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# MACKEREL SCADS AND TUNA LIVER MEATBALL: AN INNOVATIVE SNACK, SOURCE OF PROTEIN AND IRON FOR CHILD FOOTBALL PLAYERS

*Bakso Ikan Layang Hati Tuna: Kudapan Inovatif Sumber Protein Dan Zat Besi Anak Sepak Bola*

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**_ABSTRAK_**

*Pemenuhan zat gizi yang optimal bagi anak sekolah sepak bola untuk menunjang kebugaran dan ketahanan fisik. Pemanfaatan sumber pangan lokal seperti ikan layang (Decapterus sp) dan tuna yang melimpah di perairan Maluku Utara, menawarkan potensi besar dalam pengembangan kudapan bergizi. Penelitian bertujuan untuk menghasilkan formula, mengevaluasi mutu organoleptik, dan menganalisis kandungan gizi kudapan berbahan ikan layang dan hati tuna. Penelitian ini menggunakan tiga jenis tepung (tapioca, tepung sagu dan tepung maizena) dengan Rancangan Acak Lengkap (RAL). Sebanyak 30 panelis agak terlatih dilibatkan dalam pengujian organoleptik. Produk kudapan terpilih, dianalisis kandungan protein total, asam amino, lemak total, karbohidrat, dan zat besi. Data diolah menggunakan Microsoft Excel dan IBM SPSS versi 25. Uji Kruskal-Wallis untuk analisis mutu organoleptik dari tiga formula. Uji Kruskal-Wallis menunjukkan tidak ada perbedaan signifikan pada warna kudapan (p>0,05), namun terdapat perbedaan signifikan pada aroma, rasa, dan tekstur di antara tiga perlakuan tepung (p<0,05). Kudapan terpilih mengandung 18,29% karbohidrat, 7,64% lemak, 18,68 gram protein, 216,66 kkal energi, dan 3,49 mg zat besi per 100 gram. Asam amino esensial didominasi oleh lysine, valine, dan isoleucine. Formula satu dengan tepung tapioka menjadi pilihan terbaik berdasarkan penerimaan panelis terhadap rasa, warna, tekstur, dan aroma. Kebaruan dari kudapat ini terletak pada penambahan hati tuna untuk meningkatkan zat besi. Kandungan sumber protein dan zat besi mendukung pemenuhan kecukupan gizi bagi anak sekola sepak bola. 100 gram kudapan mendukung 26,62% protein dan 29,08 % zat besi dalam pemenuhan kecukupan gizi harian anak sekolah sepak bola usia 13-15 tahun.*

***Kata kunci:*** *keanekaragaman pangan, gizi olahraga remaja, kudapan berbasis ikan, hati ikan tuna, decapterus sp.*

**ABSTRACT**

The abundance of local marine resources, such as mackerel scads from North Maluku, presents an opportunity for innovative snack development. This study aimed to create a nutritionally enhanced snack for football academy students by using mackerel scads and tuna liver. The formula was developed using a Completely Randomized Design (CRD). Thirty semi-trained panelists assessed the snack's organoleptic properties. The selected product then underwent comprehensive nutritional analysis for total protein, amino acids, total fat, carbohydrate, and iron. Statistical analysis of the organoleptic data, performed with the Kruskal-Wallis test, revealed no significant difference in snack color (p=0.203>0.05). However, significant differences were observed in aroma, taste, and texture among the three flour treatments (p<0.05). Nutritional analysis per 100 grams of the selected snack showed a robust profile: 18.29% carbohydrate, 7.64% fat, 18.68



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grams protein, 216.66 kcal energy, and 3.49 mg iron. The essential amino acid content was primarily Lysine, Valine, and Isoleucine. The inclusion of tuna liver was a key innovation that significantly increased the snack's iron content. A 100-gram serving of this final product can fulfill 26.62% of the daily protein and 29.08% of the daily iron Recommended Dietary Allowance (RDA) for 13-15-year-old football students. These findings indicate the snack is a promising, source-protein, and iron food that leverages local resources to meet specific dietary needs.

