texture of smoked fish fillets which were less dense and not compact. The texture of
430 smoked fish is negatively correlated with its moisture content. The higher the moisture content in

431 smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content in smoked
432 fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

433 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
434 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
435 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
436 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
437 the mouth when chewed (Ticoalu *et al.*, 2019).

438 439 **Conclusion**

440 Based on the evaluation of the parameters of total volatile bases, moisture content, water activity, pH,
441 phenol content, polycyclic aromatic hydrocarbon content, and sensory assessment of smoked *julung*
442 *julung* fillets using liquid smoke from corn cobs, it can be concluded that treatment B is the best
443 treatment, i.e. the fillets were preheated for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20
444 minutes, and the fillets were reheated for 4 hours at 90 °C. In general, the characteristics of smoked
445 fillets using liquid smoke from corn cobs were better when compared to the conventional smoking
446 treatment. It is necessary to evaluate different smoking times on smoked *julung julung* fillets with the
447 corn cob liquid smoke method.

448 449 **Acknowledgment**

450 451 **Author contributions**

452 453 **Conflicts of interest**

454 The authors declare that there is no conflict of interest.

455 456 **Highlights**

457 Effectiveness of using liquid smoke derived from corn cob waste in the smoking process of *julung*
458 *julung* fillets

459 460 **References**

- 461 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
462 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 463 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
464 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
465 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 466 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in

Commented [WT11]: Thanks for the suggestion, but We apologize, we used a lot of literature in compiling this article. This is to support our research results. If it is reduced, we think it will reduce this article's comprehensive discussion.

- 467 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*
468 *T1-T2-2020)*, 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>
- 469 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
470 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
471 <https://doi.org/10.21767/2572-5459.100026>
- 472 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
473 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755->
474 [1315/788/1/012078](https://doi.org/10.1088/1755-1315/788/1/012078)
- 475 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
476 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 477 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
478 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 479 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
480 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 481 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
482 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
483 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 484 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
485 *Global Scientific Journal*, 1(2), 77–84.
- 486 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
487 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
488 <https://doi.org/10.1080/10498850.2020.1741752>
- 489 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
490 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
491 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 492 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
493 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
494 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 495 Baten, M. A., Won, N. E., Mohibullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
496 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
497 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 498 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
499 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
500 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 501 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
502 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 503 Berhimpon, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
504 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
505 1864–1869.
- 506 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
507 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
508 <https://doi.org/10.1007/s11694-019-00347-6>

Research and Innovation in Food Science and Technology

- 509 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from [http://www.bccdc.ca/resource-](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
510 [gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf](http://www.bccdc.ca/resource-gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf)
- 511 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
512 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
513 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 514 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
515 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
516 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 517 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
518 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
519 <https://doi.org/10.2139/ssrn.3793663>
- 520 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
521 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
522 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 523 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
524 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
525 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 526 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
527 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 528 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
529 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
530 *Publications*, 3(3), 8–14.
- 531 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
532 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 533 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
534 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
535 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 536 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
537 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
538 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 539 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
540 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
541 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 542 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
543 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 544 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
545 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
546 <https://doi.org/10.4172/2572-4134.1000127>
- 547 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
548 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 549 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
550 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of

Research and Innovation in Food Science and Technology

- 551 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.
552 <https://doi.org/10.3390/foods11192938>
- 553 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
554 418, 31–32.
- 555 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
556 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
557 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
558 <https://doi.org/10.3390/fermentation8120704>
- 559 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
560 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 561 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
562 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 563 Hardianto, L., & Yunianta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
564 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 565 Indiarso, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
566 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
567 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 568 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
569 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
571 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2006b). *Indonesia National Standard - instructions for organoleptic and or sensor*
573 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 574 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
575 Jakarta: Indonesia. (in Indonesia)
- 576 Indonesia Center of Statistic Agency. (2023). Maize Harvested Area and Production in Indonesia 2023. Retrieved from
577 <https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-sementara-.html>. (in Indonesia)
- 578
- 579 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
580 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 581 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
582 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
583 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 584 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
585 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
586 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
587 (in Indonesia)
- 588 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
589 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
590 <https://doi.org/10.1016/j.asej.2021.05.013>
- 591 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
592 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in

- 593 Indonesia)
- 594 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
- 595 <https://doi.org/10.1007/s10086-016-1606-z>
- 596 Kiczorowska, B., Samolińska, W., Greła, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
- 597 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>
- 598 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
- 599 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. <https://doi.org/10.20474/japs->
- 600 5.2.1
- 601 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
- 602 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
- 603 Indonesia)
- 604 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
- 605 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 606 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
- 607 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
- 608 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 609 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
- 610 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 611 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
- 612 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 613 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
- 614 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
- 615 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 616 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
- 617 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
- 618 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 619 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
- 620 *Today*, 3(5), 409–412.
- 621 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
- 622 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
- 623 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 624 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
- 625 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 626 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
- 627 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
- 628 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 629 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
- 630 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
- 631 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 632 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
- 633 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
- 634 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>

Research and Innovation in Food Science and Technology

- 635 Nugroho, S., Soeparma, S., & Yuliati, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the
636 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
637 (in Indonesia)
- 638 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
639 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
640 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 641 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
642 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
643 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 644 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
645 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
646 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 647 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
648 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 649 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
650 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 651 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
652 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
653 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 654 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
655 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
656 180. <https://www.atlantispress.com/article/125938018.pdf>
- 657 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
658 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
659 <https://doi.org/10.2993/0278-0771-36.2.312>
- 660 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
661 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
662 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 663 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
664 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
665 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 666 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
667 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
668 [https://scholar.archive.org/work/oconb3bhjzf3xl551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3xl551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
669 [p/itp/article/viewFile/18562/18088](https://scholar.archive.org/work/oconb3bhjzf3xl551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 670 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
671 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
672 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 673 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
674 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
675 *Riau*, 2(2), 1–6. (in Indonesia)
- 676 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot

- 677 wax. *Animal Agriculture Journal*, 3(1), 34–40.
- 678 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
679 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in
680 Indonesia)
- 681 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
682 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
683 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 684 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
685 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
686 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 687 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
688 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
689 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 690 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
691 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 692 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
693 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
694 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 695 Stolyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
696 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 697 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
698 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 699 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
700 briquettes (corncob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
701 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 702 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
703 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
704 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 705 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
706 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
707 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 708 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
709 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 710 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
711 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 712 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
713 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 714 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
715 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 716 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
717 saving life of red kakap fish filets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 718 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic

Research and Innovation in Food Science and Technology

- 719 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*
720 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 721 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid
722 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
723 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 724 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
725 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
726 6(3), 281–286.
- 727 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
728 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
729 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 730 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
731 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 732 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
733 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
734 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 735 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
736 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 737 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
738 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
739 6379. <https://doi.org/10.1021/ef5013769>

Reviewer 1

Comment 1

Line 179. Change Data analysis to Statistical analysis.

State replicates for all tests.

Response

Statistical analysis

Statistical analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0. Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test. **The TVB, total phenol, pH, moisture, water activity, and sensory assessment parameters were evaluated with three replicates.**

Comment 2

In figures just put Duncan's letters on the bars. There is no need to mention the numbers on the bars.

Provide the proper abbreviations for the treatments in figures, tables as well as the manuscript text.

Duncan's letters are misattributed, the first letters must show the biggest numbers.

Response

It has been added and corrected

Comment 3

Also, Duncan's letters should be added in Table 2.

Response

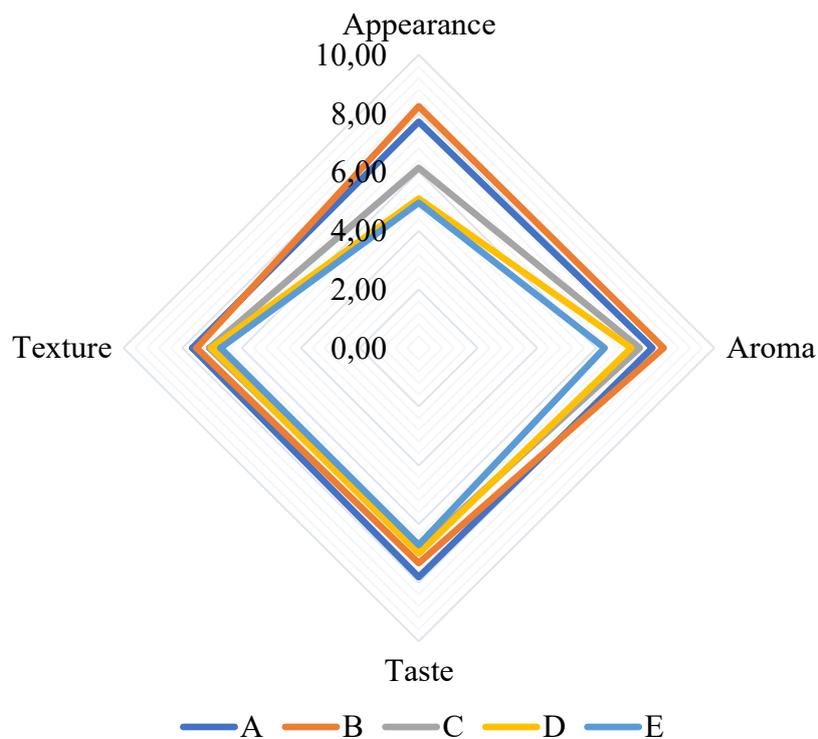
PAH testing is not replicated because because Data in table 2 using the HPLC method

Comment 4

Sensory evaluation data should be present as a radar plot.

Response

It has been corrected



Comment 5

Delete methods from the conclusion section.

It has been corrected

Conclusion

Based on the evaluation of the parameters of total volatile bases, moisture content, water activity, pH, phenol content, polycyclic aromatic hydrocarbon content, and sensory assessment of smoked *julung julung* fillets using liquid smoke from corn cobs, it can be concluded that treatment B is the best treatment, i.e. the fillets were preheated for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes, and the fillets were reheated for 4 hours at 90 °C. In general, the characteristics of smoked fillets using liquid smoke from corn cobs were better when compared to the conventional smoking treatment. It is necessary to evaluate different smoking times on smoked *julung julung* fillets with the corn cob liquid smoke method.

Comment 6

The last line of the abstract and conclusion should be revised and the best method mentioned.

Response

It has been corrected

Abstract

This study aimed to obtain the best smoking method for *julung julung* fillets (*Hemiramphus* sp.) using liquid smoke from corn cob waste. This study used three different fillet treatment methods (dried and steamed) before liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional methods (using shell, coconut wood, and corn cob). The parameters to determine the quality of smoked fish were Total Volatile Bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed that the TVB of smoked *julung julung* fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these research, it can be concluded that treatment B is the best treatment, namely fresh fillets are first heated for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated for 4 hours at 90 °C.

Reviewer 2

Comment 1

Keywords : Corn cobs, Liquid smoke

Response

Keywords: Corn cobs, Indonesia, Liquid smoke, North Sulawesi, Wood

Comment 2

Materials and Methods (Line 90) : Why used this concentration??

Response

Because based on the results of Berhimpon et al., 2018, the best concentration of liquid acid from corn cobs for fish smoking is at a concentration of 0.8%.

Commnet 3

Line 98 Treatments : References

Response

The treatments in this study were based on the results of Berhimpon et al. (2018) with added treatments, namely smoking fish without liquid smoke (using wood, head, coconut shell, and corn cobs).

Comment 4

Line 103 : Temperature of combustion furnace.

Response

The combustion furnace, at 400 °C and have a pyrolysis time of about 120 minutes (Based Aladin *et al.*, 2018).

Commnet 5

Line 108 : Reference and How?? To separate what?? how about benzopyrene?

Response

The pyrolysis based on Based Aladin *et al.*, 2018

HPLC evaluated the level of benzopyrene from liquid smoke. And the benzopyrene in liquid smoke was about 0.5 µg/kg (Table 2).

Comment 6

Line 111 : Volatile Base

Response

It has been corrected

Comment 7

Line 172 : Without any preparation??

Response

Without preparation,because the smoked fish samples used are still suitable for consumption (under 24 hours since smoking).

