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NUTRITIONAL ENRICHMENT FROM BALI SARDINELLA (*Sardinella lemuru*) HEAD MEAL IN FISH CRACKERS AS EMERGENCY FOOD

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Abstract

Various natural disasters occur frequently in Indonesia, such as heavy floods, tornadoes, landslides, volcanic eruptions, earthquakes, and tsunamis, which disrupt access to the facilities and infrastructure necessary for clothing and food needs. Emergency food is an essential alternative for victims of natural disasters because of its long shelf-life and high nutritional content. Crackers are classified as emergency foods because of their ease of transport and extended storage period. The aim of this study was to determine the optimal concentration of Bali sardinella head flour based on the nutritional characteristics of fish crackers as a food source. The method used was a completely randomized design with five treatments varying with the addition of Bali sardinella head meal: 0, 5, 10, 15, and 20%. Data were analyzed using analysis of variance (ANOVA) and a color reader for color analysis. The best results were in 5% of Bali sardinella head flour in fish crackers by proximate analysis with protein, lipid, moisture, ash, and carbohydrate was 4.93±0.46, 12.81±0.25, 11.43±0.59, 5.19±0.59, 65.64±0.99, for dietary fiber was 4.03±0.01, color properties consist of Lightness (L*) 58.15±0.07, a* 11.00±0.00, b* 27.15±0.07. This study provides valuable insights into the nutritional composition of Bali sardinella head meal in fish crackers.

Keywords: by product, color analysis, dietary fiber, natural disasters, proximate

Pengayaan Nutrisi dari Tepung Kepala Lemuru (*Sardinella lemuru*) pada *Fish Crackers* sebagai Pangan Darurat

Abstrak

Bencana alam yang sering terjadi di Indonesia, yaitu banjir bandang, angin tornado, tanah longsor, letusan gunung api, gempa bumi dan tsunami dapat memutus akses terhadap sarana dan prasarana untuk memenuhi kebutuhan sandang dan pangan. Pangan darurat merupakan sebuah alternatif yang dibutuhkan untuk korban bencana alam karena memiliki sifat daya simpan yang lama dan tinggi akan nutrisi. *Crackers* termasuk ke dalam kategori pangan darurat karena memiliki masa simpan lama dan mudah sekali dalam pengangkutannya (transportasi). Tujuan penelitian ini adalah menentukan penambahan konsentrasi terbaik tepung kepala ikan lemuru berdasarkan karakteristik gizi *fish crackers* sebagai pangan darurat. Metode yang digunakan adalah rancangan acak lengkap (RAL) dengan 5 perlakuan penambahan tepung kepala lemuru, yaitu: 0, 5, 10, 15 dan 20%. Analisis data menggunakan *analysis of variance* (ANOVA) dan *color reader* untuk analisis warna. Hasil penelitian terbaik, yaitu pada penambahan 5% tepung kepala ikan lemuru pada *fish crackers* meliputi analisis proksimat yang terdiri dari kadar air 4,93±0,46; protein 12,81±0,25; lemak 11,43±0,59; abu 5,19±0,59; karbohidrat 65,64±0,99; kadar serat pangan 4,03±0,01 dan analisis warna

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terdiri dari *lightness* (L*) 58,15±0,07; a* 11,00±0,00; dan b* 27,15±0,07. Secara keseluruhan, penelitian ini memberikan informasi mengenai komponen gizi yang bernilai dari tepung kepala lemuru pada *fish crackers*.
Kata kunci: analisis warna, bencana alam, hasil samping, proksimat, serat pangan