**Keywords:** dietary diversity, youth sports nutrition, fish-based snacks, tuna liver, *Decapterus sp.*

## INTRODUCTION

Ensuring sufficient protein and iron intake, crucial for proper growth, frequently presents a critical challenge during adolescence. Specifically, at a football academy of Ganesha Putra FSC- Purwodadi, Semarang, inadequate protein intake was found in 41% of participants [1]. Another study at football academy of Terang Bangsa Semarang reported protein and iron (Fe) intake deficiencies at 70.8% and 87.5%, respectively [2]. For Student of Football Training and Education Center (In Indonesia: *Football School-Student Education and Training Centre (SSB PPLP)*), carbohydrate, fat, and protein intake each showed an 81.2% deficit, highlighting significant unfulfilled nutritional needs [3]. Initial screenings were conducted in two football schools in Ternate City in 2024. As part of this research, it was found that the nutritional adequacy of the football school children was not yet met, 78.85% protein and 87.85% iron. Protein plays a crucial role in muscle tissue growth and immune system function, thereby supporting overall physical capacity. Adequate protein intake after training or competition can boost protein synthesis, contributing to muscle development as an energy reserve for athletes. Fish stands out as a vital source of animal protein, offering greater satiety compared to chicken, beef, and other alternatives [4]. Furthermore, fish muscle is more easily digested by the body than other animal proteins due to its lower connective tissue content [5]. Indonesia's per capita fish consumption reached 54.50 kg/year in 2022, still below the national target of 65.5 kg/year. To address this gap, developing diverse value-added fish products is an effective strategy to increase intake, meet daily protein needs, and support growth. Previous studies show that growth problems and anemia remain prevalent among football school children due to inadequate nutrient intake. Therefore, creating fish-based snacks is a strategic effort to optimize local food resources, while improving protein and iron intake in line with the dietary habits of young athletes.

The nutritional composition of fish makes it a potent source of animal protein, playing a significant role in preventing muscle mass loss due to its rich content of protein, vitamins, and minerals [6]. Therefore, developing a snack tailored to consumption habits and containing appropriate sources of protein and iron can support the nutritional adequacy of youth football players in Ternate City. Ternate was designated as a "football city" by PSSI in 2020, due to its potential human resources in the sport. Therefore, the development of this snack offers particular benefits in meeting the protein and iron needs of football athletes.

In Ternate City, mackerel scads *(Decapterus sp)* is an abundant and cost-effective fish rich in protein and iron. Tuna liver is frequently discarded as underutilized waste by the community, mainly because of its unappealing taste and texture. Therefore, these two ingredients are being transformed into new derivative products, fish meatballs, to enhance both their nutritional content and economic value. The nutritional and economic potential of the resulting snack product can be commercialized and utilized in free meal programs, as it is frequently consumed. This study aimed to develop a snack formula, analyze the organoleptic characteristics, and determine the nutritional content (energy,


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fat, protein, iron (Fe), and amino acids) of the selected product, which is made from mackerel scads *(Decapterus sp)* fortified with tuna liver.

**METHODS**

The variables measured in this study consisted of organoleptic quality (color, aroma, taste, and texture) and nutritional content, which included energy, carbohydrates, fat, protein, iron, and amino acids. The development of snacks utilizing mackerel scads *(Decapterus sp)* enriched with tuna liver was carried out using three different types of flour with a Completely Randomized Design (CRD). Ingredients for snack development included 100 grams of mackerel scad meat. Freshly caught mackerel scad. The fish meat is fresh, filleted (bones and skin removed), and then finely ground. 50 grams of tuna liver. Fresh tuna liver, ensuring no damaged or spoiled sections, is cleaned and subsequently puréed. 30 grams of laying hen eggs. Fresh, whole chicken eggs (white and yolk). 50 grams each of tapioca flour, sago flour, and corn starch. These three flours must be good quality, lump-free, and stored in a dry place. 20 grams of garlic, and appropriate amounts of salt and pepper per snack recipe. This research obtained ethical approval from the Ethics Committee of Poltekkes Kemenkes Semarang, with recommendation number 0188/EA/KEPK/2024.