Comment 8

Line 458 : A lot! Decrease that

Response

Thanks for the suggestion, but I apologize, we used a lot of literature in compiling this article. This is to support our research results. If it is reduced, we think that it will reduce the comprehensive discussion in this article.

Reviewer 3**Comment 1**

Title : Fish

Response

It has been corrected

Characteristics of Julung Julung Smoked Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs Waste

Comment 2

Line 4-6 : Delete please

Response

It has been deleted

Comment 3

Line 7 : Edit the sentence

Response

It has been edited

This study used three different fillet treatment methods (dried and steamed) before liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional methods (using shell, coconut wood, and corn cob).

Comment 4

Line 11 : Delete

Response

It has been deleted

Comment 5

Line 22 : update the data for 2024

Response

There is no data yet for 2024. We only have data for 2023.

Indonesia's maize production in 2023 is 14.46 million tons, ranking 9th in the world.

(Indonesia Center of Statistic Agency, 2023).

Comment 6

Line 30 : edit please

Response

Swastawati et al. (2007) reported the phenolic content in liquid smoke produced from 335 mg/L corn cobs.

Comment 7

Line 35 : Double “and”

Response

Using liquid smoke in food will save time, energy, and labor, so that can reduce production costs.

Comment 8

Line 89 : Weeded ???

Response

It has been corrected to be **cleaned**

Comment 9

Line 107 : Tar???

Response

charcoal formed from the pyrolysis process

Comment 10

Line 110-116 : It doesn't need to write the details of routine methods

Response

The TVB testing method is based on the instructions of Tambunan and Chamidah (2021). We still include the complete work procedure, so that readers will get complete information.

Comment 11

Line 146 : Did you use standard curve?

Response

Yes, using gallic acid as standard curve

Comment 12

Line 173 : Trained?

Response

Smoked fish samples were placed on a plastic plate with a glass of water, coded, and presented to 30 randomly selected semi-trained panelists (university students who had studied sensory assessment techniques), and the assessment process was carried out under light.

Comment 13

Line 203 : Please use a code for each treatment the figure is difficult to understand

Response

It has been corrected

Comment 14

Line 218 : The statistical analysis showed

Response

It has been corrected

Comment 15

Line 221 : Please define code below the figure and then mention in the text

Response

It has been corrected

Comment 16

Line 412 : delete

Response

It has been deleted

Comment 17

Line 438 : delete in conclusion

Response

It has been deleted

7. Bukti manuskrip telah diterima setelah revisi II



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Acknowledgement of Revision (#JRIFST-2406-1571 (R2))

1 pesan

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Date: 2024-06-03

Dear Mr. Jefri Anthonius Mandeno

Thank you for submitting the revised file of your manuscript to the **Research and Innovation in Food Science and Technology**

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8. Bukti manuskrip telah diterima dan akan dipublikasikan



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Acceptance of Manuscript (#JRIFST-2406-1571 (R2))

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Number: JRIFST-2406-1571 (R2)/137

Accepted: February 16, 2025

Manuscript ID: JRIFST-2406-1571 (R2)

Manuscript Title: **Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs**

Authors: Jefri Anthonius Mandeno, Wendy Alexander Tanod, Eko Cahyono, Yana Sammbeka, Frets Jonas Rieuwpassa, Novalina Putra Palawe, Putut Har Riyadi

Dear **Mr. Jefri Anthonius Mandeno**

Thank you for submitting your manuscript to Research and Innovation in Food Science and Technology.

I am pleased to inform you that the submitted manuscript entitled “ **Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) from Corn Cobs Waste** ” has been accepted as " Original Paper " for publication and it will now be transferred to our production department.

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10. Artikel published

Characteristics of *Julung Julung* Smoked Fillets (*Hemiramphus* sp.) using Liquid Smoke from Corn Cobs Waste

Abstract

This study aimed to obtain the best smoking method for *Julung Julung* fillets (*Hemiramphus* sp.) using liquid smoke from corn cob waste. This study used three different fillet treatment methods (dried and steamed) before liquid smoke application. This study also compared fish smoking between using liquid smoke with conventional methods (using shell, coconut wood, and corn cob). The parameters to determine the quality of smoked fish were Total Volatile Bases (TVB), moisture, water activity, pH, phenol levels, polycyclic aromatic hydrocarbon (PAH), and sensory assessment. The results showed that the TVB of smoked *Julung Julung* fillets ranged from 19.83 – 32.27 mg N/100g. The moisture ranged from 14.10 – 30.57%. Water activity ranged from 0.46 – 0.82. pH ranged from 4.60 – 5.81. Phenol levels ranged from 4.42 – 16.11 mg/g. PAH levels are still below the standard required in the Indonesian National Standard. Panelists rated neutral to really like the appearance, aroma, taste, and texture of smoked fish. From these research, it can be concluded that treatment B is the best treatment, namely fresh fillets are first heated for 4 hours at 60 – 80 °C and then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated for 4 hours at 90 °C.

Keywords: Corn cobs, Indonesia, Liquid smoke, North Sulawesi, Wood

Introduction

Corn is the second most widely grown crop in Indonesia after rice. Indonesia's maize production in 2023 is 14.46 million tons, ranking 9th in the world. (Indonesia Center of Statistic Agency, 2023). North Sulawesi is one of the contributing regions that produce corn in Indonesia. Considerable corn production will also produce waste, especially corn cobs, which are generally thrown away and burned by most Indonesians (Cahyadi *et al.*, 2021).

One of the corn cobs was used to make liquid smoke. Previous research reported that corn cobs can produce liquid smoke, a by-product of the pyrolysis of corn cob waste. The yield of liquid smoke from corn cobs is about 28.37%, with a pH value of 3.5 (Sriharti *et al.*, 2020). The particle size of corn cobs affects the yield of liquid smoke, with smaller particle sizes resulting in higher yields (Aladin *et al.*, 2018). Swastawati *et al.* (2007) reported the phenolic content in liquid smoke produced from 335 mg/L corn cobs.

Liquid smoke is a natural product made from the condensation of smoke from burning wood (Andy *et al.*, 2021). Liquid smoke is commonly used as a flavoring in food to provide a smoked flavor without the food undergoing the actual smoking process (Sari *et al.*, 2006). Using liquid smoke in food will save time, energy, and labor, so that can reduce production costs (Krah *et al.*, 2019). In addition, using liquid smoke in food can speed up and standardize the smoking process, adding flavor and microbiological safety while reducing production time (Indiarto *et al.*, 2020). Generally, various types of hardwood were used to manufacture liquid smoke (Diatmika *et al.*, 2019). The quality of the liquid smoke produced

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Reviewer comment for author

- 1-The responses to reviewers comments should be attached (Reviewers 1, 2 and 3), (Necessary)
- 2-The responses to final reviewer comments should be attached (Necessary).
- 3-The radar plot is drawn incorrectly and needs to be corrected. Attributes must be at the vertices of the polygon.

37 may vary depending on the type of wood used (Budaraga *et al.*, 2016). In addition to imparting specific
38 flavors and aromas to foods (Maulina *et al.*, 2020), liquid smoke is reported to be antimicrobial (Septana
39 *et al.*, 2020) and antioxidant (Budaraga & Putra, 2021).

40 The conventional smoking processes generally use hardwood as fuel, such as melon wood (Umar *et al.*,
41 2018), mangrove wood (Cissoko *et al.*, 2020), teak wood (Daramola *et al.*, 2020), coconut shells, and
42 coconut husks (Nugroho *et al.*, 2018). Corn cobs have also been reported to be used in the fish smoking
43 process (Sukowati, 2023). According to literature, traditional fish smoking in North Sulawesi,
44 Indonesia, uses smoke from burning coconut shells or wood charcoal (Landangkasiang *et al.*, 2017;
45 Primalasari *et al.*, 2019; Saediman *et al.*, 2021). Smoked fish processing has been known for a long time
46 because of its traditional processing techniques, simplicity, ease of implementation, and low cost
47 (Islamiyah, 2021). In North Sulawesi, Indonesia, smoked fish commonly known as *fufu* is traditionally
48 made from skipjack (*Katsuwonus pelamis*); *julung julung* (*Hemiramphus far*) (Berhimpon *et al.*, 2018);
49 and scad fish (*Decapterus* spp.) known as *pinekuhe* (Ansar & Ijong, 2021). The smoked fish product of
50 *julung julung* is a typical product from North Sulawesi and Gorontalo, commonly called *roa* or *galavea*
51 (Azis & Akolo, 2020).

52 The study's reported that the conventional smoking process has disadvantages such as smoking time,
53 concentration of carcinogenic substances, temperature, and inconsistent product quality (Racovita *et al.*,
54 2020). Conventional smoking of food products has been shown to produce carcinogenic components
55 such as polycyclic aromatic hydrocarbons (Jinadasa *et al.*, 2020). Benzo(a)pyrene (C₂₀H₁₂) is one of the
56 carcinogenic compounds produced from traditional smoking products (Jinadasa *et al.*, 2020). One
57 method to reduce carcinogenic compounds in smoked fish products is to use liquid smoke in the
58 smoking process (Nithin *et al.*, 2020; Xin *et al.*, 2021).

59 The utilization of liquid smoke in the fish smoking industry in North Sulawesi is very likely to be
60 developed. North Sulawesi was reported to have both large-scale and domestic fish-smoking industries
61 (Dotulong *et al.*, 2018; Primalasari *et al.*, 2019). Making liquid smoke is relatively simple, so it will be
62 readily accepted by fish-smoking industry players (Ali & Al Fiqri, 2020). Previous research reported
63 that using liquid smoke in smoked fish products resulted in good quality in terms of appearance, flavor,
64 and aroma (Rizal *et al.*, 2020). In addition, using liquid smoke in smoked fish products can add
65 nutritional value and durability, making it possible to reach a wider market area (Ali *et al.*, 2021).

66 Previous research reported that smoked fish dipped in liquid smoke for 15 minutes had a total plate
67 count value of 4.7×10^4 CFU/g on day six and moisture content below 60% during storage (Suroso *et al.*,
68 2018). Dipping fish in liquid smoke with a concentration of 15% and a dipping time of 60 minutes
69 showed a bacterial colony of 2.12×10^2 CFU/g (Ali *et al.*, 2021). The Indonesian National Standard on
70 smoked fish requires a maximum total plate count of 5×10^4 CFU/g and a maximum moisture content of
71 60% (Indonesia Standardization Agency, 2013). Another study reported that smoked fish processed

72 with liquid smoke had a moisture content of 47.63%, phenol content of 12.62%, and pH of 4.8
73 (Berhimpon *et al.*, 2018). The results of these studies indicate that liquid smoke is good to apply to
74 smoked fish products. This study characterized smoked fish fillets of *julung julung* (*Hemiramphus* sp.)
75 produced with liquid smoke from corn cobs waste. The study was conducted by dipping the fish fillets
76 of *julung julung* with liquid smoke, with drying and steaming treatments on the fish fillets. This study
77 aims to obtain the best smoking method for fish fillets using liquid smoke from corn cobs waste based
78 on the assessment of total volatile bases, moisture content, water activity, pH value, phenol content,
79 polycyclic aromatic hydrocarbon content, and sensory assessment.

80

81 **Materials and methods**

82 The main materials of the study were *julung julung* fish (*Hemiramphus* sp.), corn cob (*Zea mays* L.)
83 from Gangga Island in Likupang, North Sulawesi, Indonesia. This study includes the preparation of
84 liquid smoke from corn cobs waste, preparing fish (weeding and filleting), and treating fish fillets by
85 dip in liquid smoke. Fresh *julung julung* fish was obtained from traditional fishermen in Manado, North
86 Sulawesi, Indonesia (Fig. 1). The fish was placed in a cool box and given ice in a ratio of 1:1 (ice:fish)
87 (Mishra *et al.*, 2021). Then, the fish was washed, cleaned, and filleted. The cleaned fillets were dipped
88 in a 5% salt solution for 30 minutes. The concentration of liquid smoke from corn cob waste was 0.8%
89 (Berhimpon *et al.*, 2018).

90



91

92

Fig. 1. *Julung julung* (*Hemiramphus* sp.)

