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DEVELOPMENT AND NUTRITIONAL EVALUATION OF CRACKERS FORTIFIED WITH YELLOWSTRIPE SCAD (*Selaroides leptolepis*) WHOLE POWDER AS A FUNCTIONAL FOOD FOR STUNTING PREVENTION

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ABSTRACT

Yellowstripe Scad (*Selaroides leptolepis*) has potential as a fortificant to enhance the nutritional quality of crackers. The incorporation of yellowstripe scad whole fish powder not only improves the nutrient content but also reduces processing waste. Fish-based crackers can serve as dietary food products, nutrient-dense snack alternatives, and supplementary foods to support stunting prevention. This study aimed to evaluate the nutritional composition (moisture, lipid, dietary fiber, protein, and ash content) and physical quality (texture) of fish crackers. The experiment was designed using a Completely Randomized Design with a single factor, namely, the addition of yellowstripe scad whole powder (SFF) at six levels: 0, 3, 6, 9, 12, and 15%. The data obtained were analyzed using Analysis of Variance, followed by Duncan's Multiple Range Test to determine significant differences. The results revealed that the addition of yellow stripe scad whole powder significantly affected ($p<0.05$) the physicochemical properties of the yellow stripe scad crackers. Crackers with 15% yellowstripe scad whole powder exhibited the highest protein, lipid, and ash contents of 18.5, 8.97, and 8.97%, respectively. Meanwhile, the addition of 3% yellowstripe scad whole powder produced crackers with the most desirable moisture content, dietary fiber, and texture characteristics of 3.59%, 3.87%, and 1,101 N/cm², respectively.

Keywords: Selar Fish, Flour, Snack, Stunting, Substitution

INTRODUCTION

The yellowstrip scad (*Selaroides leptolepis*), commonly known in Indonesia as the selar fish or yellowtail scad, is characterized by its elongated and laterally compressed body and is widely distributed throughout the Indo-Pacific region (Surajati, 2006; Mustofa and Setyobudiandi, 2020). This species dominates capture fisheries in Indonesian waters, particularly along the northern coast of Java Island and in East Kalimantan, which are part of the national Fisheries Management Areas (WPP) (Widiyastuti et al., 2023). The yellowstripe scad has relatively thin flesh with numerous fine bones; however, its high availability and low market price make it a potential alternative nutrient source. This fish has a complex nutritional composition, including proteins, lipids, and minerals, although its utilization has largely remained limited to traditional dishes such as *pindang* (boiled fish), salted fish, and grilled fish (Sharfina et al., 2014).

Yellowstripe scad can be utilized as a fortificant in cracker production to enhance its nutritional value. Incorporating fish in the form of whole fish powder maximizes nutrient retention and minimizes processing waste. Crackers, which are widely consumed baked products, are versatile and can satisfy diverse consumer preferences (Venkatachalam and Nagarajan, 2017). According to Giannoutsos et al. (2023), crackers are thin, dry, baked products with a crisp texture, typically

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formulated using soft wheat flour as the primary ingredient. They are generally characterized by low levels of sugar, fat, and moisture (Giannoutsos et al., 2023; Venkatachalam and Nagarajan, 2017).) Furthermore, Ahmed and Abozed (2015) classified crackers into three main categories: soda, snacks, and savories.

The fortification of cracker products has emerged as a growing trend, largely because of their long shelf life, ease of accessibility, and relatively low production cost (Hallaç and Altiner, 2017; Giannoutsos et al., 2023; Batista et al., 2019). Currently, cracker fortification efforts commonly utilize ingredients rich in bioactive compounds and essential nutrients, including those derived from cereals and legumes (Giannoutsos et al., 2023). Crackers are among the most popular snack products, with consumer demand increasing steadily every year (Millar et al., 2017). In Indonesia, biscuit consumption was recorded at 21,185 ounces per capita in 2022, rising to 21,215 ounces per capita in 2023, and further increasing to 21,269 ounces per capita by 2024 (Kementan, 2024).