INTRODUCTION

The concept of a circular economy has been developed to enhance the efficiency of resource utilization and align sustainability with the economic, environmental, and social aspects. This approach refers to the 3R principles of reduction, reuse, and recycling, which aim to minimize waste and maximize the use of natural resources throughout the production and consumption processes. The significant impact of waste is that it creates an uncomfortable environment for residential areas owing to unpleasant odors, which can become a nuisance and lead to poor health outcomes for the surrounding community. By-products of fish can be utilized in various fields, including functional foods, food additives, pharmaceuticals, cosmetics, and bioenergy. Its applications include fish oil (Suseno *et al*., 2020; Suseno *et al*., 2023), gelatin (Farida *et al*., 2020), biscuits (Daeng *et al.,* 2019), antioxidants (Mutamimah *et al*., 2018; Prastyo *et al*., 2020; Yanti *et al*., 2022), papain-soluble collagen (Cahyono *et al*., 2022; Utami *et al*., 2024), anti-aging agents (Espinales *et al.,* 2023), pepton (Nurhayati *et al*., 2023), and biofuels (Jaiswal *et al.,* 2022).

Fish heads are by-products of fish that are often found in the fishing industry and have a high nutritional content. These efforts are made to utilize fish heads as raw materials for making products in order to minimize the waste produced (Lestari *et al*., 2024). According to data from the UPT PPP Muncar for 2023, the by-products of the total production of Bali sardinella (*Sardinella lemuru*) amounted to approximately 48-60 tons, with a total fish head proportion of 19 tons. Mutamimah *et al*. (2023) reported that the composition of Bali sardinella head meal includes 3.34% moisture, 19.76% protein, and 34.86% fat. Moreover, Bali sardinella contains omega-3, which has many benefits, such as prevention of thrombosis and atherosclerosis, inhibition of cardiovascular disease and cancer, reduction of depression, and improvement of eye health and brain intelligence (Appleton *et al.,* 2021). The utilization of Bali sardinella fish heads is still limited. Several studies have been conducted on the utilization of Bali sardinella by-products such as soap (Ibrahim *et al.,* 2005), biodiesel (Widianto, 2010), feed (Miranti & Putra, 2019), and fish oil (Sari *et al*., 2015; Estiasih *et al*., 2017). Therefore, it is necessary to optimize the use of Bali sardinella fish head waste to increase its value-added potential.

On the other hand, Indonesia is a country with many areas at high risk of natural disasters, including floods, extreme weather, earthquakes, and tsunamis, which can disrupt the food supply chain. In emergency situations, it is essential to provide assistance to disaster victims in the form of ready-to-eat foods, such as biscuits or crackers, which have a long shelf life and are convenient for consumption. According to the Indonesian National Standard (BSN, 2011), crackers are a type of biscuit made with or without a fermentation process and undergo a lamination process to achieve a flat shape that appears layered when broken. One advantage of crackers is that they do not contain eggs, allowing them to have a longer shelf life. Furthermore, fermentation can enhance the crispness of crackers, increase their nutritional value compared to the original ingredients, and improve their digestibility. Crackers are in high demand because they taste good, have various shapes, and are filled.

Ideally, emergency food should not only be filled but also contain sufficient nutritional content. Given their high nutritional value, Bali sardinella heads can be used in the food sector to meet nutritional needs, particularly in emergency food provision. The aim of this study was to determine the optimal concentration of Bali sardinella head flour based on the nutritional characteristics of fish crackers as a food source.

MATERIALS AND METHOD

Production of Fish Crackers

The raw material used in this study was Bali sardinella (*Sardinella lemuru*) heads obtained from the canning industry in the Banyuwangi District, East Java Province, to be incorporated into the production of fish crackers. Bali sardinella heads were processed into flour and added to fish crackers in five treatments (0, 5, 10, 15, and 20%). The other ingredients used for making fish crackers include cake flour, butter, eggs, sugar, salt, milk, and shrimp stock powder. The formulations used for fish cracker production are listed in Table 1.

The Bali sardinella head meal was produced using a milling machine (Mutamimah *et al.* 2023). The process of creating fish crackers is illustrated in Figure 1.

Proximate Composition Analysis

Proximate analysis was conducted to determine the nutritional content of fish crackers fortified with Bali sardinella head meal. The proximate parameters analyzed included moisture content, determined by the gravimetric method according to AOAC 925.10 (2005); protein assessed by the Kjeldahl method according to AOAC 945.18-B (2005); fat measured using the Soxhlet method according to AOAC 996.06 (2005); ash content analyzed by the gravimetric method according to AOAC 930.05 (2005); and carbohydrates calculated by difference (BeMiller, 1994).