Fish fillets were minced using a meat grinder or food processor to produce surimi, then washed with cold or ice water at 5°C. Salt (2%) and seasonings were added, and the mixture was stirred until sticky. Tapioca flour was incorporated to form a homogeneous dough, which was kneaded continuously to achieve a smooth texture. Meatballs were shaped and boiled, first at 40°C for 20 minutes, then at 90°C for another 20 minutes until fully cooked[7]. This product development research was conducted from May to June 2024 at the Nutrition Laboratory of Poltekkes Kemenkes Ternate and the SIG SARASWATI Food Laboratory in Bogor. Organoleptic testing involved 30 semi-trained panelists purposively selected based on the following criteria: Nutrition Department students who had completed the Food Technology course, had no taste impairments, were willing to participate, and had prior training as panelists. Exclusion criteria included allergies to skipjack tuna or tuna liver. Thirty panelists participated [8]. They were trained as panelists for product testing, and all participants provided their consent by signing an Informed Consent Form.

Organoleptic testing was conducted using the 9-point hedonic scale, assessing attributes such as color, aroma, taste, and texture. Product samples were randomly presented to panelists with individual evaluation forms to avoid bias. Panelists rated each attribute from 1 (dislike extremely) to 9 (like extremely) in a controlled environment free from distractions and communication. Collected data were then analyzed statistically to identify significant differences in product preference. [9]. Nutrient content was analyzed using the "by difference" method for carbohydrates. Total fat content was determined by the Soxhlet extraction method (AOAC 2005). Protein analysis utilized the proximate method (AOAC 2005) [10]. Iron (Fe) content was analyzed using the ICP-OES 2021 (Inductively Coupled Plasma Optical Emission Spectrometry) method. Amino acid analysis of samples was performed using Ultra Performance Liquid Chromatography (UPLC) [11]. Data were processed using Microsoft Excel and IBM SPSS version 25. Data underwent initial coding, entry, and cleaning. Quantitative data were analyzed univariately and bivariately. Organoleptic data for the mackerel scad and tuna liver snack were categorized using a 9-point hedonic scale [9]. Results from the organoleptic tests were analyzed using the non-parametric Kruskal-Wallis Test ($p < 0.05$), as the data were not normally distributed [12]. Carbohydrate, fat, protein, and iron content data were converted into milligrams, grams, or Kcal per 100 grams of snack, as appropriate for the data type. Protein content in the snack was calculated as a percentage per 100 grams of snack and compared against BPOM standards [13]. Total iron (Fe) content in the


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mackerel scad and tuna liver snack was calculated as a percentage per 100 grams of snack and compared against BPOM standards [13].

## RESULT

This study involved 30 semi-trained panelists, all of whom were students who had successfully completed an advanced Food Technology course. The panel comprised 28 females and 2 males, with ages ranging from 17 to 18 years. The hedonic test results for color, aroma, texture, and taste attributes are presented in Figure 1.

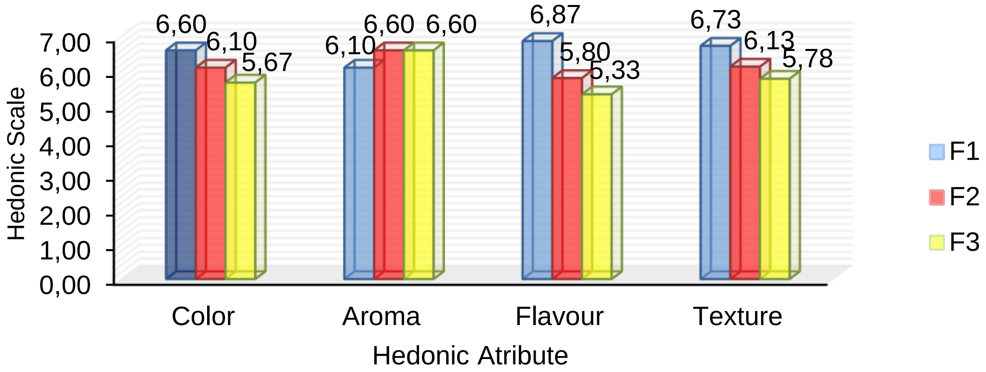


**Figure 1. Sensory Test Results for Color, Aroma, Taste, and Texture Attributes (F1: formula with tapioca flour, F2: formula with sago flour, and F3: formula with corn starch)**