Fortification of crackers using fishery-based products has also been reported by Mutamimah et al. (2024), where the addition of *S. baliensis* / lemuru fish meal significantly affected the moisture, fat, protein, ash, and dietary fiber contents of fish crackers. The inclusion of tuna fish meal significantly enhanced the nutritional quality of the crackers, particularly in terms of protein, fat, moisture, and ash content. Crackers fortified with fish are generally referred to as fish cracker.

Fish crackers can be consumed as dietary food products or alternative nutrient-dense snacks. Given their relatively complex nutritional composition, crackers fortified with yellowstripe scad may also serve as supplementary foods to support stunting prevention, particularly among children in the Balikpapan region. Stunting remains a major public health issue in Indonesia, with alarming prevalence rates. Balikpapan is no exception, as the incidence of stunting has continued to rise, leading to the issuance of Balikpapan Mayor Regulation No. 29 concerning the Guidelines for the Prevention, Screening, and Management of Stunting Cases. The local government has prioritized stunting reduction through nutritional improvement programs. Therefore, this study was conducted to evaluate the nutritional composition (moisture, lipid, dietary fiber, protein, and ash content) and physical quality (hardness) of crackers fortified with yellowstripe scad as a nutrient-rich snack.

MATERIALS AND METHOD

Materials and Properties

The ingredients used for fish cracker production included yellowstripe scad whole powder, high-quality flour (Sania), salt (Dolphin), baking soda (Kupu-Kupu), white crystal sugar (Rose Brand), shrimp stock powder (Alamee), mushroom broth powder (Totole), yeast (Fermipan instant yeast), UHT full-cream plain milk (Indomilk), and room butter (Royal Krane). The materials used in the analysis were filter paper, cotton, hexane, selenium, sulfuric acid, distilled water, sodium hydroxide, boric acid, hydrochloric acid, phosphate buffer, Termamyl enzyme, amyloglucosidase, ethanol, and acetone.

Experimental Design and Data Analysis

The experiment was conducted using a Completely Randomized Design with a single factor and three replicates. The experimental factor was the substitution of yellowstripe scad flour with wheat flour at six levels: 0% (S0), 3% (S3), 6% (S6), 9% (S9), 12% (S12), and 15% (S15). Data were subjected to analysis of variance (ANOVA) using SPSS version 25 and were further evaluated using Duncan's Multiple Range Test (DMRT).

Research Procedure

Preparation of yellowstripe scad whole powder

Yellowstripe scad flour was prepared as described by Mutamimah et al. (2024), with some modifications. The Yellowstripe scad was obtained from the Manggar-Balikpapan Fish Landing Station (TPI) in East Kalimantan. The fish were initially eviscerated to remove the viscera. The cleaned fish were then steamed for 5 min to reduce their moisture content, thereby facilitating the subsequent drying process. The steamed fish were dried using a cabinet dryer at 55 °C for 9 h and milled into powder.

Preparation of fish crackers

The formulation of fish crackers was adapted from the method described by Mutamimah et al. (2024), with modifications. Initially, the ingredients (composite flour (yellowstripe scad flour and high-protein wheat flour), baking soda, sugar, shrimp stock powder, mushroom broth powder, yeast, UHT milk, and margarine (room butter)) were homogenized using a mixer. The formula, based on 150 g of materials, consisted of composite flour and other additional materials.

The composite flour composition based on 59 g flour was obtained by substituting wheat flour with 0.0, 4.5, 9.0, 13.5, 18.0, and 22.5 g of yellowstripe scad whole powder, representing 0, 3, 6, 9, 12, and 15% of the composite flour, respectively. The materials were mixed with baking soda (0.8 g), sugar (0.7 g), shrimp stock powder (0.7 g), mushroom stock powder (2.0 g), yeast (1.0 g), full cream milk (35.25 g), and butter (11.5 g). The dough was then placed in a sealed container and fermented at ambient temperature (30–33 °C) for 60 min. Following fermentation, the dough was shaped into crackers and baked at 145 °C for 5 min. The fish crackers fortified with yellowstripe scad powder are presented in Figure 1.