93

94 The treatment in this study was applying liquid smoke from corn cobs waste to the smoking process
95 of *julung julung* fillets, which was compared with the conventional method (using coconut wood,
96 coconut shells, and corn cobs).

- (A) : Fresh fillets were dipped in liquid smoke for 20 minutes and then dried in a cabinet dryer for 4 hours at 90 °C.
- (B) : Fresh fillets were preheated in a cabinet dryer for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated in a cabinet dryer for 4 hours at 90 °C.
- (C) : Fresh fillets were steamed for 30 minutes, then dipped in liquid smoke for 20 minutes. After that, the fillets were dried in a cabinet dryer for 4 hours at 90 °C.
- (D) : Fresh fillets were smoked with the conventional method using wood and coconut shell for 6 hours at 90 °C.
- (E) : Fresh fillets were smoked with the conventional method using corncob for 6 hours at 90 °C.

97

98 **Liquid smoke manufacturing process**

99 Making liquid smoke refers to modified research (Aladin *et al.*, 2018). Modifications were made to the
100 equipment used in the pyrolysis process. Dry corn cobs were weighed to determine fuel efficiency. Corn
101 cobs are gradually burned into the combustion furnace, at 400 °C and have a pyrolysis time of about
102 120 minutes. The furnace was closed to prevent smoke from escaping from the tank. The smoke
103 generated from the combustion flows through a pipe connected to a storage tank covered with ice cubes.
104 The smoke that passes through the pipe will become cold, so condensation occurs, turning the smoke
105 into liquid. The smoke that has been formed is collected into a container attached to the end of the pipe.
106 The liquid smoke obtained is then allowed to settle the tar formed for three weeks and filtered (using
107 Whatman filter paper No. 10) to obtain clear liquid smoke.

108 **Total volatile bases assay**

109 Total Volatile Base (TVB) assay refers to research by Tambunan & Chamidah (2021). TVB assay aims
110 to determine the amount of volatile base compounds formed from protein breakdown—the principle of
111 TVB analysis, namely by evaporating volatile base compounds at room temperature for 24 hours. The
112 compound is then bound with boric acid and titrated with an HCl solution. After the boric acid solution
113 was stored in the inner chamber of the Conway cell containing the blank (V_0) and the filtrate (V_1), the
114 boric acid solution was titrated with 0.02 N HCl so that the boric acid solution changed color to pink.
115 TVB levels in the smoked fish meat were expressed as mg N/100g.

116
$$TVB \left(\text{mg} \frac{\text{N}}{100\text{g}} \right) = \frac{(V_1 - V_0) \times N.HCl \times \text{dilution} \times 100}{\text{sample weight (g)}}$$

117

118

119 **Moisture content assay**

120 The moisture content is determined by the Indonesia National Standard (Indonesia Standardization
121 Agency, 2006a). An empty porcelain cup is weighed (A). Then, the sample was weighed to ± 2 g in a
122 porcelain cup of known mass (B). The samples were dried in an oven at 105°C for 20 hours. The samples
123 were then cooled in a desiccator, after which the samples in the cup were weighed (C). Moisture content
124 was expressed as %.

125
$$\text{Moisture (\%)} = \frac{B (g) - C (g)}{B(g) - A (g)} \times 100\%$$

126

127 **Water activity (Aw) assay**

128 Water activity assay used an Aw meter (Rotronic, HygroPalm 23-AW-A). The Aw meter was set up at
129 room temperature for 2 hours. The water activity of smoked fish was measured by placing the sample
130 into a sample container and conditioning it for 30-60 minutes. The Aw meter sensor is contacted with
131 the sample in the container. Then the water activity (Aw) value can be read on the Aw meter panel
132 (Saputra *et al.*, 2014).

133

134 **pH assay**

135 The sample weighed as much as 30 g, then 400 mL of distilled water was added at 28 °C. The sample
136 was homogenized with a magnetic stirrer to be evenly stirred. The pH meter electrode was inserted into
137 the sample solution. The data taken in this test is the pH value read by the pH meter (Hanna Instruments
138 HI99192) (Lekahena & Jamin, 2018).

139

140 **Phenol level assay**

141 Samples were extracted by adding 1 mL ethanol p.a., 5 mL distilled water, and 0.5 mL Folin Ciocalteu
142 50%, homogenized, and allowed to stand for 5 minutes. Then, 1 mL of 5% Na₂CO₃ and left in the dark
143 for ± 60 minutes with gallic acid as a standard. The absorbance value was read on a spectrophotometer
144 (Thermo Scientific Genesys 50) with a wavelength of 725 nm. Total phenolics were expressed as mg/g
145 (Indonesia Standardization Agency, 2004; Muliadin *et al.*, 2022).

146
$$\text{Total Phenol } \left(\frac{mg}{g}\right) = \frac{\text{Gallic acid equivalence } \left(\frac{mg}{L}\right) \times \text{Volume (L)}}{\text{Sample weight (g)}}$$

147

148 **Polycyclic aromatic hydrocarbon (PAH) assay**

149 PAH content testing was carried out based on the instructions Basak *et al.* (2010). A 5 g sample was
150 weighed and collected in a 100 ml flask. Then 5 mL of 50% KOH solution, 75 mL of methanol, 1 mL
151 of internal standard solution (9,10 dimethylantracene), and some boiling stones were added. After that,

the mixture was boiled for 4 hours in a soxhlet. The liquid phase was transferred to a separatory funnel and extracted with 100 mL of n-hexane with shaking for 3 min. The MeOH:KOH phase was drained and discarded. The combined n-hexane phase was rinsed twice, each with 50 mL of H₂O-MeOH (8:1) and 50 mL of water. The methanol-water and water phases were dried and discarded. The organic phase was concentrated in a rotary evaporator (40°C) to a volume of about 10 mL. The concentrated extract was dried under nitrogen gas.

After that, the silica gel column was cleaned by dissolving 15 g of silica gel in n-hexane and transferred to a column (200 mm long; diameter: 12 mm). Then, 1 g of anhydrous sodium sulfate was added. The concentrated sample extract was transferred to the column and eluted with 1 mL of n-hexane. A stock solution containing 0.1 mg mL⁻¹ of 9,10 dimethylantracene was dissolved in n-hexane and stored at 4°C in a volumetric flask (with a glass stopper) wrapped in aluminum foil to avoid possible light degradation. Working standard solutions were prepared from the stock solutions. Analysis of PAH compounds used a Hewlett-Packard 1100 HPLC equipped with an Agilent-110 fluorescence detector. The injection volume was 10 µL. Mobile phase gradient (acetonitrile-water): 80% acetonitrile + 20% water with a flow rate of 1 ml min⁻¹ and a wavelength of 270 nm. The external standard mixture was used for PAH concentration calculation.

Sensory assessment assay

Sensory assessment assay refers to the Indonesia National Standard (Indonesia Standardization Agency, 2006b). The sensory assessment was based on a hedonic scale (Table 1). Smoked fish samples were placed on a plastic plate with a glass of water, coded, and presented to 30 randomly selected semi-trained panelists (university students who had studied sensory assessment techniques), and the assessment process was carried out under light. The parameters observed were appearance, aroma, taste, and texture. Panelists rated acceptance of the samples on a scale of 1 – 9.

Table 1. Score sheet of hedonic assessment

Specification	Score
Really like it	9
Really like	8
Like	7
Rather like	6
Neutral	5
Rather dislike	4
do not like	3
Very dislike	2
Really don't like it	1

179 **Statistical analysis**

180 Statistical analysis was performed using Statistical Product and Service Solutions (SPSS) version 20.0.
181 Statistical analysis of data was performed based on one-way analysis of variance (ANOVA) using a
182 significance level of ($P < 0.05$). Specific group differences were determined using Duncan's test. The
183 TVB, total phenol, pH, moisture, water activity, and sensory assessment parameters were evaluated
184 with three replicates.

185
186 **Results and discussion**

187 Liquid smoke production was carried out using a simple liquid smoke distillation device. This process
188 consumed 17 kg of corn cobs and 12 kg of crushed ice. Liquid smoke from corn cobs is more accessible
189 than coconut shells or wood (Maulina & Karo, 2021). Using coconut shells or wood as fuel will form a
190 flame, thus reducing the volume of smoke in the furnace (Kabir Ahmad *et al.*, 2022). The smoked *julung*
191 *julung* were analyzed for TVB, moisture content, water activity, pH value, phenol content, PAH content,
192 and sensory assessment.

193
194 **Total volatile bases**

195 The total volatile base (TVB) value is measured to determine the quality of the smoked fish. TVB value
196 is one of the parameters used to determine the decline in fish quality and measures the amount of volatile
197 base compounds formed due to protein degradation (Castro *et al.*, 2006). Volatile bases formed in fish
198 muscle tissue mainly consist of ammonia, trimethylamine (TMA), and dimethylamine (DMA) (VELP
199 Scientifica, 2013). TVB value is an essential characteristic for the quality assessment of seafood
200 products and is emerging as the most commonly used chemical parameter to assess the palatability of
201 seafood (Rasulu *et al.*, 2020). The results of *total volatile bases* on smoked fish fillets of *julung*
202 *julung* are presented in Fig. 2.

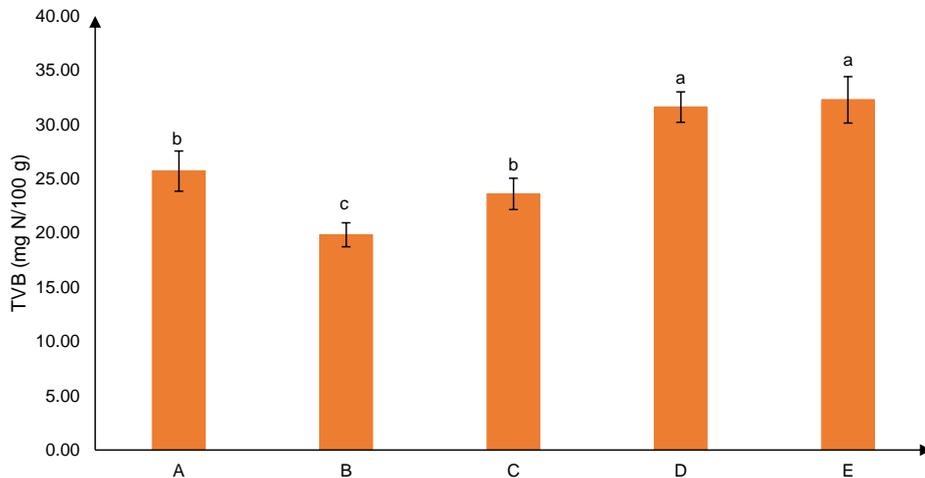


Fig. 2. Total volatile bases of *julung julung* smoked fillet

Fig. 2 shows the analysis of the variance of smoked fish fillets with different smoking method treatments affecting changes in TVB content ($p < 0.05$). The TVB content of smoked fish fillets ranged from 19.83 – 32.27 mg N/100g, with the lowest TVB value in treatment B. The treatment of the smoking method with liquid smoke from corn cob waste (treatments A, B, and C) had lower TVB levels when compared to the conventional smoking method (treatments D and E). A literature search has not found why liquid smoking has a lower TVB value than conventional smoking methods. However, one possibility is that the liquid smoke smoking method allows the smoke components to be absorbed into the fish meat better than the conventional smoking method. Better absorption of liquid smoke phenol components in fish meat can inhibit and control microbial growth that causes a decrease in the quality of smoked fish (Santoso *et al.*, 2015). A literature study showed that the average TVB value of smoked mackerel (*Euthynnus affinis*) treated with liquid smoke addition ranged from 24.63 – 28.38 mg N/100g (Hardianto & Yunianta, 2015). Another study reported smoked mackerel with a smoking process using rubber wood liquid smoke, producing smoked fish products with lower TVB values (Suroso *et al.*, 2018). The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value of smoked fish fillets. The analysis of variance indicates that the drying process of smoked fish fillets before immersion into liquid smoke can maintain the quality of smoked fish (Kaparang *et al.*, 2013). The statistical analysis also showed that treatments A – C and D – E had no difference in TVB value, indicating that the moisture content between the two treatments was not different. TVB value is closely related to moisture content (Rasulu *et al.*, 2020).