Panelists' preferences for the color of mackerel scad (Decapterus sp) and tuna liver snacks differed across the three formulations: F1 (tapioca flour), F2 (sago flour), and F3 (corn starch). F1 received the highest rating, with 53.3% of panelists choosing "like" and an average score of 6.60 ± 0.95 SD. F2 showed more varied responses, including 30% "slightly like" and 3.3% "very much dislike," with an average of 6.10 ± 0.42 SD. F3 had 36.7% "like" and 26.7% "slightly like," averaging 5.69 ± 1.27 SD. Despite these differences, statistical analysis showed no significant variation in color across the three formulations, consistent with their visual similarity (Figure 2).


**Figure 2. Visual of Mackerel Scad *(Decapterus sp.)* and Tuna Liver Snacks (F1: formula with tapioca flour, F2: formula with sago flour, and F3: formula with corn starch)**

Panelist preferences for the **aroma** of mackerel scad (Decapterus sp.) and tuna liver snacks varied across formulations. In F1, 56.7% rated the aroma as "like," with an average score of 6.60 ± 0.95 SD. F2 showed a more even distribution, with 26.7% selecting "slightly like" or "neutral," and only 3.3% "very much dislike" (mean 6.60 ± 0.96 SD). In F3, "like" (36%) and "slightly like" (30%) were most common, with an average of 6.60 ± 1.42 SD.

For **taste**, F1 performed best, with 36.7% each choosing "like" and "very much like," and a mean of 6.87 ± 1.22 SD. F2 showed mixed responses, dominated by "neutral" and "slightly like" (26.7% each), averaging 5.80 ± 1.49 SD. F3 scored lowest, with 46.7% "slightly like" and a mean of 5.33 ± 1.53 SD.

Regarding **texture**, 40% of panelists rated F1 as "like," followed by 23.3% "slightly like," yielding a mean of 6.73 ± 1.23 SD. In F2, preferences were more spread, with "neutral" (30%) most common and a mean of 6.03 ± 1.21 SD. F3 was dominated by


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"slightly like" (43.3%) with a mean of 5.50 ± 1.16 SD. Overall, F1 (tapioca flour) consistently achieved the highest scores for aroma, taste, and texture, while F3 (corn starch) received the lowest.

**Table 1. Hedonic Characteristics of Mackerel Scad And Tuna Liver - Snack Formulations**

| Parameter | F1 | F2 | F3 | Mean±SD | *p* |
|---|---|---|---|---|---|
| Color | 6.60±0.95 | 6.10±1.42 | 5.67±1.27 | 6.12±1.21 | 0.203 |
| Aroma | 6.10±0.96 | 6.60±0.96 | 6.60±1.42 | 6.43±1.11 | 0.015* |
| Taste | 6.87±1.22 | 5.80±1.49 | 5.33±1.53 | 6.00±1.41 | 0.000* |
| Texture | 6.73±1.23 | 6.03±1.21 | 5.50±1.16 | 6.09±1.20 | 0.001* |
| Overall | 6.58±0.00 | 6.13±1.09 | 5.78±1.27 | 6.16±1.24 | |

Note: Values are presented as mean ± SD. *Indicates a significant difference based on the Kruskal-Wallis test ($p < 0.05$). F1: formula with tapioca flour, F2: formula with sago flour, and F3: formula with corn starch.

Table 1 shows that the overall mean sensory scores of mackerel scad (Decapterus sp.) and tuna liver snacks across formulations F1, F2, and F3 were 6.12 ± 1.21 for color, 6.43 ± 1.11 for aroma, 6.00 ± 1.41 for taste, and 6.09 ± 1.20 for texture. Statistical analysis revealed no significant difference in color preference ($p = 0.203$). In contrast, significant differences were observed for aroma ($p = 0.001$), taste ($p = 0.000$), and texture ($p = 0.015$), indicating variations in panelist preferences for these sensory attributes at $p < 0.05$.