Dietary Fiber Analysis (AOAC 991.43, 2005)

The dietary fiber content was determined using an enzymatic method. A

Table 1 The formula of fish crackers product
Tabel 1 Formula produk *fish crackers*

Ingredients	Concentration of Bali sardinella head flour (%)				
	0	5	10	15	20
Bali sardinella head flour	0.0	5.0	10.0	15.0	20.0
Cake flour	59.0	54.0	49.0	44.0	39.0
Butter	11.5	11.5	11.5	11.5	11.5
Milk	23.5	23.5	23.5	23.5	23.5
Salt	0.8	0.8	0.8	0.8	0.8
Shrimp stock powder	2.0	2.0	2.0	2.0	2.0
Yeast	0.8	0.8	0.8	0.8	0.8
Sugar	0.7	0.7	0.7	0.7	0.7
Mushroom broth	1.0	1.0	1.0	1.0	1.0
Baking soda	0.7	0.7	0.7	0.7	0.7

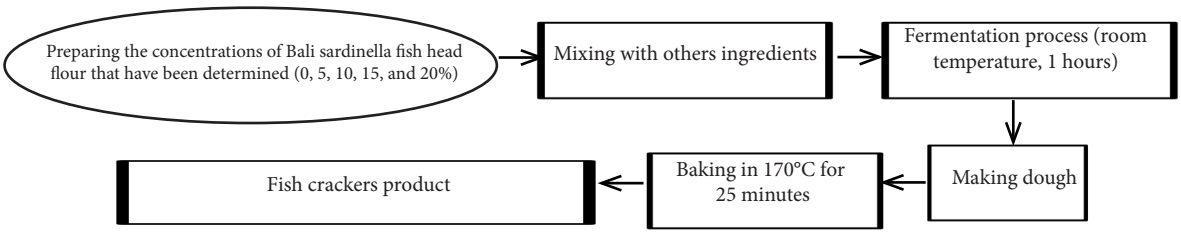

Figure 1 Fish crackers production flow chart
Gambar 1 Diagram alir pembuatan *fish crackers*

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sample (0.5 g) was placed in an Erlenmeyer flask and 50 mL of phosphate buffer (pH 6.0) and 0.1 mL of α-amylase were added. The sample was covered with aluminium foil and heated in a water bath at 100°C for 30 min, after which it was cooled. Next, 20 mL of distilled water, 5 mL of 1N HCl, and 1 mL of 1% pepsin were added and the mixture was heated at 100°C for an additional 30 min. The Erlenmeyer flask was then removed from the heat, and 5 mL of 1N NaOH and 0.1 mL of β-amylase enzyme were added. The flask was covered with aluminium foil and heated at 100°C for 1 h. After cooling, the mixture was filtered through constant-weight filter paper. The residue was washed with 2 × 10 mL of 95% ethanol and 2 × 10 mL of acetone. The sample was then dried in an oven at 105°C overnight, cooled in a desiccator, and weighed to obtain the final weight of insoluble dietary fiber. The filtrate was made up to 100 mL with distilled water and combined with 400 mL of 95% ethanol. The mixture was allowed to settle for 1 h. Subsequently, the filtrate was filtered through filter paper and washed with 2 × 10 mL of 95% ethanol and 2 × 10 mL of acetone. The sample was dried overnight in an oven at 105°C, placed in a desiccator, and weighed to obtain the final weight of soluble dietary fiber. The calculation of total dietary fiber was based on the following formula:

Total dietary fiber=insoluble fiber+soluble fiber

Color Determination (Setyawardani *et al.*, 2022)

Color was determined using a color reader. The sample was placed in a petri dish, and the power button on the color reader was pressed (Konica Minolta CR-10). The sensor of the color reader was then attached to the sample in a petri dish, and the test results were recorded. The color determination results are presented as the L*, a*, and b* values. The standard scale of color in food was as follows: L* represents darkness to lightness from 0 to 100, a* is greenness to redness from 0 to 80, and b* represents blueness to yellowness from 0 to 80.