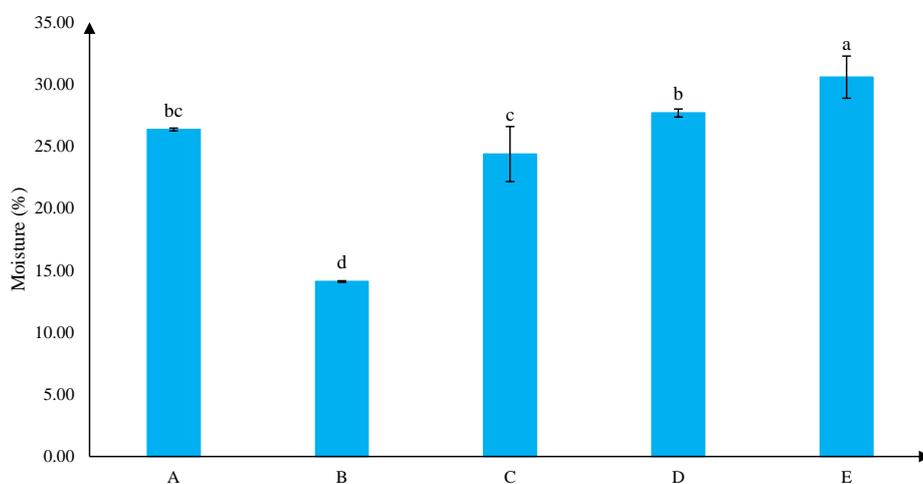
226 The European standard (European Market Observatory for Fisheries and Aquaculture, 2020) states that
 227 the limit range of TVB value for smoked fish is 25 – 35 mg N/100 g. All treatments' TVB value of the
 228 smoked fish fillets still met the European standard. Previous studies reported TVB values of fresh fish
 229 fillets of 8.70 ± 0.86 mgN/100g (Moosavi-Nasab *et al.*, 2021) and 12.94 ± 0.92 mg N/100g (Bouzgarrou
 230 *et al.*, 2020). Messina *et al.* (2021) reported that smoked fish fillets that underwent two drying processes
 231 had a TVB value of <20 mg N/100g. Another study also reported the TVB value of smoked fish fillet
 232 samples with hot smoking and cold smoking, which amounted to 17.80 ± 0.17 and 18.95 ± 0.20 mg
 233 N/100g, respectively (El-Lahamy *et al.*, 2019). Aydin *et al.* (2020) reported a TVB value of smoked
 234 fish with hot smoking of 11.82 ± 0.05 mg N/100g.

235

236 **Moisture content**

237 Moisture content is an important parameter to determine the quality of smoked fish produced. The
 238 moisture content contained in smoked fish can affect the shelf life of smoked fish because water in food
 239 is a medium for microbes to grow (Kaban *et al.*, 2019). The smoking process was reported to reduce
 240 the moisture content of fresh fish to a range between 9 and 17% (Sikoki & Aminigo, 2002). The moisture
 241 content of smoked fish fillets is presented in Fig. 3.

242



243

244

245

Fig. 3. Moisture content of *julung julung* smoked fillet

246 Fig. 3 shows the analysis of the variance of smoked *julung julung* fillets with different smoking methods
 247 treatment affects moisture content ($p < 0.05$). The moisture content of smoked *julung julung* fillets
 248 ranged from 14.10 – 30.57%, with the lowest moisture content in treatment B. The moisture content

249 value in smoked fish products from all treatments still meets the Indonesian National Standard No.
250 2725:2013 on smoked fish, which is a maximum of 60% (Indonesia Standardization Agency, 2013).
251 Darianto *et al.* (2018) reported that the smoking process can reduce the moisture content of fish to below
252 40%, which can help preserve it longer. The treatment of the smoking method with liquid smoke with
253 corn cob (Treatment A, B, C) has a lower moisture content when compared to the treatment of the
254 conventional smoking method (Treatment D and E). This result is because the smoking chamber is not
255 fully enclosed in the conventional smoking method, so the heat generated could be more optimal.
256 Suboptimal heat can increase moisture content and cause the moisture content of smoked fish to
257 decrease only slightly (Amos & Paulina, 2017). Whereas in the liquid smoke smoking method,
258 temperature and humidity can be controlled better so that the moisture content of the product can be
259 reduced efficiently (Salindeho & Lumoindong, 2017).

260 The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value
261 of smoked fish fillets showed a difference between treatment B, treatment A – C, and treatment D – E
262 on the moisture content of smoked fish fillets. The results of the variance study indicate that the drying
263 process of smoked fish fillets before the dip in liquid smoke in treatment B can help reduce the moisture
264 content. This study's results are from previous research, which also reported a significant decrease in
265 moisture content in smoked fish products with two times drying treatment (Messina *et al.*, 2021). The
266 statistical analysis also showed that treatments A and C were not different because steaming in treatment
267 C will increase the moisture content of the product (Salmatia *et al.*, 2020). The conventional smoking
268 method with corn cob fuel has the highest moisture content; this result is the conventional smoking
269 process with corn cobs, and the heat generated is lower than smoking using wood (Asmara *et al.*, 2022).

270

271 **Water activity (Aw)**

272 Water activity is one of the essential parameters in the quality of smoked fish. Water activity (Aw) is
273 expressed as the ratio of the vapor pressure in the food to the vapor pressure of pure water, and it predicts
274 whether water tends to move from the food product into the cells of microorganisms that may be present.
275 A well-smoked fish has a water activity of <0.50 and a moisture content between 15 and 25% to inhibit
276 the growth of pathogenic microorganisms in smoked fish products (Mondo *et al.*, 2020). According to
277 British Columbia Centre for Disease Control (2013), the maximum water activity value for smoked fish
278 is 0.97. Water activity correlates with the moisture content of a smoked fish product and is two important
279 factors affecting food safety and quality (Fitri *et al.*, 2022). The water activity values of smoked fish
280 fillets can be seen in Fig. 4.

281

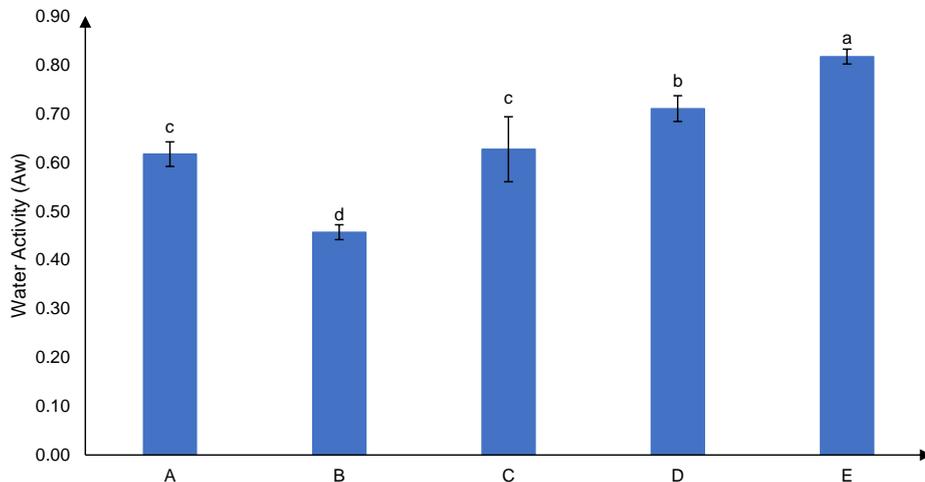


Fig. 4. Water activity of *julung julung* smoked fillet

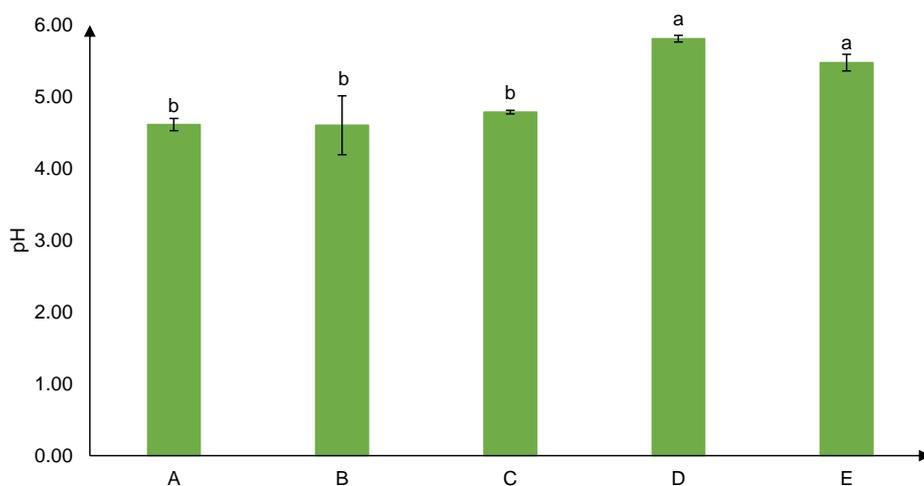
Fig. 4 shows the analysis of the variance of smoked fish fillet *julung julung* with different smoking method treatments affecting water activity ($p < 0.05$). The water activity value of smoked fish fillet ranged from 0.46 – 0.82, with the lowest water activity in treatment B. The treatment of the smoking method with corn cob liquid smoke (Treatment A, B, C) had a lower water content when compared to the treatment of the conventional smoking method (treatment D and E).

The water activity value of fish meat can vary depending on the cooking method, temperature, and duration of heating (Oliveira *et al.*, 2017; Zhang *et al.*, 2023). Therefore, the factor of fish fillet treatment before immersion in liquid smoke caused the difference in water activity value in treatment B compared to treatments A and C. The water activity value is directly proportional to the water content value of each treatment. The heating process can reduce the moisture content of fish meat (Kiczorowska *et al.*, 2019), thus affecting the water activity of fish meat (Gómez *et al.*, 2020).

pH

The pH value of smoked fish is an essential factor affecting its quality. The pH value will decrease with increasing smoking time (Baten *et al.*, 2020b). The analysis of the variance of smoked fish fillets *julung julung* with different smoking method treatments affects the pH value ($p < 0.05$). The pH of smoked fish fillet ranged from 4.60 to 5.81 (Fig. 5). The treatment of the smoking method with corn cob liquid smoke (treatments A, B, and C) had a lower pH value when compared to the conventional smoking method (treatments D and E). Swastawati *et al.* (2022) also reported that the pH value of smoked barracuda fish with the liquid smoke method was significantly lower than that of the conventional

305 method. Another study also reported that using liquid smoke can reduce pH caused by the condensation
 306 of organic acids in the smoking process (Puke & Galoburda, 2020). The pH value of smoked fish
 307 correlates with the phenol content contained in the smoke component, and an increase in phenol content
 308 causes a decrease in pH (Berhimpon *et al.*, 2018).
 309



310
 311 **Fig. 5.** pH of *julung julung* smoked fillet
 312

313 **Phenol level**

314 Phenol is a compound found in wood smoke. Phenol compounds enter food through diffusion and
 315 capillary action, affecting taste, color, and aroma and extending shelf life (Remy *et al.*, 2016). In
 316 addition, phenol compounds are also reported to act as antioxidants that can prevent rancidity in fish
 317 meat (Sérot *et al.*, 2004). Leksono *et al.* (2020) also noted that the higher the phenol level in smoke, the
 318 stronger the flavor and aroma of smoked fish. The analysis of the variance of smoked fish fillets *julung*
 319 *julung* with different smoking method treatments affecting phenol level ($p < 0.05$). The phenol level of
 320 smoked fish fillet ranged from 4.42 to 16.11 mg/g (Fig. 6). The treatment of the smoking method with
 321 corn cob liquid smoke (treatments A, B, and C) had higher phenol level when compared to the
 322 conventional smoking method (treatments D and E).
 323