Figure 1. Fish crackers fortified yellowstripe scad powder

Procedure Analysis

Moisture Content (AOAC, 2012)

The moisture content was determined using a gravimetric method. Empty crucibles were first dried in an oven at 100–105 °C for 30 min, cooled in a desiccator for 30 min, and weighed (C). Approximately 2 g of the sample was placed in a crucible and weighed (D). The crucibles containing the samples were then dried in an oven at 100–105 °C for 24 h. After drying, the samples were cooled in a desiccator and reweighed until a constant weight was obtained (E). The moisture content was calculated using the following equation:

$$MC\ (\%) = \frac{D - E}{D - C} \times 100 \qquad (1)$$

Where:

MC = Moisture content (%)
C = Weight of empty crucible (g)
D = Weight of crucible + sample before drying (g)
E = Weight of crucible + sample after drying (g)

Determination of Fat Content (AOAC, 2012)

The fat content of the fish crackers was determined using the Soxhlet extraction method. Initially, the extraction flask was dried in an oven at 105 °C for 30 min, followed by cooling in a desiccator for 20 min, and weighed (F). Approximately 2 g of the sample was wrapped in filter paper, placed in a thimble, and sealed with cotton wool. The prepared thimble was then inserted into a Soxhlet extractor containing hexane as the solvent. The complete Soxhlet assembly, including the extraction flask, thimble, and condenser, was set up, and extraction was conducted for 5 h. After extraction, the solvent was removed, and the extracted fat was dried in an oven at 105°C for 60 min, cooled in a desiccator, and weighed (G). The fat content of the fish crackers (%) was calculated using the following equation:

$$L(\%\ wb) = \frac{G - F}{S} \times 100$$

$$L\ (\%\ db) = \frac{L\ (\%bb)}{(100 - M)\%bb} \times 100$$

Where:

S = Sample weight (g)
L = Fat content (%)
M = Moisture content fraction of the sample

Determination of Protein Content (AOAC, 2005)

The protein content of the fish crackers was determined using the Kjeldahl method, which consists of three main stages: digestion, distillation, and titration. In the digestion stage, 1 g of the sample was placed in a Kjeldahl flask, followed by the addition of one

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selenium tablet and concentrated H_2SO_4. The mixture was then heated at 400 °C for approximately 60 min until the solution turned green and was subsequently allowed to cool until a solid residue was formed. The residue was quantitatively transferred and diluted with distilled water to a final volume of 100 mL. For distillation, 10 mL of the digested solution was transferred into a distillation flask, followed by the addition of 10 mL 40% NaOH. The released ammonia was distilled and collected in an Erlenmeyer flask containing 10 mL of boric acid solution. Distillation was continued for approximately 15 min until the boric acid solution changed from red to blue. For titration, the distillate was titrated with 0.1028 N HCl until the boric acid solution reverted to its initial red color. The protein content was then calculated based on the nitrogen content using a conversion factor as show in the equation below.

$$\text{Nitrogen (\%)} = \frac{(\text{mL HCl sample} - \text{mL HCl blanko}) \times \text{N HCl} \times 14}{\text{mg sample}} \times 100$$

$$\text{\% Protein} = \text{\% Nitrogen} \times \text{conversion factor}$$

Determination of Ash Content (AOAC, 2005)

The ash content of the fish crackers was determined using a gravimetric method. Empty crucibles were dried in an oven at 105 °C for 30 min, cooled in a desiccator for 15 min, and weighed (J). Approximately 5 g of the sample was accurately weighed and transferred into pre-weighed crucibles (K). The crucibles containing the samples were subsequently dried in an oven at 105 °C until no smoke was observed. Thereafter, the samples were ashed in a muffle furnace at 600 °C for 6 h until they were completely converted to ash. Following ashing, the crucibles were cooled in a desiccator for 30 min and reweighed (L). The ash content (%)was calculated using the following equation:

$$\text{Ash \%} = \frac{L - J}{K - J} \times 100$$

Where:

J = Weight of the empty crucible (g)

K = Weight of the crucible with sample before drying (g)

L = Weight of the crucible with sample after ashing (g)

Determination of Dietary Fiber Content in Fish Crackers Using the Enzymatic Gravimetric Method (AOAC, 2012)

Prior to dietary fiber analysis, the fat content of the sample was removed using the Soxhlet extraction method. The filter papers were dried in an oven and weighed to obtain their initial masses. Approximately 0.5 g of the defatted sample was placed in an Erlenmeyer flask, followed by the addition of 25 mL of 0.08 M phosphate buffer at pH 6.0. Subsequently, 0.05 mL of Termamyl enzyme was added, and the mixture was incubated in a shaking water bath at 95 °C for 30 min, followed by cooling. After cooling, 5 mL of 0.275 N NaOH was added to adjust the pH to 7.5, and 0.05 mL of the protease enzyme was introduced. The mixture was then incubated in a shaking water bath at 60 °C for 30 min, and subsequently cooled. The cooled solution was adjusted to pH 4.0–4.5 using 5 mL of 0.325 N HCl, and 0.15 mL of amyloglucosidase was added. The mixture was then incubated at 60 °C for 30 min in a shaking water bath. The final hydrolysate was filtered through pre-weighed Whatman No. 42 filter paper using a vacuum filtration system (B1).

Insoluble Dietary Fiber (IDF)

The residue retained on the filter paper was sequentially washed with 2 × 15 mL of 78% ethanol, 2 × 15 mL of 95% ethanol, and 2 × 15 mL of acetone. The filter paper containing the residue was then transferred to an empty aluminum dish, dried at 105°C for 12 h to a constant weight, cooled in a desiccator, and weighed (B2). The residue was subsequently analyzed for protein and ash content for correction purposes.

Soluble Dietary Fiber (SDF)

The filtrate was adjusted to a total volume of 70 mL with distilled water, followed by the addition of 279 mL of preheated 95% ethanol at 60 °C. The mixture was incubated for 60 min to precipitate SDF and then filtered through filter paper. The residue was sequentially washed with 2 × 15 mL of 78% ethanol, 2 × 10 mL of 95% ethanol, and 2 × 10 mL acetone. The filter paper containing the residue was transferred to an empty aluminum dish, dried at 105°C for 12 h, cooled in a desiccator, and weighed (B2). The protein and ash contents of the residue were subsequently analyzed for correction. The dietary fiber content of the fish crackers on a wet weight basis was calculated using the following formula:

$$IDF\ (\%wb) = \frac{B2\text{-}B1}{sampel\ (g)} - \%\ ash\ residu\text{-}\%protein\ residu\ (g)$$

$$SDF\ (\%wb) = \frac{B2\text{-}B1}{sample\ weight\ s\ (g)} - \%\ ash\ residue - \%\ protein\ residue\ (g)$$

$$TDF\ (\%wb) = IDF + SDF$$

The dietary fiber content on a dry weight basis (db) was calculated to account for the moisture content of the samples using the following equation:

$$IDF\ (\%db) = \frac{\%IDF}{100\%\text{-moisture content }\%} x100$$

$$SDF\ (\%db) = \frac{\%SDF}{100\%\text{-moisture content }\%} x100$$

$$TDF\ (\%db) = \frac{\%TDF}{100\%\text{-moisture content }\%} x100$$

Texture (Hardness)

The hardness was determined using a penetration test with a Texture Analyzer TA-XT2. The instrument was set with the following parameters: pre-test speed of 2.0 mm/s, post-test speed of 5.0 mm/s, penetration distance of 5.0 mm, test duration of 5.0 s, and an automatic trigger system with a trigger force of 10 g. Cracker samples were placed on a support rig and tested using a stainless-steel ball probe with a diameter of 0.25 in. (p/0.25 s). This setup was used to evaluate the product fracturability through penetration testing. The texture parameter measured in this study was hardness, expressed in N/cm² (Huda and Ikhlas, 2009.)

