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Substitution of Tuna (*Thunnus Sp*) Fish Skin Soils in The Flat Chips Cook Making Process

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A B S T R A C T

Innovation in making crackers is done by adding crushed tuna fish skin as a protein-rich substitute. This study aims to: (1) Analyze the sensory test of crackers, (2) Determine the swelling power and oil absorption capacity of crackers with a tuna skin crushed formulation, and (3) Determine the effect of tuna fish skin substitution on the air and protein content of crackers. The study used a Completely Randomized Design (CRD) with four treatments: A0 (0%), A1 (25%), A2 (35%), and A3 (45%) crushed tuna fish skin. The parameters tested included sensory tests (color, taste, aroma, crispness), physical tests (swelling power and oil absorption), and chemical tests (air and protein content). The results showed that tuna fish skin substitution significantly affected the color, taste, and crispness of crackers (P<0.05), but did not affect the aroma (P>0.05)

INTRODUCTION

Tuna (Thunnus sp.) is a fishery commodity with high economic value and nutritional benefits for health. This fish contains 22.6–26 grams of protein per 100 grams and 0.2–2.7 grams of fat per 100 grams (Tambunan, 2022). Nutrients such as protein and omega-3 are also found in its waste, such as fish skin. However, to date, the utilization of tuna waste remains limited, particularly the skin, which has the potential to be a nutritious food ingredient.

To date, the tuna processing industry has focused primarily on the flesh (fillet), while other parts, such as the skin, bones, and innards, remain as waste that has not been fully utilized (Kalibukbuk, 2022). However, tuna skin waste has a higher protein content than other waste and has great potential for development into food products such as gelatin and fish skin crackers. Utilizing this byproduct not only has a positive impact on the environment but also provides new economic value to the fisheries industry.

One popular food product with good market prospects is crackers. They are popular with a wide range of people and are available in a variety of variations. Crackers made from skin, whether from livestock or fish, tend to command a higher selling price (Nurnidar & Kiflah, 2023). However, the use of fish skin as a raw material for crackers is still rare. The nutritional content of snack products on the market today is generally low, especially in terms of protein content (Maulid et al., 2021), so utilizing fish skin could be an innovative solution to increase the nutritional value of these products.

The development of flat chip crackers using crushed tuna skin as a substitute is an innovation in the functional food industry. According to FAO data, approximately 30% of the weight of fish caught ends up as waste, including tuna skin (Ardian et al., 2022). Several studies have shown that processed fish skin products are well-received by consumers when processed using appropriate techniques (Kolanus et al., 2019). In addition to providing nutritional benefits, utilizing fish skin waste also supports sustainable and environmentally friendly resource management and opens up new business opportunities based on local ingredients (Pratiwi et al., 2023).

This study aims to analyze the use of crushed tuna skin as a substitute in the production of flat chip crackers. The research focused on evaluating sensory quality (color, taste, aroma, and crispiness), physical testing (expansion and oil absorption), and chemical testing (protein and moisture content). The results of this research are expected to serve as a scientific reference in the development of tuna fish waste-based food products, as well as contribute to reducing fishery waste and increasing the nutritional value of snacks consumed by the public.

LITERATURE REVIEW

The utilization of fish by-products has become an important aspect of sustainable food production. Tuna (Thunnus sp.), one of the most economically significant marine species, is widely processed for its meat, generating substantial by-products such as bones, heads, and skins. Among these, tuna skin contains high amounts of collagen, protein, and essential amino acids, making it a potential functional ingredient in food applications (Nalinanon et al., 2008; Zhuang et al., 2009).

Fish skin is rich in type I collagen and has good film-forming, water-holding, and emulsifying properties (Jongjareonrak et al., 2005). These properties suggest that tuna skin solids, when processed into powders or pastes, may be incorporated into starchy snack products like chips to enhance texture, nutritional value, and shelf life. According to Zhang et al. (2018), incorporating marine collagen in food can improve chewiness and moisture retention.

Tuna skin solids contain high-quality proteins, gelatin, and omega-3 fatty acids, which are beneficial for cardiovascular and cognitive health (Sathivel et al., 2002). Their integration into processed snack foods may also enhance the protein content and provide a source of bioactive peptides with antioxidant properties (Kim & Mendis, 2006). This aligns with the growing trend of functional snacks that not only satisfy hunger but also provide health benefits.