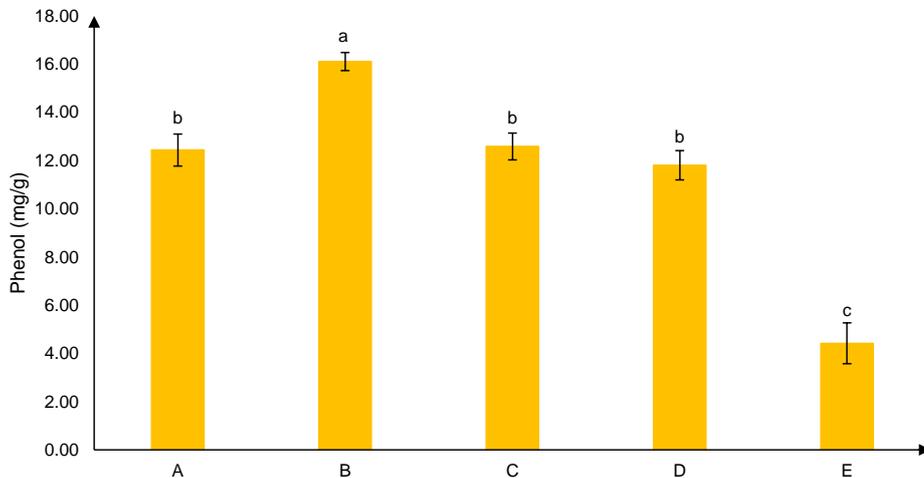


Fig. 6. Phenol level of *julung julung* smoked fillet

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325
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327 The statistical analysis showed a difference between treatments B, A – C, and D – E on the TVB value
328 of smoked fish fillets showed phenol levels in treatments A, C, and D were not different. Previous
329 research reported that the drying treatment of fish meat can increase phenolic compounds in smoked
330 fish products (Sérot *et al.*, 2004). The high phenol content in treatment B is thought to be because the
331 pre-heated process causes the fish meat to lose water so that when dipped in liquid smoke, the fish fillets
332 absorb a large amount of liquid smoke. Previous studies have reported that when the fish surface is
333 dried, there is less smoke condensation than products smoked at lower temperatures. The results of this
334 study indicate that a dry fish surface allows for better absorption of smoke components (Belichovska *et*
335 *al.*, 2019).

336 The study reported phenol levels in liquid smoke from corn cob waste of 0.335 mg/g (Swastawati *et al.*,
337 2007) and 2.55% (Leviyani *et al.*, 2019). The phenol level of smoked fish with the conventional method
338 of smoking with corn cobs is lower due to the high acid content, which can potentially reduce the phenol
339 content of smoked fish (Swastawati *et al.*, 2012). Anggraini & Nurhazisa (2017) reported that the phenol
340 content of liquid smoke from coconut shells was 3.04%, while liquid smoke from corn cob was 1.38%.
341

342 **Polycyclic aromatic hydrocarbon (PAH) levels**

343 Polycyclic aromatic hydrocarbons are a group of organic compounds formed by incomplete combustion,
344 such as wood. Therefore, the type of fuel used in the fish smoking process affects the PAH content of
345 smoked fish (Jinadasa *et al.*, 2020). One of the carcinogenic PAHs, benzo(a)pyrene, is a carcinogenic

marker in smoked fish products (Stołyhwo & Sikorski, 2005). Polycyclic aromatic hydrocarbon (PAH) levels in smoked fish fillets can be seen in Table 2.

Table 2. Polycyclic aromatic hydrocarbon levels in *julung julung* smoked fillet

Polycyclic Aromatic Hydrocarbon	Smoked <i>Julung Julung</i> fish (µg/kg)					Corn Cob Liquid Smoke 0.8% (µg/kg)
	A	B	C	D	E	
Benzo(a)pyrene	nd	nd	nd	1.5	0.2	0.5
Benzo(b)fluoranthene	1.2	1.0	1.2	2	1.8	2.5
Benzo(a)anthracene	nd	nd	nd	0.5	nd	0.2
Benzo(g)perylene	0.4	0.2	0.4	1.0	0.8	1.0

nd = not detected

Table 2 shows that the PAH levels in smoked fish are still below the standard required in the Indonesian National Standard No. 2725 of 2013 on smoked fish, which is benzo(a)pyrene max 5 µg/kg (Indonesia Standardization Agency, 2013). The polycyclic aromatic hydrocarbon compound regulated in the Indonesian National Standard is only benzo(a)pyrene. Stołyhwo & Sikorski (2005) reported benzo(a)pyrene levels in smoked fish with hot and cold smoking processes ranging from 0.05 to about 60 µg/kg. Other studies have reported benzo(b,k)fluoranthene levels in salmon and rainbow trout ranging from 1.83 to 9.55 µg/kg, while benzo(g,h)perylene levels in salmon were 0.44 µg/kg (Basak *et al.*, 2010). Berhimpon *et al.* (2018) also reported benzo(a)pyrene levels in smoked skipjack fish of 0.25 µg/kg. The level of benzo(a)pyrene in smoked barracuda was reported to be 0.32 µg/kg, benzo(b)fluoranthene 0.35 µg/kg, benzo(k)fluoranthene 0.21 µg/kg, benzo(a)anthracene 0.44 µg/kg, and benzo(g,h)perylene 2.56 µg/kg (Asamoah *et al.*, 2021).

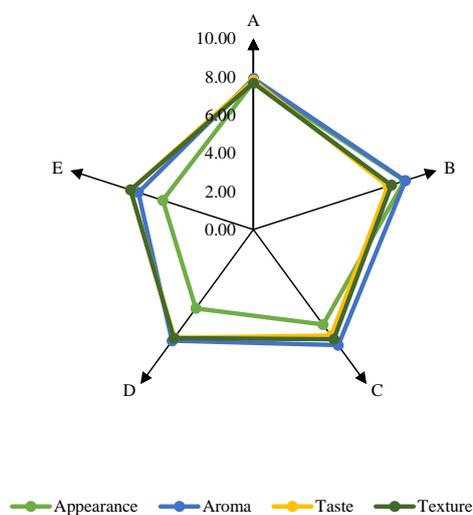
High PAH levels in smoked fish are due to the lignin content of the material used as fuel in the smoking process (Asamoah *et al.*, 2021). The lignin content in corn cobs is reported to be about 17 – 21% (Thangavelu *et al.*, 2018; Olajuyigbe *et al.*, 2019; Gandam *et al.*, 2022). The lignin content of coconut shell was approximately 59.5% (Wang & Sarkar, 2018), while that of coconut wood was about 50% on a dry weight basis (Anuchi *et al.*, 2022). Lignin is reported to absorb PAH compounds because PAH compounds can bind well with lignin (Oliveira *et al.*, 2019). During pyrolysis and gasification processes, lignin components react to produce aromatic tar and coke, which can form PAH compounds (Zhou *et al.*, 2014; Kawamoto, 2017). Therefore, PAH compounds in smoked fish smoked using corncobs are lower than those smoked with shells and coconut wood.

Sensory assessment

A sensory assessment is carried out to evaluate the panelist's preference level, including appearance, aroma, taste, and texture. A sensory assessment must determine the quality of the smoked fish product and ensure it meets the applicable standards (Hadanu & Lomo, 2019). The sensory characteristics of

376 smoked fish products affect consumer acceptance and preference. Sensory assessment by panelists helps
 377 to identify the sensory attributes that are most appealing to consumers, allowing manufacturers to
 378 customize products according to consumer assessment (Ekelemu *et al.*, 2021). Indonesian National
 379 Standard No. 2725:2013 regarding smoked fish requires a minimum sensory assessment of 7 (Score 1-
 380 9) (Indonesia Standardization Agency, 2013). The results of the panelists' assessment of *julung julung*
 381 smoked fillet from each treatment can be seen in Fig. 7.

382



383

384

385

Fig. 7. Sensory assesment of *julung julung* smoked fillet

386 Fig. 7 shows the analysis of the variance of the sensory assessment of the appearance of smoked *julung*
 387 *julung* fillets with different smoking method treatments affecting the appearance of smoked fish
 388 ($p < 0.05$). The panelists' assessment of the appearance of smoked fish fillets ranged from 4.95 to 8.24,
 389 with the highest panelists' assessment in treatment B. Based on the requirements of the Indonesian
 390 National Standard, only treatments A and B met the minimum panelist assessment requirement of 7.
 391 The moisture content factor is thought to have influenced the panelists' assessment of the appearance of
 392 smoked fish, so panelists less favored treatment C with steaming. Moisture content can affect the
 393 physical properties of fish, such as the appearance and texture of smoked fish (Baten *et al.*, 2020a).
 394 Smoked fish with high moisture content will make the color of smoked fish look paler (Flick, 2010).
 395 Treatments D and E were less favored by panelists, presumably because conventional smoking methods
 396 produce darker products (dark brown), less bright and less shiny. Smoking fish with liquid smoke has
 397 smoked fish products with a golden color and clean and shiny surface (Berhimpon *et al.*, 2018). Another

398 factor that affects the appearance of smoked fish is the length of the smoking process. The longer the
399 smoking process, the darker the color will be. The time of the smoking process for smoked fish using
400 the liquid smoke method is shorter than the conventional method (Puke & Galoburda, 2020; Baten *et*
401 *al.*, 2020b). The smoking process can change the color of fish, giving it a distinctive golden color due
402 to the interaction of carbonyls with amino components on the surface of the meat. The color and
403 appearance of smoked fish also positively correlate with phenol content. Phenol compounds in smoke
404 interact with amino acid components in fish meat, producing a distinctive golden color in smoked fish
405 (Montazeri *et al.*, 2013).

406 Fig. 7 shows the analysis of the variance of the sensory assessment of the aroma of smoked fish
407 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
408 smoked fish ($p>0.05$). However, the aroma sensory assessment of treatments A, B, C, and D still meets
409 the minimum assessment of the Indonesian National Standard on smoked fish. The sensory assessment
410 of smoked fish aroma was lowest in treatment E. Previous studies have reported that smoking fish with
411 corn cobs as a fuel source resulted in the lowest aroma scores, indicating less aromatic smoked fish
412 (Asmara *et al.*, 2022). The aroma and taste of smoked fish are strongly influenced by the time of
413 smoking (Tahir *et al.*, 2020). This assessment indicates that the time of the smoking process of 4 and 6
414 hours in all treatments has not influenced the taste and aroma of smoked fish.

415 Fig. 7 shows the analysis of the variance of the sensory assessment of the taste of smoked fish
416 fillets *julung julung* with different smoking method treatments that did not affect the appearance of
417 smoked fish ($p>0.05$). The taste of smoked fish is influenced by the time of the smoking process.
418 Previous studies have reported that longer smoking time can improve the sensory attributes of taste
419 (Baten *et al.*, 2020b). This result indicates that the 2-hour time difference between the liquid smoke
420 smoking treatment and the conventional smoking method has not affected the taste of smoked fish. A
421 distinctive smoked taste without bitterness is a criterion for assessing the taste of good quality smoked
422 fish (Sukowati *et al.*, 2021).

423 Fig. 7 shows the analysis of variance of the sensory assessment of the texture of smoked fish fillet *julung*
424 *julung* with different smoking method treatments giving effect to the texture of smoked fish ($p<0.05$).
425 Panelists' assessment of the texture of smoked fish *julung julung*, ranged from 6.71 – 7.67, with the
426 highest panelist assessment in treatments A and B. The statistical analysis showed that treatments A and
427 B differed from treatments C, D, and E. This result was thought to be because the fish fillets were dipped
428 in liquid smoke, giving a dry, compact, and tender texture. Whereas in treatment C (fish fillets subjected
429 to steaming), the texture of the smoked fillets was rather sticky and not solid. Treatments D and E
430 produced the texture of smoked fish fillets which were less dense and not compact. The texture of
431 smoked fish is negatively correlated with its moisture content. The higher the moisture content in

432 smoked fish, the softer and less firm the texture (Chan *et al.*, 2022). High moisture content in smoked
433 fish products results in less dense fish muscle fibers (Chang *et al.*, 2021).

434 A good texture of smoked fish is compact, moderately elastic, and not sticky (Sulistijowati *et al.*, 2021).
435 The Indonesian National Standard requires that the texture of smoked fish is dense and compact and the
436 tissue is very tight (Indonesia Standardization Agency, 2013). Based on consumer surveys, the preferred
437 texture of smoked fish is dense, slightly wetter, and easy to chew, and there is a sensation of liquid in
438 the mouth when chewed (Ticoalu *et al.*, 2019).