RESULT AND DISCUSSION

The macronutrient components of yellowstripe scad crackers were determined to evaluate their nutritional value as a potential functional food for stunting prevention. The physical quality of the crackers was further assessed using instrumental texture analysis. Texture is a critical parameter for consumer acceptance, as crackers are typically expected to possess both hardness and crispness. The results of the macronutrient and physical property analyses, including protein, moisture, fat, dietary fiber content, and texture, are presented in Table 1, and in a form of diagram in Figure 2 to show the profile characteristic changes more clearly.

Moisture Content

Moisture content is a critical parameter in crackers, as it directly affects product crispness, texture, and shelf life (Venkatachalam and Nagarajan, 2017). According to Yanti et al. (2023), the moisture content is closely associated with the shelf life of food products, as it affects their physical, chemical, and microbiological properties and enzymatic activity.

The addition of 3% yellowstripe scad (*Selaroides leptoletis*) flour compared to the control did not significantly affect the moisture content of fish crackers ($p < 0.05$). Comparable results were observed among 3, 6, and 9% yellowstripe scad whole powder additions, whereas significant differences emerged at 12 and 15% flour incorporation. The results of the moisture content analysis of yellowstripe scad -based fish crackers are presented in Figure 2a, Table 1.

Table 1. Chemical and physical composition of yellowstripe scad crackers

Composite flour (% yellowstripe scad flour)	Moisture content (%)	Protein (%)	Lipid (%)	Ash (%)	Dietary Fiber (%)	Texture (N/cm^2)
0 (S0)	3.52 ^{a}	8.15 ^{a}	4.12 ^{a}	1.56 ^{a}	5.65 ^{a}	933 ^{a}
3 (S3)	3.59 ^{ab}	10.29 ^{b}	8.09 ^{b}	3.92 ^{b}	3.87 ^{b}	1,101 ^{b}
6 (S6)	3.68 ^{b}	12.41 ^{c}	10.67 ^{c}	4.01 ^{b}	3.01 ^{b}	1,281 ^{c}
9 (S9)	3.78 ^{bc}	14.55 ^{d}	13.02 ^{d}	5.87 ^{c}	2.32 ^{c}	1,374 ^{d}
12 (S12)	3.86 ^{c}	16.76 ^{e}	15.05 ^{e}	6.14 ^{c}	1.08 ^{d}	1,432 ^{e}
15 (S15)	3.97 ^{c}	18.54 ^{f}	17.31 ^{f}	8.97 ^{d}	0.98 ^{d}	1,609 ^{f}

Note: Data (mean±SD) were calculated from five replicates. The data were analyzed by ANOVA. Data within the same column followed by different letters showed significantly different (Tukey test, p<0.05).