**Table 2. Nutritional Composition of the Selected Snack Product (per 100 g)**

| Nutrient | Mean±SD |
|---|---|
| Ash Content (%/g) | 1.84±0.01 |
| Moisture Content (%/g) | 63.31±0.08 |
| Total Fat (%/g) | 7.64±0.04 |
| Carbohydrate (%/g) | 18.290.03 |
| Protein (%/g) | 18.69±0.32 |
| Energy (kcal/g) | 216.66±1.77 |
| Iron (mg/g) | 3.49±0.09 |

Note: Values are presented as mean ± SD. Selected fish-based snack = F1 (formula with tapioca).

Table 2 presents the nutritional analysis results, showing consistent nutrient composition across samples. Ash content was 1.84 ± 0.01%, moisture 63.31 ± 0.08%, fat calories 68.75 ± 0.40 kcal, total fat 7.64 ± 0.04%, total calories 216.66 ± 1.77 kcal, carbohydrates 18.29 ± 0.03%, protein 18.69 ± 0.32%, and iron 3.49 ± 0.09 mg per 100 g. These findings indicate stable and uniform nutritional values across all tested samples.

**Table 3. Essential Amino Acid Characteristics of Selected Fish-Based Snack 100 grams**

| Amino Acid | Mean±SD |
|---|---|
| L-Isoleucine (mg/gr) | 594,52±7.03 |
| L-Lysine (mg/gr) | 1068,93±31.25 |
| L-Valine (mg/gr) | 997,01±22.4 |

Note: Values are presented as mean ± SD. Selected fish-based snack = F1 (formula with tapioca).

Analysis of the essential amino acid profile for Formulation F1 was also conducted, with results presented in Table 3. The analysis of amino acid content in Table 3 shows significant variation among the tested amino acids. L-Lysine content was recorded at 1068,93 ± 31.25 milligrams per 100 grams. The recommended daily intake of the amino acid L-Lysine for 13-15 year-old adolescents is 12 milligrams / kilo grams of body weight. Based on an average ideal body weight of 50.7 kilo grams, their daily L-Lysine requirement is approximately 608.4 milligrams[14]. L-Valine had an average content of 997,01 ± 22.4 milligrams per 100 grams. The recommended daily intake of the amino acid L-Valine for adolescents aged 13-15 is 10 milligrams per kilo grams of body weight.


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Given an average ideal body weight of 50.7 kilo grams, their estimated daily requirement is 507 milligrams. While L-Isoleucine was the lowest, at 594,52± 7.03 milligrams per 100 grams. The recommended daily intake of the amino acid L-Isoleucine for adolescents aged 13-15 is 10 milligrams / kilo grams of body weight. Given an average ideal body weight of 50.7 kilo grams, their estimated daily requirement is approximately 507 milligrams[14]. To meet recommended nutritional needs, a 100-gram serving of this snack provides adequate support beyond staple foods, particularly in fulfilling the requirements for L-Lysine and L-Isoleucine. The L-Valine content, however, only meets 50.85% of the recommended amount.

## DISCUSSION

### Differences in Formula on Panelist Preferences for Sensory Attributes

The impact of tapioca and sago flour on the color of processed fish products depends on how the starch from these flours interacts with fish protein during cooking [15]. The sensory test results indicated an average color score of 6.10 ± 1.42 for Formulation F1 and 6.60 ± 0.95 for Formulation F2. Corn starch typically lacks natural pigments that would alter product color, tending to preserve the original white or pale hue of the fish [16]. However, the use of corn starch resulted in a lower average sensory score of 5.67 ± 1.27 compared to tapioca and sago flours. The resulting color of the dough from these three flours was primarily influenced by the fish meat and tuna liver. Each flour type possesses distinct properties that can affect the final color of processed fish products. The study on mackerel fish balls indicated that tapioca starch produced a more visually appealing and preferred color [17].