439

440 **Conclusion**

441 Based on the evaluation of the parameters of total volatile bases, moisture content, water activity, pH,
442 phenol content, polycyclic aromatic hydrocarbon content, and sensory assessment of smoked *julung*
443 *julung* fillets, it can be concluded that treatment B is the best treatment, i.e. the fillets were preheated
444 for 4 hours at 60 – 80 °C, then dipped in liquid smoke for 20 minutes. After that, the fillets were reheated
445 for 4 hours at 90 °C. In general, the characteristics of smoked fillets using liquid smoke were better
446 when compared to the conventional smoking treatment. It is necessary to evaluate different smoking
447 times on smoked *julung julung* fillets with corn cob liquid smoke method.

448

449 **Acknowledgment**

450

451 **Author contributions**

452

453 **Conflicts of interest**

454 The authors declare that there is no conflict of interest.

455

456 **Highlights**

457 Effectiveness of using liquid smoke derived from corn cob waste in the smoking process of *julung*
458 *julung* fillets

459

460 **References**

- 461 Aladin, A., Yani, S., Modding, B., & Wiyani, L. (2018). Pyrolysis of corncob waste to produce liquid smoke. *IOP Conference*
462 *Series: Earth and Environmental Science*, 175, 012020. <https://doi.org/10.1088/1755-1315/175/1/012020>
- 463 Ali, F., & Al Fiqri, R. (2020). The simple design of pyrolysis tool for making liquid smoke from shells and rubber seeds as
464 a food preservative. *Journal of Physics: Conference Series*, 1500, 012064. [https://doi.org/10.1088/1742-](https://doi.org/10.1088/1742-6596/1500/1/012064)
465 [6596/1500/1/012064](https://doi.org/10.1088/1742-6596/1500/1/012064)
- 466 Ali, F., Cundari, L., Miskah, S., & Prasetyo, H. (2021, Nov). Effect of variations concentration and pH of liquid smoke in
467 the immersion with various types of fish. *Proceedings of the 4th Forum in Research, Science, and Technology (FIRST-*

Research and Innovation in Food Science and Technology

- 468 *T1-T2-2020*), 7, 328–338. <https://doi.org/10.2991/ahe.k.210205.055>
- 469 Amos, S. O., & Paulina, I. (2017). Assessment of smoked fish quality using two smoking kilns and hybrid solar dryer on
470 some commercial fish species in Yola, Nigeria. *Journal of Animal Research and Nutrition*, 2(1), 6.
471 <https://doi.org/10.21767/2572-5459.100026>
- 472 Andy, Malaka, R., Purwanti, S., Ali, H. M., & Aulyani, T. L. (2021). Liquid smoke characteristic from coconut shell and
473 rice husk. *IOP Conference Series: Earth and Environmental Science*, 788, 012078. <https://doi.org/10.1088/1755-1315/788/1/012078>
- 474
- 475 Anggraini, S. P. A., & Nurhazisa, T. (2017). Performance optimization of liquid smoke device with agricultural waste
476 material. *International Journal of ChemTech Research*, 10(13), 21–28.
- 477 Ansar, N. M. S., & Ijong, F. G. (2021). Fish processing potential in Bebalang Village Sangihe Island Regency. *Jurnal Ilmiah*
478 *Tindalung*, 7(1), 7–12. <https://doi.org/10.54484/jit.v7i1.372> (in Indonesia)
- 479 Anuchi, S. O., Campbell, K. L. S., & Hallett, J. P. (2022). Effective pretreatment of lignin-rich coconut wastes using a low-
480 cost ionic liquid. *Scientific Reports*, 12(1), 1–11. <https://doi.org/10.1038/s41598-022-09629-4>
- 481 Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., & Hyldig, G. (2021). Polycyclic aromatic hydrocarbons (PAHs)
482 in fish smoked using traditional and improved kilns: Levels and human health risk implications through dietary
483 exposure in Ghana. *Food Control*, 121, 107576. <https://doi.org/10.1016/j.foodcont.2020.107576>
- 484 Asmara, S., Oktafri, Tamrin, & Windasari, P. (2022). Effect of amount and type of fuel on the smoked fish quality. *Open*
485 *Global Scientific Journal*, 1(2), 77–84.
- 486 Aydin, C., Kurt, Ü., & Kaya, Y. (2020). Comparison of the effects of ohmic and conventional heating methods on some
487 quality parameters of the hot-smoked fish pâté. *Journal of Aquatic Food Product Technology*, 29(4), 407–416.
488 <https://doi.org/10.1080/10498850.2020.1741752>
- 489 Azis, R., & Akolo, I. R. (2020). Analysis of organoleptic quality and water content of smoked roa fish (*Hemiramphus* sp.)
490 with different methods of smoking. *Jurnal Ilmu Pertanian Indonesia*, 25(4), 487–492.
491 <https://doi.org/10.18343/jipi.25.4.487> (in Indonesia)
- 492 Basak, S., Şengör, G. F., & Karakoç, F. T. (2010). The detection of potential carcinogenic PAH using HPLC procedure in
493 two different smoked fish, case study: Istanbul/Turkey. *Turkish Journal of Fisheries and Aquatic Sciences*, 10(3),
494 351–355. <https://doi.org/10.4194/trjfas.2010.0307>
- 495 Baten, M. A., Won, N. E., Mohibbullah, M., Yoon, S. J., Hak Sohn, J., Kim, J. S., & Choi, J. S. (2020). effect of hot smoking
496 treatment in improving sensory and physicochemical properties of processed Japanese Spanish Mackerel
497 *Scomberomorus niphonius*. *Food Science and Nutrition*, 8(7), 3957–3968. <https://doi.org/10.1002/fsn3.1715>
- 498 Baten, M. A., Won, N. E., Sohn, J. H., Kim, J.-S., Mohibbullah, M., & Choi, J.-S. (2020). Improvement of sensorial,
499 physicochemical, microbiological, nutritional and fatty acid attributes and shelf life extension of hot smoked half-dried
500 pacific saury (*Cololabis saira*). *Foods*, 9(8), 1–15.
- 501 Belichovska, K., Belichovska, D., & Pejkovski, Z. (2019). Smoke and smoked fish production. *Meat Technology*, 60(1), 37–
502 43. <https://doi.org/10.18485/meattech.2019.60.1.6>
- 503 Berhimon, S., Montolalu, R. I., Dien, H. A., Mentang, F., & Meko, A. U. I. (2018). Concentration and application methods
504 of liquid smoke for exotic smoked Skipjack (*Katsuwonus pelamis* L.). *International Food Research Journal*, 25(5),
505 1864–1869.
- 506 Bouzgarrou, O., Baron, R., & Sadok, S. (2020). Determination of the quality of liquid smoked tilapia fillets based on
507 physicochemical analysis. *Journal of Food Measurement and Characterization*, 14(2), 978–991.
508 <https://doi.org/10.1007/s11694-019-00347-6>
- 509 British Columbia Centre for Disease Control. (2013). *Salting Fish* (pp. 1–2). Retrieved from <http://www.bccdc.ca/resource->

Research and Innovation in Food Science and Technology

- 510 gallery/Documents/Educational%20Materials/EH/FPS/Fish/SaltingFish.pdf
- 511 Budaraga, I. K., Arnim, Marlida, Y., & Bulanin, U. (2016). Liquid smoke production quality from raw materials variation
512 and different pyrolysis temperatures. *International Journal on Advanced Science, Engineering and Information*
513 *Technology*, 6(3), 306–315. <https://doi.org/10.18517/ijaseit.6.3.737>
- 514 Budaraga, I. K., & Putra, D. (2021). Analysis antioxidant IC₅₀ liquid smoke of cocoa skin with several purification methods.
515 *IOP Conference Series: Earth and Environmental Science*, 757, 012053. [https://doi.org/10.1088/1755-](https://doi.org/10.1088/1755-1315/757/1/012053)
516 [1315/757/1/012053](https://doi.org/10.1088/1755-1315/757/1/012053)
- 517 Cahyadi, I., Anna, I. D., & Prasetyo, T. (2021). Biomass characteristics optimization design of corn cobs-based pellet using
518 response surface methodology. *International Conference on Science, Technology, and Environment 2020*, 41–50.
519 <https://doi.org/10.2139/ssrn.3793663>
- 520 Castro, P., Padrón, J. C. P., Cansino, M. J. C., Velázquez, E. S., & Larriva, R. M. De. (2006). Total volatile base nitrogen
521 and its use to assess freshness in European sea bass stored in ice. *Food Control*, 17(4), 245–248.
522 <https://doi.org/10.1016/j.foodcont.2004.10.015>
- 523 Chan, S. S., Feyissa, A. H., Jessen, F., Roth, B., Jakobsen, A. N., & Lerfall, J. (2022). Modeling water and salt diffusion of
524 cold-smoked Atlantic salmon initially immersed in refrigerated seawater versus on ice. *Journal of Food Engineering*,
525 312, 110747. <https://doi.org/10.1016/j.jfoodeng.2021.110747>
- 526 Chang, L., Lin, S., Zou, B., Zheng, X., Zhang, S., & Tang, Y. (2021). Effect of frying conditions on self-heating fried Spanish
527 mackerel quality attributes and flavor characteristics. *Foods*, 10, 98. <https://doi.org/10.3390/foods10010098>
- 528 Cissoko, B., Kante, C., Camara, A., & Sakouvogui, A. (2020). Impact of logging and fish smoking on mangroves in
529 management units 5 and 7 in Sangareya - Dubréka (Guinea). *International Journal of Multidisciplinary Research and*
530 *Publications*, 3(3), 8–14.
- 531 Daramola, J. A., Fasakin, E. A. & Famurewa, J. A. V. (2020). Fish smoking kiln using agricultural wastes as energy source
532 (A). *The International Journal of Engineering and Science*, 9(4), 29–33. <https://doi.org/10.9790/1813-0904032933>
- 533 Darianto, Sitohang, H. T. S., & Amrinsyah. (2018). Analysis of factors that influence the fumigation process on catfish
534 fumigation machines. *Journal of Mechanical Engineering, Manufactures, Materials and Energy*, 2(2), 56–66.
535 <https://doi.org/10.31289/jmemme.v2i2.2154>
- 536 Diatmika, I. G. N. A. Y. A., Kencana, P. K. D., & Arda, G. (2019). Characteristics of tabah bamboo stem liquid smoke
537 (*Gigantochloa nigrociliata* BUSE-KURZ) pyrolyzed at different temperatures. *Jurnal BETA (Biosistem Dan Teknik*
538 *Pertanian)*, 7(2), 278–285. <https://doi.org/10.24843/jbeta.2019.v07.i02.p07> (in Indonesia)
- 539 Dotulong, V., Montolalu, L. A., & Damongilala, L. J. (2018). Smoked skipjack fish processing technology to increase
540 processor quality and income. *Media Teknologi Hasil Perikanan*, 6(2), 33–36.
541 <https://doi.org/10.35800/mthp.6.2.2018.19522> (in Indonesia)
- 542 Ekelemu, J. K., Nwabueze, A. A., Irabor, A. E., & Otuye, N. J. (2021). Spicing: A means of improving organoleptic quality
543 and shelf life of smoked catfish. *Scientific African*, 13, e00930. <https://doi.org/10.1016/j.sciaf.2021.e00930>
- 544 El-Lahamy, A. A., Khalil, K. I., El-Sherif, S. A., & Mahmud, A. A. (2019). Effect of smoking methods and refrigeration
545 storage on microbiological quality of catfish fillets (*Clarias gariepinus*). *Oceanography and Fisheries*, 8(5), 1–5.
546 <https://doi.org/10.4172/2572-4134.1000127>
- 547 European Market Observatory for fisheries and aquaculture. (2020). *The EU Fish Market*. European Market Observatory for
548 Fisheries and Aquaculture Products. Retrieved from www.eumofa.eu
- 549 Fitri, N., Chan, S. X. Y., Che Lah, N. H., Jam, F. A., Misnan, N. M., Kamal, N., Sarian, M. N., Mohd Lazaldin, M. A., Low,
550 C. F., Hamezah, H. S., Rohani, E. R., Mediani, A., & Abas, F. (2022). A comprehensive review on the processing of
551 dried fish and the associated chemical and nutritional changes. *Foods*, 11(19), 2938.