Research on incorporating fish processing residues into food products has been increasing. For example, surimi by-products have been used in crackers, and fish gelatin has been applied in confectionery (Shyni et al., 2010). There is also evidence of fish skin hydrolysates being used in baked products (Gómez-Guillén et al., 2011). However, specific studies on tuna skin in flat chip products are still limited, offering a promising opportunity for innovation.

The substitution of tuna skin solids in flat chips must consider texture, flavor, and appearance. According to sensory studies, fish-based additives may affect consumer acceptance if the fishy odor is too strong (Ogunbanwo et al., 2021). Processing methods such as blanching, enzymatic hydrolysis, or flavor masking can be applied to reduce off-flavors and improve palatability (Kristinsson & Rasco, 2000).

Integrating tuna skin solids into starch-based matrices such as cassava, rice, or wheat flour involves understanding their hydration behavior, protein-starch interactions, and thermal stability. The drying process, particle size, and level of substitution are critical factors influencing the quality of the final chip product (Liu et al., 2019). Furthermore, technological adaptation is needed to ensure proper dough consistency, crispness, and oil absorption rates.

Utilizing tuna skin by-products in food production contributes to waste reduction and circular economy principles. It adds value to materials that would otherwise be discarded and reduces the environmental footprint of fish processing industries (Arvanitoyannis & Kassaveti, 2008). For small- and medium-scale processors, this approach can lower raw material costs while offering a unique product niche.

METHODOLOGY

This research will be conducted from February to April 2025 at the Fisheries Processing Workshop, Fisheries Product Processing and Storage Study Program, Department of Agricultural Technology, and the Nutrition and Chemistry Laboratory, Department of Fisheries Cultivation, Pangkep State Agricultural Polytechnic.

Research Tools and Materials

The main ingredient used in this study is tuna skin, which is used to make flat chip crackers. Additional ingredients include tapioca flour, wheat flour, salt, garlic powder, MSG, and cooking oil.

The tools used include: a basin, stove, frying pan, knife, spoon, digital scale, blender, dough mold, and steamer. For laboratory analysis, tools such as an oven, porcelain cup, gegep, tongs, desiccator, stainless steel spoon, analytical balance, Kjeldahl flask, digester, Buchi distillation apparatus, 250 ml Erlenmeyer flask, 25 ml burette, 25 ml volumetric pipette, and sensory test questionnaire were used.

Research Design

This study used a one-factor Completely Randomized Design (CRD) with four levels of tuna skin mash addition (0%, 25%, 35%, and 45%) and three replications.

After the crackers were produced, they were tested for yield, sensory evaluation (color, taste, aroma, crispiness), and physical characteristics (expansion and oil absorption). Sensory test data were analyzed using the Kruskal-Wallis test. The best treatment from the hedonic test results was then analyzed for protein and moisture content. The results of these chemical tests were compared with the quality standards for skin crackers according to the Indonesian National Standard (SNI) (1999).

Research Procedure

Tuna skin was obtained from PT. Chen Woo Fishery, then cleaned of scales and rinsed with salt water to reduce the fishy odor. The skin was steamed for approximately 5 minutes to soften, then cut into small pieces and blended. The ground skin was mixed with additional ingredients (tapioca flour, wheat flour, salt, garlic powder, and MSG) according to the formulation for each treatment. The dough was steamed thinly for approximately 10 minutes until cooked, then molded into flat chips. The crackers were dried in the sun for 3–4 days or dried in an oven. Once dry, the crackers were fried for 10–20 seconds in hot oil, packaged in polypropylene plastic, and then subjected to sensory testing by panelists.