The use of tapioca, sago, and corn flours in processed fish products influences the final product's aroma. While these flours do not inherently possess strong aromas, they contribute to a more subtle aroma profile in processed fish, which can be further enhanced or modified by the cooking techniques employed [18]. This study's findings indicate that the use of tapioca, sago, and corn flours resulted in significantly different aromas ($p < 0.05$). Tapioca flour, derived from cassava starch, is notably neutral and nearly odorless. Snacks prepared with tapioca flour exhibited an aroma typical of fish balls in general, influenced by the seasonings, fish meat, and tuna liver used. Tapioca flour tends to impart a slightly sweet and light scent and does not significantly alter the fish's natural aroma when mixed [19]. The sensory evaluation for Formulation F1 showed that panelists generally liked the aroma, with an average score of 6.10 ± 0.96. Research on mackerel fish balls indicates that tapioca starch creates a stronger aroma of fish and spices due to its neutral properties [17].

The chemical composition, including starch, protein, fat, and fiber, influences food taste [20]. This study's findings indicate a significant difference in taste among the snack formulations using tapioca, sago, and corn flours. These flours play a more direct role in enhancing product texture, which, in turn, influences the overall taste perception of processed fish products [21]. Tapioca flour has a neutral taste, devoid of strong odors or flavors. Sensory evaluation for Formulation F1, which used tapioca flour, showed that panelists liked the taste of the snack, with an average sensory score of 6.87 ± 1.22. While not imparting a distinct flavor, tapioca flour contributes to a chewy and elastic texture [22]. The snack in Formulation F2, incorporating sago flour, had an average sensory score of 5.80 ± 1.49, which was lower than tapioca flour but higher than corn starch. Similar to tapioca, sago flour does not drastically alter the fish's taste but enriches the texture, making the product more palatable and chewy. Corn starch imparts a slightly more distinct flavor. This taste adds value to the fish product by providing a stronger savory note. Based on research on mackerel fish balls, the use of tapioca starch results in a more pronounced flavor of the fish and spices used [17].

Flour serves to provide texture in processed fish products [23]. This study's findings demonstrate that the use of tapioca, sago, and corn flours resulted in significantly


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different textures (p = 0.015). Tapioca flour contains approximately 85-90% amylopectin, higher than other flours [24]. Snacks in Formulation F1, which utilized tapioca flour, were well-liked by panelists, achieving an average sensory score of 6.73 ± 1.23. When used in fish dough, sago flour aids in binding ingredients and imparts a chewy texture to processed fish products [19]. Formulation F2, using sago flour, achieved an average sensory score of 6.03 ± 1.21 and was favored by panelists. The application of sago flour yields a smoother product [25]. Corn starch, however, has a different effect on the texture of processed fish products compared to tapioca and sago flours. Corn starch contains starch with a higher amylose content relative to amylopectin, resulting in a lighter texture. Based on research on mackerel fish balls, the use of tapioca starch results in a chewier texture[17].

The selected Formula 1 snack has acceptable organoleptic properties (color, aroma, taste, and texture) that were developed to increase the intake of fish-based protein. Based on panelist feedback, the snack is expected to be well-received by football academy students. This snack holds great promise for consumption, as it effectively helps meet protein and iron needs. Economically, its utilization is highly efficient for commercial ventures because it is made from low-cost, abundant raw materials. Given its status as a widely consumed snack, it can also be recommended for school meal programs. By using local food sources, it does not disrupt students' dietary habits.

**Selected Formula Macro and Micro Nutrient Content**

The ash content of the mackerel scad (Decapterus sp) and tuna liver snack averaged 1.84 ± 0.01% per 100 grams, which falls below the Indonesian National Standard (in Indonesia: *Standar Nasional Idonesia (SNI)*) for fish balls. Ash content indicates the mineral and inorganic matter in a food product; a lower ash content generally suggests better food quality [26]. Similarly, the moisture content analysis yielded an average of 63.31 ± 0.08% per 100 grams, also below the Indonesian National Standard for fish balls.

Carbohydrates are essential nutrients required by the body in larger quantities compared to other macronutrients. The carbohydrate content of formulation F1, which utilized tapioca flour, was 18.29% per 100 grams. The nutritional value of carbohydrates is derived from the ingredients used. When compared to catfish fish balls (a different type of fish-based snack) made with the same flour, the carbohydrate content was found to be similar [27]. In formulation F1, 40 grams of tapioca flour were used per snack recipe. To increase the carbohydrate content, the proportion of flour could be increased, as tapioca flour serves as a primary carbohydrate source [9]. The selection of tapioca flour was based on its favorable contributions to texture, taste, aroma, and color, which are key organoleptic components evaluated by panelists. Tapioca flour is commonly used as a base ingredient in dough preparation, influencing the texture, color, and taste characteristics of the final product.