Research and Innovation in Food Science and Technology

- 552 <https://doi.org/10.3390/foods11192938>
- 553 Flick, G. J. (2010). Smoked fish: Old product with new appeal offers enhanced taste, shelf life. *Global Aquaculture Advocate*,
554 418, 31–32.
- 555 Gandam, P. K., Chinta, M. L., Gandham, A. P., Pabbathi, N. P. P., Konakanchi, S., Bhavanam, A., Atchuta, S. R., Baadhe,
556 R. R., & Bhatia, R. K. (2022). A new insight into the composition and physical characteristics of corncob—
557 substantiating its potential for tailored biorefinery objectives. *Fermentation*, 8(12), 704.
558 <https://doi.org/10.3390/fermentation8120704>
- 559 Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J. (2020). The effects of processing and preservation technologies
560 on meat quality: Sensory and nutritional aspects. *Foods*, 9(10), 1–30. <https://doi.org/10.3390/foods9101416>
- 561 Hadanu, R., & Lomo, C. P. (2019). Organoleptic test analysis and effect of liquid smoke concentration on smoked fish. *IOP*
562 *Conference Series: Earth and Environmental Science*, 382, 012017. <https://doi.org/10.1088/1755-1315/382/1/012017>
- 563 Hardianto, L., & Yuniarta. (2015). The effect of liquid smoke on chemical and organoleptic of tuna (*Euthynnus affinis*).
564 *Jurnal Pangan dan Agroindustri*, 3(4), 1356–1366. (in Indonesia)
- 565 Indiarto, R., Nurhadi, B., Tensiska, Subroto, E., & Istiqamah, Y. J. (2020). Effect of liquid smoke on microbiological and
566 physico-chemical properties of beef meatballs during storage. *Food Research*, 4(2), 522–531.
567 [https://doi.org/10.26656/fr.2017.4\(2\).341](https://doi.org/10.26656/fr.2017.4(2).341)
- 568 Indonesia Standardization Agency. (2004). *Indonesian National Standard - how to test phenol levels by spectrophotometer*
569 (SNI 06-6989.21-2004). Jakarta: Indonesia. (in Indonesia)
- 570 Indonesia Standardization Agency. (2006a). *Indonesia National Standard - determination of water content in fishery*
571 *products* (SNI 01-2354.2-2006). Jakarta: Indonesia. (in Indonesia)
- 572 Indonesia Standardization Agency. (2006b). *Indonesian National Standard - instructions for organoleptic and or sensor*
573 *testing*. (SNI 01-2346-2006). Jakarta: Indonesia. (in Indonesia)
- 574 Indonesia Standardization Agency. (2013). *Indonesian National Standard - smoked fish with hot smoking* (SNI 2725:2013).
575 Jakarta: Indonesia. (in Indonesia)
- 576 Indonesia Center of Statistic Agency. (2023). Maize Harvested Area and Production in Indonesia 2023. Retrieved from
577 [https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-](https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-mentara-.html)
578 [sementara-.html](https://www.bps.go.id/id/pressrelease/2023/10/16/2049/luas-panen-dan-produksi-jagung-di-indonesia-2023--angka-mentara-.html). (in Indonesia)
- 579 Islamiyah, S. Al. (2021). Suitability of smoked roa fish (*Hemirhampus* sp.) with traditional smoke methods and liquid smoke
580 methods. *Jurnal Sains Dan Teknologi Hasil Pertanian*, 1(2), 53–63. (in Indonesia)
- 581 Jinadasa, B. K. K. K., Monteau, F., & Fowler, S. W. (2020). Review of polycyclic aromatic hydrocarbons (PAHs) in fish
582 and fisheries products; a Sri Lankan perspective. *Environmental Science and Pollution Research*, 27(17), 20663–
583 20674. <https://doi.org/10.1007/s11356-020-08305-2>
- 584 Kaban, D. H., Timbowo, S. M., Pandey, E. V., Mewengkang, H. W., Palenewen, J. C., Mentang, F., & Dotulong, V. (2019).
585 Analysis of water content, pH, and mold in skipjack smoked (*Katsuwonus pelamis* L.) in vacuum packages in cold
586 temperature storage. *Media Teknologi Hasil Perikanan*, 7(3), 72–79. <https://doi.org/10.35800/mthp.7.3.2019.23624>
587 (in Indonesia)
- 588 Kabir Ahmad, R., Anwar Sulaiman, S., Yusup, S., Sham Dol, S., Inayat, M., & Aminu Umar, H. (2022). Exploring the
589 potential of coconut shell biomass for charcoal production. *Ain Shams Engineering Journal*, 13(1), 101499.
590 <https://doi.org/10.1016/j.asej.2021.05.013>
- 591 Kaparang, R., Harikedua, S. D., & Suwetja, I. K. (2013). Determination of the quality of dry smoked tandipang fish
592 (*Dussumieria acuta* C.V) during room temperature storage. *Jurnal Media Teknologi Hasil Pertanian*, 1(1), 1–6. (in
593 Indonesia)

Research and Innovation in Food Science and Technology

- 594 Kawamoto, H. (2017). Lignin pyrolysis reactions. *Journal of Wood Science*, 63(2), 117–132.
595 <https://doi.org/10.1007/s10086-016-1606-z>
- 596 Kiczorowska, B., Samolińska, W., Grela, E. R., & Bik-Małodzińska, M. (2019). Nutrient and mineral profile of chosen fresh
597 and smoked fish. *Nutrients*, 11(7), 1–12. <https://doi.org/10.3390/nu11071448>
- 598 Krah, C. Y., Sutrisno, & Harahap, I. S. (2019). Use of liquid smoke for sustainable food preservation and postharvest loss
599 and waste reduction (A review). *Journal of Applied and Physical Sciences*, 5(2), 37–47. <https://doi.org/10.20474/japs->
600 5.2.1
- 601 Landangkasiang, A. I. N., Taher, N., & Kaparang, J. (2017). The quality of smoked skipjack tuna (*Katsuwonus pelamis* L.)
602 obtained from various processors in North Sulawesi. *Jurnal Media Teknologi Hasil Perikanan*, 5(3), 180–183. (in
603 Indonesia)
- 604 Lekahena, V. N. J., & Jamin, R. (2018). The quality of smoked skipjack during storage time at room temperature. *IOP*
605 *Conference Series: Earth and Environmental Science*, 175, 012003. <https://doi.org/10.1088/1755-1315/175/1/012003>
- 606 Leksono, T., Edison, Irasari, & Ikhsan, M. N. (2020). The effect of different variety of fire-woods on smoking of selais
607 catfish (*Cryptopterus bicirchis*). *IOP Conference Series: Earth and Environmental Science*, 430, 012002.
608 <https://doi.org/10.1088/1755-1315/430/1/012002>
- 609 Leviyani, R. A., Kurniasih, R. A., & Swastawati, F. (2019). Application of liquid smoke for chikuwa tilapia. *IOP Conference*
610 *Series: Earth and Environmental Science*, 246, 012084. <https://doi.org/10.1088/1755-1315/246/1/012084>
- 611 Maulina, S., Amalia, R., & R Kamny, E. (2020). Effect of pyrolysis temperature and time on liquid smoke characteristics.
612 *E3S Web of Conferences*, 148, 02007. <https://doi.org/10.1051/e3sconf/202014802007>
- 613 Maulina, S., & Karo, E. O. br. (2021). Improving the quality of liquid smoke from pyrolysis of oil palm fronds with the
614 adsorption–distillation purification process. *IOP Conference Series: Materials Science and Engineering*, 1122,
615 012101. <https://doi.org/10.1088/1757-899x/1122/1/012101>
- 616 Messina, C. M., Arena, R., Ficano, G., Randazzo, M., Morghese, M., La Barbera, L., Sadok, S., & Santulli, A. (2021). Effect
617 of cold smoking and natural antioxidants on quality traits, safety and shelf life of farmed meagre (*Argyrosomus regius*)
618 fillets, as a strategy to diversify aquaculture products. *Foods*, 10(11), 2522. <https://doi.org/10.3390/foods10112522>
- 619 Mishra, M., Kulkarni, G. N., & Ghosh, S. K. (2021). Fresh fish: Handling, transportation and preservation. *Biotica Research*
620 *Today*, 3(5), 409–412.
- 621 Mondo, B. C., Akoll, P., & Masette, M. (2020). Water activity, microbial, and sensory evaluation of smoked fish (*Mormyrus*
622 *caschive* and *Oreochromis niloticus*) stored at ambient temperature, Terekeka-South Sudan. *International Journal of*
623 *Fisheries and Aquaculture*, 12(2), 47–60. <https://doi.org/10.5897/IJFA2020.0783>
- 624 Montazeri, N., Oliveira, A. C. M., Himelbloom, B. H., Leigh, M. B., & Crapo, C. A. (2013). Chemical characterization of
625 commercial liquid smoke products. *Food Science & Nutrition*, 1(1), 102–115. <https://doi.org/10.1002/fsn3.9>
- 626 Moosavi-Nasab, M., Khoshnoudi-Nia, S., Azimifar, Z., & Kamyab, S. (2021). Evaluation of the total volatile basic nitrogen
627 (TVB-N) content in fish fillets using hyperspectral imaging coupled with deep learning neural network and meta-
628 analysis. *Scientific Reports*, 11, 5094. <https://doi.org/10.1038/s41598-021-84659-y>
- 629 Muliadin, M., Dewanto, D. K., Wahyudi, D., Tanod, W. A., Riyadi, P. H., & Muhsoni, F. F. (2022). Screening bioactive
630 components of sea bamboo (*Isis hippuris*) extract from Central Sulawesi. *Jurnal Kelautan dan Perikanan Terapan*
631 (*JKPT*), 5(1), 1–9. <https://doi.org/10.15578/jkpt.v5i1.10596> (in Indonesia)
- 632 Nithin, C. T., Joshy, C. G., Chatterjee, N. S., Panda, S. K., Yathavamoorthi, R., Ananthanarayanan, T. R., Mathew, S., Bindu,
633 J., & Gopal, T. K. S. (2020). Liquid smoking - A safe and convenient alternative for traditional fish-smoked products.
634 *Food Control*, 113, 107186. <https://doi.org/10.1016/j.foodcont.2020.107186>
- 635 Nugroho, S., Soeparma, S., & Yuliati, L. (2018). Analysis of the effect of alternative fuels in fish smoking cabinets on the