Research Parameters

The research parameters were based on sensory, physical, and chemical analysis. The sensory testing was based on panelists' preferences for color, taste, aroma, and crispiness. The physical testing consisted of yield, swelling power, and oil absorption, while the chemical testing consisted of protein and water content analysis.

a. Sensory Testing

Sensory testing was conducted using the hedonic method for color, taste, aroma, and crispiness by 30 untrained panelists. Rating scale: 1 (dislike very much) to 5 (like very much).

b. Cracker Expansion

The expansion of fried crackers can be determined based on the percentage of linear expansion by measuring the surface of the dry product, which is a thin, round sheet, before and after frying. The average is then calculated, and the percentage of linear expansion is calculated using the formula:

$$\% \, Linear \ development \ power = \frac{P_2 - P_1}{P_1} x100\% \quad (1)$$

Description:
P1: Line length before frying
P2: Length of the line after frying

c. Oil Absorbency

The calculation of oil absorbency is based on the percentage ratio between the weight of crackers before frying and the weight of crackers after frying at 180°C. The formula used to calculate oil absorption is as follows:

$$Absorbency \, (\%) = \frac{W_2 - W_1}{W_1} x100\% \quad (2)$$

Description:
W1 : Weight of crackers before frying
W2 : Weight of crackers after frying

d. Protein Content Analysis

Determination of protein content in fishery products according to SNI 01-2354-4 (2006), is carried out with the principle of 3 stages consisting of the deconstruction stage, the distillation stage, and the titration stage.

e. Analysis of Water Content

Water content according to SNI 2354.2 (2015), is the number of unbound water molecules (free water) contained in a product. The method used is gravimetry, which is a testing method based on weighing.

6. Data Analysis

The first data analysis of the research results was the hedonic test using the Kruskal-Wallis test. After obtaining the best treatment from the results of the hedonic test, the protein content and water content were tested.

RESEARCH RESULT

Yield of tuna skin crackers

The yield of tuna fish skin in each treatment is calculated from the final weight of tuna fish skin crackers divided by the initial weight of tuna fish skin cracker dough multiplied by 100%. The yield of tuna fish skin in each treatment in 500 g can be seen in Table 1.

Table 1. Yield of Tuna Fish Skin Flat Chips Crackers

No.	Treatment	Yield
1	A1	77.0 %
2	A2	69.4 %
3	A3	53.6 %

Tuna fish skin Flat Chips crackers with treatment A3 (45% tuna fish skin) produced lower yields compared to treatment A1 (25% tuna fish skin). This is because the more tuna fish skin used in making tuna fish skin flat chips crackers, the smaller the cracker's growth capacity, so that it can affect the yield of tuna fish skin flat chips crackers. Tuna fish skin contains high collagen collagen has an important role in the formation of gel texture in food products (Rahmawan Kusa et al., 2022). The higher the water content retained in the product, the higher the yield (Firdayani et al., 2015; Paseru, 2017).

Organoleptic testing with hedonic method was conducted to determine the level of acceptance of tuna fish skin flat chips crackers with different additions of tuna fish skin. According to Tarwendah (2017), hedonic testing aims to determine the difference in quality between several similar products by giving an assessment of certain properties and to determine the level of liking for a product. The data obtained was analysed with the Kruskal-Wallis test. The organoleptic test graph can be seen in Figure 1.