While fat often carries a negative perception due to its association with increased risks of obesity and cardiovascular disease, healthy fats play an essential role in maintaining metabolic balance. Healthy fats, abundantly found in fish, offer numerous benefits to the body, particularly for young athletes during their growth phase. Analysis showed that formulation F1 contained 7.64% fat per 100 grams, making it a suitable option to complement a healthy diet. Fat provides longer-lasting energy compared to carbohydrates. The fat content in this snack is derived from mackerel scads, tuna liver, and eggs, which are primary ingredients [28]. When compared to catfish fish balls, the fat content of this snack was lower, a difference attributed to the primary ingredients used, as catfish inherently has a higher fat content than mackerel scads [27].

At this age, adolescents experience a period of rapid growth, which includes increased muscle mass, bone development, and other physical changes that necessitate sufficient protein intake [29]. The analysis of this snack revealed a protein content of 18.69% per 100 grams. The ingredients used in formulation F1, such as mackerel scad


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meat, eggs, and tuna liver, function as compact structural binders. These ingredients also act as emulsifiers, effectively binding water and fat to create a high-quality snack structure [27]. Beyond their binding properties, these ingredients significantly contribute to the snack's protein content. Fresh mackerel scad provides 22 grams of protein per 100 grams, tuna liver contributes 5.65 grams per 50 grams, and laying hen eggs offer 6.20 grams per 30 grams, all of which contribute significantly to the snack's nutritional content [30]. This protein content is derived from the various ingredients, and their combination not only provides nutritional value but also plays a crucial role in forming a compact and stable snack structure [31]. Furthermore, these ingredients serve as effective emulsifiers, adept at binding water and fat, thereby yielding a product with superior texture and appearance [27].

The raw materials in the snack, including mackerel scad meat, eggs, and tuna liver, significantly contribute to the snack's protein quality. Fresh mackerel scad, with approximately 22 grams of protein per 100 grams, is a primary contributor to the snack's protein levels. Laying hen eggs, containing 6.20 grams of protein per 30 grams, also boost protein content while adding tenderness to the product's texture. Tuna liver, providing 5.65 grams of protein per 50 grams, further enriches the snack's nutritional value with essential amino acids vital for bodily functions, particularly for cell growth and repair [32]. As a protein source, formulation F1 snacks contribute 34.18% of the total energy from protein, approaching the 35% requirement for "protein source food" as stipulated by the food and drug supervisory agency [13]. Even though the protein content of formulation F1 snacks doesn't quite reach 35%, it still qualifies as a valuable protein source. Despite the protein content of snack formula F1 not meeting 35%, it remains a valuable protein source. The protein content observed in mackerel scad fish meatballs enriched with tuna liver was higher when compared to mackerel fish meatballs supplemented with carrots, which yielded only 6.8 gram per 100 grams [33]. Only catfish fish balls, with a protein content of 21.57 grams per 100 grams, were able to surpass the protein value of the mackerel scad fish ball group [27].

The iron (Fe) content in this snack is 3.49 grams per 100 grams. The raw materials, including mackerel scad meat, eggs, and tuna liver, significantly contribute to the snack's iron quality. Fresh mackerel scad, containing approximately 2 milligrams of iron per 100 grams, provides a substantial contribution to the snack's iron levels. Laying hen eggs, with 3.0 milligrams of iron per 30 grams, also play a role in increasing the product's iron content. Additionally, tuna liver, which contains 0.45 milligrams of iron per 50 grams, along with the flours and seasonings used, contributes further to the snack's overall iron content. Based on calculations, this snack contributes over 15% of the Recommended Dietary Allowance (RDA) for iron, thus meeting the requirements for a "source of iron food," according to the standards set by the National Agency of Drug and Food Control [13]. While the iron content in this product doesn't exceed 30%, Formulation F1 can serve as a sufficient nutritional source to support balanced iron intake, supplementing staple foods to ensure adequate overall nutrition. The iron content of this snack is higher than that of mackerel fish balls fortified with moringa leaves, which contain only 0.0155 milligrams per 100 grams [34], However, it's lower than anchovy fish flour balls, which have 31.72 milligrams per 100 grams. [35].