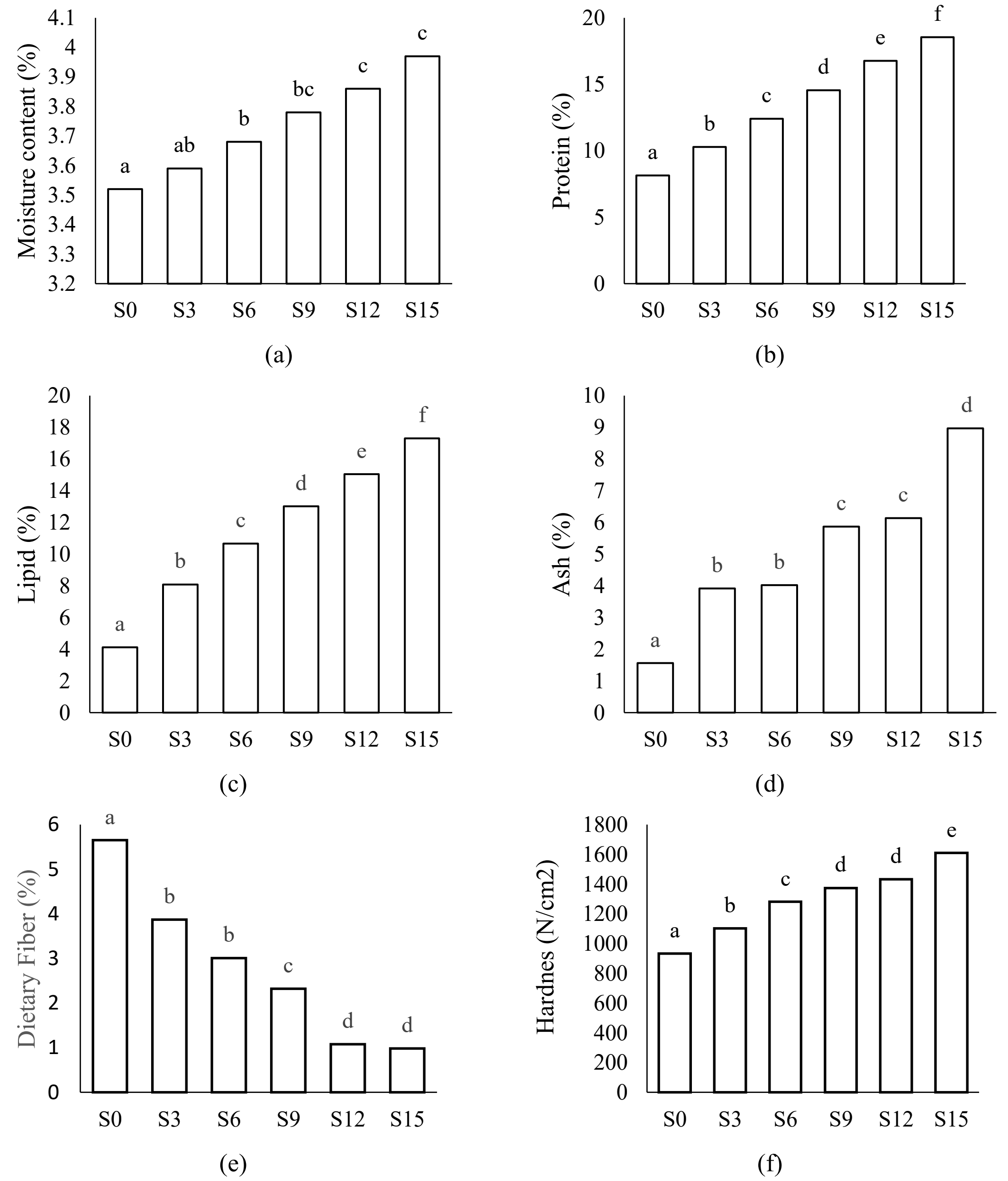

Figure 2. Effects of yellowstripe scad powder on chemical properties and texture of yellowstripe crackers. S0 – S6 were referred to Table 1.

The moisture content of fish crackers ranged from 3.52% to 3.97%, with the highest value observed in samples containing 15% yellowstripe scad whole powder (S5) at 3.97% and the lowest in the control sample without fish addition (S0) at 3.52%. An increase in the concentration of yellowstripe scad whole powder corresponded to a gradual increase in the moisture content of the crackers. This trend is consistent with the findings of Ernisti (2018), who reported that higher amounts of Siamese catfish flour led to an increase in the moisture content of crackers. Similarly, Breemer et al. (2023) reported that the addition of skipjack tuna (*Katsuwonus pelamis*) flour was positively correlated with a higher moisture content in tortilla chips.