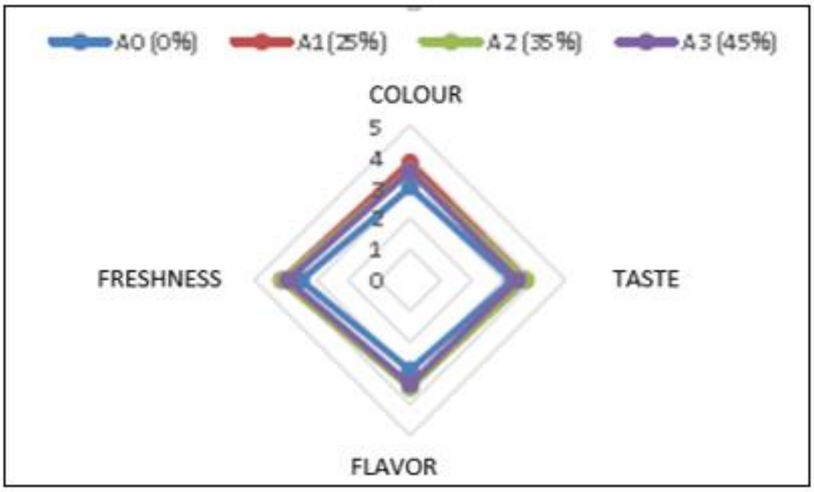

Figure 1. Organoleptic Test Chartc

Color is the first visual impression received by panelists and can influence initial interest in a product. The Kruskal-Wallis test results showed that the addition of tuna skin powder significantly affected color parameters ($P<0.05$), with a significance value of 0.04. Treatment A1 (25% tuna skin) produced the highest color value (3.80), while A0 (no tuna skin) had the lowest value (3.00). A further Mann-Whitney U test showed a significant difference between A0 and treatments A1, A2, and A3, but no significant difference between A1 and A2 and A3. This indicates that the addition of tuna skin caused a significant color change from A0 to the other treatments, but not enough difference between A1 and A3 to be considered similar color groups by panelists.

Taste is an important factor in consumer assessment of food products because it reflects product quality and acceptability. Based on the Kruskal-Wallis test, the addition of tuna skin significantly affected flavor parameters ($P<0.05$; $p=0.02$), with the highest value in treatment A1 (3.73) and the lowest in A0 (3.30). A further Mann-Whitney U test showed that A0 was significantly different from all other treatments, while A1 was not significantly different from A2, but A2 was significantly different from A3. Increasing the proportion of tuna skin provided a stronger flavor, but A3 (45%) tended to produce a fishy aftertaste that decreased panelist acceptance, resulting in the highest taste preference achieved in formulation A1.

Aroma is assessed using the sense of smell and plays an important role in determining initial impressions of a food product. However, the Kruskal-Wallis test showed that the addition of crushed tuna skin had no significant effect on aroma parameters (P>0.05; p=0.06). This indicates that although there were differences in average aroma values between treatments, these differences were not consistent enough for panelists to identify as statistically significant changes. Treatment A2 (35%) had the highest aroma score (3.46), while A0 (without tuna skin) had the lowest (2.90). However, statistically, there was no significant variation in aroma between the treatment groups.

Crispiness is an important parameter in cracker products because it relates to the texture and distinctive sound when bitten, which influences consumer acceptance. Based on the Kruskal-Wallis test, the addition of tuna skin significantly affected the crispiness of the crackers (P<0.05; p=0.01). Treatment A1 showed the highest crispiness score (4.13), while A0 had the lowest (3.50). A further Mann-Whitney U test showed that A0 was significantly different from A1, A2, and A3. A1 was not significantly different from A2, but A3 was significantly different from both. Increasing the collagen and protein content of tuna skin is believed to improve the crispiness of the product, but in treatment A3, the texture changed drastically, causing a decrease in the score compared to A1 and A2.

Crackers expandability

The physical characteristics of tuna fish skin flat chips crackers are also seen from the crackers expandability test. The durability of tuna fish skin flat chips crackers with different tuna fish skin additions can be seen in Table 2.

Table 2. Flowering Power Results

No.	Treatment	Flowering Power
1	A0	51,25 ± 21,26
2	A1	80,25 ± 18,55
3	A2	53,25 ± 27,25
4	A3	37,00 ± 31,67

Expansion can be defined as the maximum increase in volume and weight. Crackers expand due to the vapour pressure created by heating (frying), which causes the water content trapped in the crackers to push against the structure of the material forming the expanded product. The expandability of tuna fish skin flat chips crackers is expressed in percent (%). The expandability of flat chips crackers is determined based on the percentage comparison between the product area before and after the frying process, where a higher percentage value reflects better expandability (Safitri et al., 2019). The results of the analysis showed that the A1 treatment (25% tuna fish skin inclusion) produced the highest expandability of 80.25% ± 18.55, while the lowest value was recorded in the A0 treatment (no tuna fish skin inclusion) at 51.25% ± 21.26. The decrease in expandability as the concentration of tuna fish skin inclusion increased is thought to be due to the high content of collagen and structural proteins, which form a dense network and inhibit development during the frying process.

Oil absorbency

Oil absorption is one of the important quality characteristics for dry food products. The oil absorption of tuna fish skin flat chips crackers with different tuna fish skin additions can be seen in Table 3.