The snack's nutritional content, especially its protein and iron, can be effectively utilized by the body. Protein is crucial for forming muscle cells and growth hormones, while iron is essential for synthesizing hemoglobin, which transports oxygen in red blood cells. Given its acceptable sensory profile and adequate nutrition, this snack is expected to promote increased nutrient intake, positively impacting nutritional status, body mass, hemoglobin levels, VO2max capacity, and physical fitness. The benefits of F1 snacks include contributing 26.7% of the protein and 29,08% of the iron required for the daily


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Recommended Dietary Allowance (RDA) of children aged 13-15. Interventions for school soccer players aged 13-15 can help meet dietary needs beyond staple foods.

**Selected Formula Amino Acid Content**

The L-Lysine content in the tested formulation F1 snack product was 1068,93 ± 31.25 milligrams per 100 grams. This figure indicates that the product contains a significant amount of this essential amino acid, which plays a vital role in various biological functions, including protein synthesis, growth, and tissue maintenance. The nutritional value of this snack product is highly influenced by its raw materials: mackerel scad meat, laying hen eggs, and tuna liver. These three ingredients are renowned for being rich in high-quality protein, which naturally contains essential amino acids like lysine [36]. Furthermore, laying hen eggs and tuna liver are complete animal protein sources, providing all the essential amino acids required by the body [37].

Isoleucine primarily functions in muscle maintenance and repair, and it plays a critical role in energy metabolism [38]. The measured isoleucine content in the formulation F1 snack was 594,52±7,03 milligrams per 100 grams. The L-Isoleucine content in the tested snack product is influenced by the raw materials used. Mackerel scad meat, laying hen eggs, and tuna liver are excellent sources of animal protein that naturally contain essential amino acids, including L-Isoleucine. Mackerel scad meat not only provides important amino acids [39], but laying hen eggs and tuna liver also significantly contribute to isoleucine provision, with additional nutritional benefits such as essential vitamins and minerals for the body [36].

Within the body, Valine has similar functions to isoleucine, primarily in repairing muscle tissue damaged by physical stress and enhancing muscle protein synthesis [40]. This amino acid aids in repairing damage incurred after intense physical activity, such as strenuous training or high-energy sports The valine content in the Formulation F1 snack was 997,01 ± 22.4 SD milligrams per 100 grams. This value indicates that Formulation F1 snacks contain essential amino acids crucial for meeting nutritional needs, particularly for bodies undergoing growth or recovery. The valine content composition in this product is significantly influenced by the raw materials used in its formulation. Mackerel scad meat, laying hen eggs, and tuna liver are primary sources of animal protein with high essential amino acid content [36]. These three raw materials are known for their complete amino acid profiles, enabling formulation F1 snacks to contribute to optimal nutritional adequacy.

A limitation of this study lies in the use of human panelists for snack quality testing, employing a hedonic scale. This approach results in subjective findings, based on the individual perceptions of each panelist. This research's strength is its development of a new snack product offering superior nutritional value, particularly as a good source of protein and iron. However, the study faced limitations because shelf-life testing, microbiological quality, and the consistency of nutrient content could not be performed due to restricted time. Direct organoleptic evaluation of this snack was not performed on football school children.

## CONCLUSIONS

This study found no significant difference in the color among snack formulations F1, F2, and F3. However, there were significant differences in the aroma, taste, and texture across these three formulations. Formulation F1, which incorporated mackerel scads (Decapterus sp) and tuna liver with tapioca flour, was recommended by panelists as the best option among the tested formulations. A 100-gram fish snack contains 18,69 grams (26.62% ) protein and 3,49 miligrams (29.08%) iron, which can help fulfill the daily Recommended Dietary Allowance (RDA) of 13-15-year-old football school children. Future research could explore the use of flours high in protein and calcium to further


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enhance the snack's amino acid and calcium content, potentially employing novel methods.

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