Statistical Analysis

The study employed a completely randomized design with one factor consisting of five treatments of Bali sardinella head meal at concentrations of 0, 5, 10, 15, and 20%, each repeated three times. The data obtained from the research results were analyzed using analysis of variance (ANOVA) with the SPSS software. If a significant effect was observed on the variables of interest, Duncan's Multiple Range Test (DMRT) was applied at a 95% confidence level.

RESULTS AND DISCUSSION

Proximate Composition of Fish Crackers

The nutritional content, as presented in Table 2, obtained through proximate analysis of a product is crucial for determining the amount of energy contained within the product.

Moisture

The moisture content of fish crackers fortified with Bali sardinella head flour varied

Table 2 Proximate composition of fish crackers
Tabel 2 Komposisi proksimat *fish crackers*

Bali sardinella head flour (%)	Parameters (%)				
	Moisture	Protein	Fat	Ash	Carbohydrate
0	6.27±0.71^{d}	14.23±0.37^{e}	9.61±0.70^{a}	3.24±0.21^{a}	66.65±0.88^{a}
5	4.93±0.46^{bc}	12.81±0.25^{d}	11.43±0.59^{b}	5.19±0.59^{b}	65.64±0.99^{a}
10	4.18±0.31^{ab}	11.13±0.51^{c}	13.57±0.69^{c}	6.27±0.70^{c}	64.85±0.98^{a}
15	3.54±0.42^{a}	9.12±0.44^{b}	15.89±0.29^{d}	7.51±0.58^{d}	63.94±0.82^{a}
20	3.47±0.22^{a}	8.03±0.38^{a}	16.85±0.28^{d}	8.39±0.47^{d}	63.26±0.47^{a}
SNI 2973:2022	≤5	≥4.5	-	-	-

Different letter notations in each outcome indicate significant differences (p<0.05)

by concentration, with the lowest moisture content observed at 20% (3.47%) and the highest at 0% (6.27%). The difference was statistically significant ($p<0.05$). The results indicated that as the proportion of solid Bali sardinella head flour increased, the moisture content of fish crackers decreased. This finding contrasts with the results of Ernisti *et al.* (2018), who reported that the moisture content of patin fish crackers tended to increase with the addition of a higher amount of patin fish flour, ranging between 5 and 5.9%, resulting in a higher moisture content than that of fish crackers made with Bali sardinella head flour. According to Lahagu *et al.* (2023), greater use of fish flour correlates with a lower moisture content in the resulting products.

Moisture content is important for determining the shelf life of food because of its effects on the physical, chemical, microbiological, and enzymatic properties (Yanti *et al.*, 2023). Based on the moisture content of fish crackers, they can be stored for extended periods. According to the research findings of Sugiyono *et al.* (2013), crackers with a moisture content below 5% have a shelf life of five months. A key requirement for emergency food is long shelf life. Given their low moisture content, fish crackers are suitable for use as emergency food.

Protein

The protein content of the fish crackers fortified with Bali sardinella head flour ranged from approximately 8.03% to 14.23%. The protein content exhibited a significant variation ($p<0.05$) and tended to decrease as the proportion of Bali sardinella head flour increased. This decrease in protein content is likely due to an increase in other nutritional components such as fat content (Yanti *et al.*, 2023). In addition, lower protein levels may result from the high temperatures during heating.

Research conducted by Akhmadi *et al.* (2019) reported that crackers with the addition of waste in the form of milkfish bones had a protein content ranging from 2.29% to 7.30%. Similarly, Kustiani *et al.* (2017) indicated that crackers produced with the addition of catfish heads contained 9.04%–11.50% protein. Specifically, the addition of 10% catfish head flour to crackers resulted in a protein content of 11%, which is consistent with the findings of this study, in which the addition of 10% Bali sardinella head flour yielded a protein content of 11%.