Research and Innovation in Food Science and Technology

- 636 quality of smoked products. *Jurnal Rekayasa Mesin*, 9(3), 191–200. <https://doi.org/10.21776/ub.jrm.2018.009.03.6>
637 (in Indonesia)
- 638 Olajuyigbe, F. M., Fatokun, C. O., & Oni, O. I. (2019). Effective substrate loading for saccharification of corn cob and
639 concurrent production of lignocellulolytic enzymes by *Fusarium oxysporum* and *Sporothrix carnis*. *Current*
640 *Biotechnology*, 8(2), 109–115. <https://doi.org/10.2174/2211550108666191008154658>
- 641 Oliveira, A. C. de, Aguilar-Galvez, A., Campos, D., & Rogez, H. (2019). Absorption of polycyclic aromatic hydrocarbons
642 onto depolymerized lignocellulosic wastes by *Streptomyces viridosporus* T7A. *Biotechnology Research and*
643 *Innovation*, 3(1), 131–143. <https://doi.org/10.1016/j.biori.2019.04.002>
- 644 Oliveira, F. A. de, Neto, O. C., Santos, L. M. R. dos, Ferreira, E. H. R., & Rosenthal, A. (2017). Effect of high pressure on
645 fish meat quality – A review. *Trends in Food Science and Technology*, 66, 1–19.
646 <https://doi.org/10.1016/j.tifs.2017.04.014>
- 647 Primalasari, I., Sukiyono, K., & Romdhon, M. M. (2019). Technical efficiency of skipjack smoked fish processing business
648 in North Sulawesi province and its determinant factors. *Agric*, 31(1), 41–52. (in Indonesia)
- 649 Puke, S., & Galoburda, R. (2020). Factors affecting smoked fish quality: A review. *Research for Rural Development*, 35,
650 132–139. <https://doi.org/10.22616/rrd.26.2020.020>
- 651 Racovita, R. C., Secuianu, C., Ciuca, M. D., & Israel-Roming, F. (2020). Effects of smoking temperature, smoking time,
652 and type of wood sawdust on polycyclic aromatic hydrocarbon accumulation levels in directly smoked pork sausages.
653 *Journal of Agricultural and Food Chemistry*, 68(35), 9530–9536. <https://doi.org/10.1021/acs.jafc.0c04116>
- 654 Rasulu, H., Praseptianga, D., Joni, I. M., & Ramelan, A. H. (2020). Introduction test edible coating fresh fish fillet of tuna
655 and smoked fish using biopolymer nanoparticle chitosan coconut crab. *Advances in Engineering Research*, 194, 173–
656 180. <https://www.atlantispress.com/article/125938018.pdf>
- 657 Remy, C. C., Fleury, M., Beauchêne, J., Rivier, M., & Goli, T. (2016). Analysis of PAH residues and amounts of phenols in
658 fish smoked with woods traditionally used in French Guiana. *Journal of Ethnobiology*, 36(2), 312–325.
659 <https://doi.org/10.2993/0278-0771-36.2.312>
- 660 Rizal, W. A., Nisa, K., Maryana, R., Prasetyo, D. J., Pratiwi, D., Jatmiko, T. H., Ariani, D., & Suwanto, A. (2020). Chemical
661 composition of liquid smoke from coconut shell waste produced by SME in Rongkop Gunungkidul. *IOP Conference*
662 *Series: Earth and Environmental Science*, 462, 012057. <https://doi.org/10.1088/1755-1315/462/1/012057>
- 663 Saediman, H., Merlina, J., Rianse, I. S., Taridala, S. A. A., & Rosmawaty, R. (2021). Economic returns and constraints of
664 traditional fish smoking in North Buton District of Southeast Sulawesi. *IOP Conference Series: Earth and*
665 *Environmental Science*, 782, 022049. <https://doi.org/10.1088/1755-1315/782/2/022049>
- 666 Salindeho, N., & Lumoindong, F. (2017). Nutmeg shells liquid smoke application for yellowstripe scad fish processing.
667 *Jurnal Ilmu Dan Teknologi Pangan*, 5(1), 9–17. Retrieved from
668 [https://scholar.archive.org/work/oconb3bhjzf3x1551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.ph](https://scholar.archive.org/work/oconb3bhjzf3x1551pgus2g62a/access/wayback/https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088)
669 [p/itp/article/viewFile/18562/18088](https://ejournal.unsrat.ac.id/index.php/itp/article/viewFile/18562/18088) (in Indonesia)
- 670 Salmatia, S., Isamu, K. T., & Sartinah, A. (2020). The effect of the boiling and steaming process on the content of albumin
671 and proximate snakehead fish (*Channa striata*). *Journal of Fisheries Processing Technology*, 3(1), 67–73. Retrieved
672 from <http://ojs.uho.ac.id/index.php/jfp> (in Indonesia)
- 673 Santoso, F., Mus, S., & Sari, N. I. (2015). The effect of thickness and soaking time on quality of smoked fillet mackerel
674 (*Euthynnus affinis*) with liquid smoke. *Jurnal Online Mahasiswa Fakultas Perikanan Dan Ilmu Kelautan Universitas*
675 *Riau*, 2(2), 1–6. (in Indonesia)
- 676 Saputra, G. A., Sarengat, W., & Abduh, S. B. M. (2014). Water activity, bacterial count and drip loss of duck scalded in hot
677 wax. *Animal Agriculture Journal*, 3(1), 34–40.

Research and Innovation in Food Science and Technology

- 678 Sari, R. N., Utomo, B. S. B., & Widiyanto, T. N. (2006). Liquid smoke and its applications for fisheries products. *Jurnal*
679 *Pascapanen dan Bioteknologi Kelautan dan Perikanan*, 1(1), 65–74. <https://doi.org/10.15578/squalen.v5i3.53> (in
680 Indonesia)
- 681 Septana, A. I., Pratama, A. M., & Wijayanti, A. D. (2020). In vitro antibacterial activity and gas chromatography – mass
682 spectrometry analysis of liquid smoke of rice husk. *Indonesian Journal of Veterinary Sciences*, 1(2), 69–74.
683 <https://doi.org/10.22146/ijvs.v1i1.58511>
- 684 Sérot, T., Baron, R., Knockaert, C., & Vallet, J. L. (2004). Effect of smoking processes on the contents of 10 major phenolic
685 compounds in smoked fillets of herring (*Cuplea harengus*). *Food Chemistry*, 85(1), 111–120.
686 <https://doi.org/10.1016/j.foodchem.2003.06.011>
- 687 Shoukat, S. (2020). Potential anti-carcinogenic effect of probiotic and lactic acid bacteria in detoxification of
688 benzo[a]pyrene: A review. *Trends in Food Science and Technology*, 99, 450–459.
689 <https://doi.org/10.1016/j.tifs.2020.02.029>
- 690 Sikoki, F. D., & Aminigo, E. R. (2002). Bacteriological and sensory properties of smoke-dried fish stored at ambient
691 temperature. *Global Journal of Agricultural Sciences*, 1(1), 21–25. <https://doi.org/10.4314/gjass.v1i1.2198>
- 692 Sriharti, Indriati, A., & Saparita, R. (2020). Utilization of liquid smoke corn cobs for germination tomato (*Solanum*
693 *lycopersicum*) seeds. *IOP Conference Series: Earth and Environmental Science*, 462, 012049.
694 <https://doi.org/10.1088/1755-1315/462/1/012049>
- 695 Stolyhwo, A., & Sikorski, Z. E. (2005). Polycyclic aromatic hydrocarbons in smoked fish - A critical review. *Food*
696 *Chemistry*, 91(2), 303–311. <https://doi.org/10.1016/j.foodchem.2004.06.012>
- 697 Sukowati, D. (2023). Identification of the Mixed Briquette Composition Effect (Teak Leaves and Corncob Charcoal) on the
698 Characteristics of Smoked Fish. *Journal of Natural Sciences*, 4(1), 1–9. <https://doi.org/10.34007/jonas.v4i1.326>
- 699 Sukowati, D., Prasetyo, D. Y. B., & Yuwono, T. A. (2021). Analysis of the sensory quality of smoked fish fueled by mixed
700 briquettes (corn cob charcoal and teak leaves) and wood fuel. *Jurnal Pijar MIPA*, 16(1), 81–85.
701 <https://doi.org/10.29303/jpm.v16i1.1712> (in Indonesia)
- 702 Sulistijowati, R., Tahir, M., & Nur, K. U. (2021). Effect type chilli and concentration of cmc toward vitamin c and dissolved
703 solid of smoked fish chilli sauce. *IOP Conference Series: Earth and Environmental Science*, 681, 012011.
704 <https://doi.org/10.1088/1755-1315/681/1/012011>
- 705 Suroso, E., Utomo, T. P., Hidayati, S., & Nuraini, A. (2018). The smoking of mackerel using liquid smoke from red-digested
706 rubber wood. *Jurnal Pengolahan Hasil Perikanan Indonesia*, 21(1), 42–53.
707 <https://doi.org/10.17844/jphpi.v21i1.21261> (in Indonesia)
- 708 Swastawati, F., Agustini, T. W., Darmanto, Y., & Dewi, E. N. (2007). Liquid smoke performance of lamtoro wood and corn
709 cob. *Journal of Coastal Development*, 10(3), 189–196.
- 710 Swastawati, F., Riyadi, P. H., Kurniasih, R. A., Setiaputri, A. A., & Sholehah, D. F. (2022). Safety, quality, and nutritional
711 aspect of smoked barracuda fish. *F1000Research*, 11(May), 1–15. <https://doi.org/10.12688/f1000research.122511.1>
- 712 Swastawati, F., Susanto, E., Cahyono, B., & Trilaksono, W. A. (2012). Quality characteristic and lysine available of smoked
713 fish. *APCBEE Procedia*, 2(2007), 1–6. <https://doi.org/10.1016/j.apcbee.2012.06.001>
- 714 Tahir, M., Salengke, S., Mursalim, Metusalach, & Caesarendra, W. (2020). Performance of smokehouse designed for
715 smoking fish with the indirect method. *Processes*, 8(2), 204. <https://doi.org/10.3390/pr8020204>
- 716 Tambunan, J. E., & Chamidah, A. (2021). Influence of cinnamon essential oil addition on edible coating of chitosan on
717 saving life of red kakap fish fillets (*Lutjanus sp.*). *Journal of Fisheries and Marine Research*, 5(2), 262–269.
- 718 Thangavelu, K., Desikan, R., Taran, O. P., & Uthandi, S. (2018). Delignification of corncob via combined hydrodynamic
719 cavitation and enzymatic pretreatment: Process optimization by response surface methodology. *Biotechnology for*

Research and Innovation in Food Science and Technology

- 720 *Biofuels*, 11(1), 1–13. <https://doi.org/10.1186/s13068-018-1204-y>
- 721 Ticoalu, F., Ondang, H., Tumanduk, N., Kaligis, D. D., Mulalinda, P., & Wowiling, F. (2019). Administration of liquid
722 smoke from rice straw in processing presto smoked skipjack tuna (*Katsuwonus pelamis*). *Jurnal Bluefin Fisheries*,
723 1(1), 34–39. <https://doi.org/10.15578/jbf.v1i1.6> (in Indonesia)
- 724 Umar, F., Oyero, J. O., Ibrahim, S. U., Maradun, H. F., & Ahmad, M. (2018). Sensory evaluation of African catfish (*Clarias*
725 *gariepinus*) smoked with melon shell briquettes and firewood. *International Journal of Fisheries and Aquatic Studies*,
726 6(3), 281–286.
- 727 VELP Scientifica. (2013). *Determination of the total volatile basic nitrogen (TVBN) in Fish according to Conway and Byrne*
728 *method* (p. 2). Retrieved from [https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
729 [290202.pdf](https://www.velp.com/public/file/VELPApplicationNoteTVBNFF-K-009-2013A3-290202.pdf)
- 730 Wang, Q., & Sarkar, J. (2018). Pyrolysis behaviors of waste coconut shell and husk biomasses. *International Journal of*
731 *Energy Production and Management*, 3(1), 34–43. <https://doi.org/10.2495/EQ-V3-N1-34-43>
- 732 Xin, X., Bissett, A., Wang, J., Gan, A., Dell, K., & Baroutian, S. (2021). Production of liquid smoke using fluidized-bed fast
733 pyrolysis and its application to green-lipped mussel meat. *Food Control*, 124, 107874.
734 <https://doi.org/10.1016/j.foodcont.2021.107874>
- 735 Zhang, D., Ayed, C., Fisk, I. D., & Liu, Y. (2023). Effect of cooking processes on tilapia aroma and potential umami
736 perception. *Food Science and Human Wellness*, 12(1), 35–44. <https://doi.org/10.1016/j.fshw.2022.07.016>
- 737 Zhou, H., Wu, C., Onwudili, J. A., Meng, A., Zhang, Y., & Williams, P. T. (2014). Polycyclic aromatic hydrocarbon
738 formation from the pyrolysis/gasification of lignin at different reaction conditions. *Energy and Fuels*, 28(10), 6371–
739 6379. <https://doi.org/10.1021/ef5013769>



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Authors: Jefri Anthonius Mandeno, Wendy Alexander Tanod, Eko Cahyono, Yana Sammbeka, Frets Jonas Rieuwpassa, Novalina I
Frianto Putra Palawe, Putut Har Riyadi

Dear Mr. Jefri Anthonius Mandeno

It is of great pleasure and delight to inform that your manuscript entitled **Characteristics of Julung Julung Smoked Fillets (Hemiramphus sp.) using Liquid Smoke from Corn Cobs Waste** has been published online via **Research and Innovation in Food Science and Technology**

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