Protein Content

The protein content of the yellowstripe scad whole powder crackers ranged from 8.15% to 18.54%. Analysis of variance

(ANOVA) demonstrated that the addition of yellowstripe scad (*Selaroides leptoletis*) flour significantly affected the protein content of the crackers ($p < 0.005$). The highest protein content was observed in the formulation containing 15% fish flour (S5), whereas the lowest was found in the control sample without fish flour (S0). Increasing the concentration of yellowstripe scad whole powder correspondingly increased the protein content of the fish crackers. The protein content of the yellowstripe scad crackers is shown in Figure 2b and Table 1b**.**

Similar findings were reported by Mutamimah et al. (2024), who showed that crackers substituted with sardine head flour at concentrations of 5–20% exhibited protein content ranging from 8.03% to 14.23%. Similarly,other studies have demonstrated that the incorporation of tuna flour increases the protein content of crackers. Comparable results were also observed by Nawaz et al. (2019), who found that the addition of whole fish powder (WFP) at concentrations of 5–15% significantly enhanced the protein content of crackers, with values ranging from 14.23% to 19.56%.

According to Sinaga et al. (2018), fresh yellowstripe scad (*Selaroides leptolepis*) contains a relatively high protein content of approximately 18.8%, which decreases to approximately 5.3% when it is processed into a fish hydrolysate. This characteristic explains the elevated protein levels in crackers fortified with yellowstripe scad whole powder compared to those enriched with other fish flours at equivalent substitution levels. The higher protein content observed in this study can also be attributed to the use of whole fish flour prepared from the entire body of yellowstripe scad, which is consistent with the findings of Nawaz et al. (2019).

Lipid Content

Lipid content is important in food products, as it affects both their nutritional value and shelf life. In general, higher lipid levels are associated with a reduced shelf life owing to increased susceptibility to lipid oxidation. The results of the flipid content analysis of yellowstripe scad crackers are shown in Figure 2c and Table 1.

The lipid content of the fish crackers ranged from 4.12% to 17.31%. Analysis of variance revealed that the incorporation of yellowstripe scad (*Selaroides leptoletis*) flour significantly affected the fat content of the crackers ($p < 0.005$). The highest lipid content was recorded in samples containing 15% fish flour (S5), whereas the lowest was observed in the control sample without fish flour (S0). A progressive increase in lipid content was evident with higher substitution levels of yellowstripe scad whole powder. These results are consistent with those of Mutamimah et al. (2024), who reported that the inclusion of Bali sardine flour at levels of 5–20% increased the lipid content of fish crackers, ranging from 11.43% to 16.85%.

Ash Content

Ash represents the micromolecular chemical component of food, derived from the inorganic residue that remains after the complete combustion of organic matter under controlled temperature and pressure. The ash content of a food product reflects its mineral composition, which generally consists of both organic and inorganic salts (Pangestuti and Darmawan, 2021). The ash content of the yellowstripe scad crackers obtained in this study is shown in Figure 2d and Table 2.

The ash content of yellowstripe scad crackers ranged from 1.56% to 8.97%. The addition of yellowstripe scad (*Selaroides leptoletis*) flour significantly affected the ash content of the crackers ($p < 0.005$). The highest ash content was observed in samples with 15% fish flour (S5), whereas the lowest was observed in the control sample without fish flour (S0). Increasing the concentration of yellowstripe scad whole powder resulted in a proportional increase in ash content, consistent with the findings of Mutamimah et al. (2024), who reported that the mineral content of Bali sardine-based fish crackers increased with higher levels of sardine head flour.

The addition of tuna flour significantly elevated the ash content of the fish crackers. The higher ash content in yellowstripe scad crackers observed in the present study can also be attributed to the use of whole yellowstripe scad powder prepared from the entire body of yellowstripe scad. This finding

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aligns with that of Nawaz et al. (2019), who demonstrated that incorporating whole fish powder into cracker production significantly increased ash content, primarily due to the high levels of hydroxyapatite and collagen derived from fish bones.