According to Indonesian National Standard 2973 (2022), the minimum protein content in crackers or biscuits is 4.5%. The fish crackers produced in all treatments met the protein standards set by national standards. Proteins are essential nutrients for energy requirements and play a crucial role in immune function in the body (Rofidah *et al.,* 2024). Furthermore, emergency food products must meet specific nutritional requirements with a recommended protein content of 10–15%. The treatments with 0, 5, and 10% Bali sardinella head flour fell within this category.

Fat

The fat content of the fish crackers ranged from 9.61% to 16.85%, with significant variations ($p<0.05$). An increase in fat content was observed as the amount of Bali sardinella head flour incorporated into the fish crackers increased. Specifically, the fat content increased in direct correlation with increasing addition of Bali sardinella head flour. As Bali sardinella heads contain a high amount of fat (Mutamimah *et al.,* 2023), adding this flour enhances the fat content of the product.

In comparison, the fat content in milkfish bone crackers is 4% (Akhmadi *et al.,* 2019), whereas catfish head crackers exhibit fat contents ranging from 16.95% to 18.71% (Kustiani *et al.,* 2017). Thus, the fat content of fish crackers made with Bali sardinella head flour was significantly higher than that of milkfish bone crackers but lower than that of catfish head crackers. Furthermore, the fat content of fish is advantageous because it is rich in polyunsaturated fatty acids, particularly omega-3s (Mutamimah *et al.*, 2023).

Ash

Ash is an inorganic residue that remains after the material is burned at high temperatures in an ash furnace. The ash content is indicative of the minerals present in a material and can be categorized into

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two types: organic salts and inorganic salts (Pangestuti & Darmawan, 2021). A higher ash content in fish crackers suggests greater mineral content. Based on these research findings, the ash content in fish crackers increased from 3.25% at 0% concentration of Bali sardinella head flour to 8.39% at 20% concentration. Significant variations were observed (p<0.05) in the ash content. Crackers that did not contain Bali sardinella head flour exhibited the lowest ash content, whereas those treated with Bali sardinella head flour exhibited the highest ash content. These findings align with those of Kustiani *et al*. (2017), who reported that the addition of fish flour increased the ash content of the biscuits. Furthermore, the increase in the ash content of fish crackers is likely attributable to the presence of minerals in Bali sardinella head meal (Mutamimah *et al.*, 2023).

Carbohydrate

The carbohydrate content in this study was determined using a rough calculation method, also known as carbohydrates, rather than laboratory analysis. Carbohydrate content was calculated by subtracting the total components (100%) of moisture, fat, protein, and ash content (Devi *et al.,* 2017). The carbohydrate content ranged from 63.66% to 66.65%. The addition of Bali sardinella head flour to fish crackers did not significantly affect the carbohydrate content, as no significant differences were observed across all treatment samples. According to Kustiani *et al*. (2017), the carbohydrate content in catfish head crackers ranges from 63.34% to 68.16%, which is not markedly different from that of crackers produced with the addition of Bali sardinella head flour. It is believed that the high amount of cake flour added contributed to the elevated carbohydrate content. Kojansow *et al.* (2022) indicated that cake flour is rich in carbohydrates, primarily from sugars and starches.

Dietary Fiber

Dietary fiber is a food component that plays a crucial role in human health. Fibers are classified into two types based on their solubility in water: soluble and insoluble. The dietary fiber content of the fish crackers is presented in Table 3.

As the amount of Bali sardinella head meal increased in fish crackers, dietary fiber content decreased (p<0.05). Masrul (2018) indicated that consuming fiber-rich foods can reduce cholesterol levels in the blood and prevent inflammation of the colon wall. Typically, high levels of fat correlate with lower dietary fiber content, which is evident in fish crackers, where the fat content is elevated. Additionally, according to Mutamimah *et al.* (2023), Bali sardinella head meal contains high fat content.