Table 3. Oil Absorbency Results

No.	Treatment	Oil Absorbency (%) ± SD*
1	A0	65,00 ± 10,13
2	A1	142,5 ± 5,97
3	A2	131,0 ± 4,16
4	A3	103,0 ± 5,77

Oil absorption is the ability of crackers to absorb oil during the frying process. Oil absorbency shows the amount of oil that can be absorbed by the food matrix. The oil absorption of tuna fish skin flat chips crackers is influenced by the development volume, moisture content before and after frying (Maureen et al., 2015). The higher the percentage value, the greater the product's ability to absorb oil. The results showed that treatment A1 had the highest oil absorption of 142.5% ± 5.97, while treatment A0 had the lowest value of 65.00% ± 10.13. A high absorbency indicates a thorough maturity of the product, hence more oil is absorbed into the crackers. In addition, increasing the number of tuna skin flaps decreased the oil absorption, possibly due to a denser dough structure that limits oil absorption during frying.

Chemical characteristics of tuna fish skin crackers

The treatment analysed in the chemical test was the best treatment in terms of hedonics, namely Treatment A1 (25%). The chemical characteristics of tuna fish skin flat chips crackers, including protein and water content can be seen in Table 4.

Table 4. The Results of The Analysis of Protein Content and Water Content of Tuna Fish Skin Flat Chips Crackers with The Addition of 25% Tuna Fish Skin Flakes

Parameters	Averages ± SD*	(SNI 01-4308-1999)
Protein Content	7,40 ± 0,035	Minimum of 6
Moisture Content	3,52 ± 0,028	Maximum of 11

Protein content

Protein is one of the important quality indicators in food products because it plays a role in nutritional value and is a major consideration for consumers in choosing products (Wahyuni et al., 2017). In this study, protein content was analysed using the Kjeldahl method which works based on the principle of measuring total nitrogen in the material, then converted to protein content. The test results showed that treatment A1 (25% tuna fish skin), which was also the most preferred treatment based on the hedonic test, had a protein content of

7.40%. This value has exceeded the minimum standard set by SNI 01-2713-1999, which is 6%, so this product can be categorised as a protein source food that is suitable for consumption. This high protein content is most likely derived from tuna skin, which is known to be rich in collagen and other functional protein compounds. The addition of tuna fish skin lumps not only plays a role in increasing nutritional value, but can also be an alternative to the utilisation of fishery waste into nutritious and economical value-added products.

Moisture content

Moisture content is the percentage of water content in an ingredient and is one of the important parameters in food quality, because it affects the texture, appearance, flavour, and shelf life of the product. Based on the test results, treatment A1 with the addition of 25% tuna fish skin, which is also the most hedonically preferred treatment, has a moisture content of 3.52%. This value is far below the maximum threshold according to SNI 01-2713-1999, which is 11%, so the product is classified as having low moisture content. This low moisture content is beneficial because it can extend the shelf life and maintain the crispness of the crackers. The low moisture content can be caused by an effective drying process, where the water molecules in the material easily evaporate. However, according to Huda et al. (2016), the collagen content in fish skin also plays a role, as collagen can form a solid structure that resists water evaporation during drying. Therefore, the moisture content in crackers is strongly influenced by the combination of the processing process and the composition of the raw materials.

CONCLUSIONS

Based on the research findings on the production of flat chip crackers using tuna fish skin as a partial substitute, it can be concluded that incorporating tuna skin significantly affects the overall quality of the product, particularly in sensory, physical, and chemical attributes. Sensory evaluation revealed that tuna skin addition had a notable impact on color, taste, and crispness ($P<0.05$), with the 25% substitution (treatment A1) achieving the highest scores among all treatments. However, the aroma was not significantly influenced by the tuna skin addition ($P>0.05$).

In terms of physical properties, the A1 treatment also demonstrated superior performance, with an expandability of 80.25% and oil absorption rate of 142.5%. Chemically, the crackers with 25% tuna skin substitution complied with the Indonesian National Standard (SNI 01-2713-1999) for fish crackers, showing a protein content of 7.43% and moisture content of 3.54%.

Therefore, using 25% tuna fish skin in the formulation of flat chips crackers yields a product with desirable organoleptic and physical traits, meets nutritional quality standards, and presents a promising opportunity to transform fish processing by-products into value-added, innovative snack products.

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