Dietary Fiber

Dietary fiber is an essential component of food that plays a critical role in supporting human health, particularly by enhancing the gastrointestinal function. However, excessive dietary fiber negatively affected the sensory quality of yellowstripe scad fish crackers (Figure 2e and Table 2).

The dietary fiber content of yellowstripe scad crackers ranged from 0.98% to 5.65%. The addition of yellowstripe scad whole powder (*Selaroides leptoletis*) significantly affected the dietary fiber content of the crackers ($p < 0.005$). The highest fiber content was observed in the control sample without fish flour (S0), while the lowest was observed in crackers with 15% fish flour (S5). Increasing the concentration of yellowstripe scad whole powder resulted in a progressive decrease in dietary fiber content.

This finding is consistent with that of Mutamimah et al. (2024), who reported that higher levels of fish flour increased fat content, which in turn reduced fiber levels. Similarly, Nawaz et al. (2019) demonstrated that the incorporation of whole fish powder, characterized by low starch and fiber content, reduced both carbohydrate and fiber content, accompanied by an increase in fat content. To enhance the dietary fiber content of fish crackers, plant-based ingredients rich in fiber, such as mung bean flour, should be incorporated. In addition to improving the fiber content, the inclusion of mung bean flour mitigated the characteristic “fishy” odor in fish crackers.

Texture (Hardness)

Texture is a critical quality attribute of crackers, with hardness and fracturability serving as key parameters that influence consumer perceptions of crispness and crunchiness. These properties are highly desirable in cracker-type products (Batista et al., 2019; Millar et al., 2017; Yilmaz and Karaman, 2017). According to Tunick et al., (2013), texture is among the most important quality attributes of crackers, as consumers strongly associate these products with a crisp and crunchy eating experience. The results of the hardness analysis of the yellowstripe scad crackers are presented in Figure 2f and Table 2.

The addition of of yellowstripe scad (*Selaroides leptoletis*) flour had a significant effect on the texture of fish crackers ($p < 0.005$). Increasing the concentration of yellowstripe scad whole powder resulted in greater hardness of the crackers. The highest hardness was observed in samples with 15% fish flour (S15), whereas the lowest was observed in samples with 3% fish flour (S3).

However, contrasting findings have been reported in other studies. Breemer et al. (2023) found that increasing the amount of skipjack tuna (*Katsuwonus pelamis*) flour decreased the hardness of tortilla chips, as higher flour concentrations were associated with increased product moisture. Similarly, Giannoutsos et al. (2023) observed that higher levels of substitution reduced the hardness and fracturability of crackers. This effect was attributed to the reduced availability of wheat flour, which lowers the content of gliadin and glutenin proteins essential for CO_2 retention during dough fermentation, thereby producing a more elastic and expanded dough (Giannoutsos et al., 2023; Nammakuna et al., 2016)

Moreover, dietary fiber has been shown to negatively affects product crispness by impairing dough rheology and uniformity (Venkatachalam and Nagarajan, 2017). Bolek (2020) further reported that a higher fiber content increases the water absorption capacity, which can reduce the texture quality of the cracker. In the present study, however, increasing the levels of yellowstripe scad whole powder was associated with a decrease in the dietary fiber content, which may partly explain the observed increase in cracker hardness.

CONCLUSION

The results of this study indicate that the addition of yellowstripe scad whole powder had a significant effect ($p < 0.005$) on the physicochemical properties of yellowstripe scad crackers. Crackers with

15% yellowstripe scad whole powder exhibited the highest protein (18,5%), lipid (8,97)%), and ash content (8,97%), while the addition of 3% yellowstripe scad whole powder produced crackers with the most desirable moisture content (3,59%), dietary fiber (3,87%), and texture (1,101 N/cm²) characteristics.

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