According to Zakaria *et al.* (2024), the dietary fiber content of fish crackers is 26.96%. This result is much higher than that of dietary fiber in fish crackers supplemented with Bali sardinella head flour. This is because, in addition to the difference in composition, green bean flour, which is a source of dietary fiber, was added. The adult need for dietary fiber is approximately 25 g. Fiber can be obtained from various foods, such as nuts and vegetables. Therefore, it can be concluded that

Table 3 Dietary fiber content of fish crackers
Tabel 3 Kandungan serat pangan *fish crackers*

Bali sardinella head flour (%)	Insoluble fiber	Soluble fiber	Dietary fiber
0	3.45±0.04^{a}	0.83±0.03^{a}	4.28±0.01^{a}
5	3.25±0.04^{b}	0.78±0.01^{b}	4.03±0.01^{b}
10	3.10±0.05^{c}	0.68±0.02^{c}	3.78±0.07^{c}
15	2.90±0.05^{d}	0.65±0.04^{c}	3.54±0.06^{d}
20	2.68±0.08^{e}	0.57±0.02^{d}	3.25±0.03^{e}

Different letter notations in each outcome indicate significant differences (p<0.05)

fish crackers supplemented with green bean flour exceed the dietary fiber intake for the daily needs of adults.

Color Properties

Color determination is important because the appearance of food is the first characteristic consumers notice when considering its consumption. The color properties of the fish crackers are listed in Table 4.

L*, with a value of 0, is an indicator of black color, whereas 100 is white. a* has positive and negative values with a range of 0–80. If the value obtained is positive (0-80), it indicates red; if the value is negative (-0)–(-80), it indicates green. b* is the same as a* and has both positive and negative values. A positive value of 0-70 indicates yellow, whereas a negative value of (-0)–(-70) indicates blue. As the amount of Bali sardinella head flour added to fish crackers increased, the color darkened. The values shown in Table 4 indicate that a lower value corresponds to a darker color in fish crackers. This relationship suggests that as the composition of Bali sardinella head flour increased, the lightness value decreased. Similar results were obtained by Ernisti *et al.* (2018), who found that the more fish added to crackers, the darker the color produced, although the L* results were higher, namely 71.83% - 56.17%, so the resulting color was brighter compared to fish crackers with the addition of Bali sardinella.

Bali sardinella is a fatty fish that is typically darker in color than fish with lower fat content (Husni *et al.*, 2019). The addition of Bali sardinella head flour to the cracker dough resulted in darker coloration. Therefore, the lower the lightness value, the darker the color of the fish-crackered product. Color serves as a primary attraction in food products before consumers recognize and evaluate other properties (Rahmawati & Wahyuni, 2021).

CONCLUSION

The use of Bali sardinella flour in the production of fish crackers can enhance their nutritional value, particularly in terms of fat content. According to the Indonesian national

Table 4 Color properties of fish crackers
Tabel 4 Sifat warna *fish crackers*

Bali sardinella head flour (%)	Parameters	Unit	Results
0	Lightness (L*)	%	61.25±0.07^{e}
	a*	-	10.70±0.00^{a}
	b*	-	28.65±0.07^{d}
5	Lightness (L*)	%	58.15±0.07^{d}
	a*	-	11.00±0.00^{a}
	b*	-	27.15±0.07^{c}
10	Lightness (L*)	%	53.25±0.07^{c}
	a*	-	10.85±0.21^{a}
	b*	-	24.65±0.07^{b}
15	Lightness (L*)	%	50.80±0.00^{b}
	a*	-	9.80±0.14^{a}
	b*	-	23.00±0.14^{a}
20	Lightness (L*)	%	48.20±0.00^{a}
	a*	-	11.15±0.07^{a}
	b*	-	22.00±0.04^{a}

Different letter notations in each outcome indicate significant differences (p<0.05)

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standards, the optimal concentration of Bali sardinella head flour is 5%. Further research is required to confirm this hypothesis. Considering their nutritional content, fish crackers can potentially serve as high-nutrient emergency foods. For commercialization, additional analyses are required, including product preference testing and the determination of the shelf life of fish crackers.

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