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Physicochemical and Sensory Evaluation of Novel Composite Flour System in *Saurida tumbil* Fishballs: Arrowroot (*Maranta arundinacea*) and Seaweed (*Eucheuma cottonii*) as Sustainable Tapiocal Alternative

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ABSTRACT

Diversification is a strategy to enhance the market value of rucah fish by expanding processed products, such as fish balls, to boost fish consumption. Substituting arrowroot flour (*Maranta arundinacea*) and *Eucheuma cottonii* flour aims to optimize the use of fish as a nutritious ingredient, offering a healthy, economical, and appealing alternative for food products or snacks. The purpose of this study is to determine the effect of tapioca flour substitution with arrowroot root flour and *E. cottonii* flour on the physical, chemical, and organoleptic characteristics of log fish meatballs. This study used a non-factorial complete random design (CRD), with 18 levels of treatment, namely: tapioca flour (A) 0, 22.5, and 30g; arrowroot root flour = (B) 15, 22.5, and 30g; *E.cottonii* flour = (C) 22.5 and 30g, with 3 repeats. The results showed that the substitution treatment of tapioca flour with arrowroot root flour and *E. cottonii* flour had a real effect (P<0.05) on all test parameters, except that the carbohydrate and fat levels did not show a real effect (P>0.05). This product was found with an average carbohydrate content at 27.07%, protein content at 10.44%, fat content at 2.20%, water content at 58.08%, ash content at 0.80%. It show that the fish meatballs produced have better nutritional content. According to the Indonesian National Standard (SNI) for fish meatballs, the quality requirements specify a maximum water content of 70%, a maximum ash content of 2%, and a minimum protein content of 7%. The analyzed product meets these standards, as its water and ash contents are below the maximum limits, while its protein content is well above the minimum requirement.

INTRODUCTION

Trash fish are small, low-value fish regularly treated as waste and primarily used in non-human products like animal feed. These by-catch species, including lizardfish (*Saurida tumbil* Bloch, 1795) is one type of fish that has a low selling price that is quite abundant **(Kholis *et al.*, 2023)**. Despite their rich nutritional value, inadequate utilization and handling result in waste and low market prices compare to other fish **(Zulfahmi *et al.*, 2021)**.

This fish is widely processed into surimi, salted fish, a mixture of dumplings and crackers because it is not a fish that is preferred to be consumed as a whole, because of its unattractive appearance and has many thorns **(Manurung *et al.*, 2024)**. One of the ways used in increasing the selling value of lizard fish is diversification of fishery product processing. Diversification of processed products aims to increase fish consumption by diversifying processed fishery products. One of the fishery diversifications is making fishball.

Fish meatballs are a valuable and nutritious fishery product made from processed fish patties combined with spices, flour, and additives, then shaped and boiled **(Hasni *et al.*, 2022)**. Stated that fish meatballs are rich in protein, minerals, and vitamins, widely popular as a ready-to-eat food **(Nugroho *et al.*, 2020)**. High-quality meatballs can be produced without chemical additives, using both primary and supplementary ingredients **(Hambali *et al.*, 2023)**. Arrowroot tubers (*Maranta arundinacea*) are potential alternatives to plant-based carbohydrate sources **(Melyandra *et al.*, 2024)** offering high productivity and nutritional value. They are low in glycemic index and they have a high nutritional content. Arrowroot tuber flour contains 81.97% carbohydrates, 26.37% amylose, 73.63% amylopectin, 6.14% protein, 0.63% fat, 6.76% dietary fiber, and 358 calories/100 g energy **(Noviardi *et al.*, 2020)**. This makes it an excelent product with potential for development innovation in processing **(Alifah, 2021; Al Zamzami *et al.*, 2025)**.

Eucheuma cottonii seaweed is a high value seaweed with a complete nutritional content, including water, protein, fat, crude fiber and ash. It contains enzymes, nucleic acids, amino acids, vitamins (A, B, C, D, E and K) and macro minerals and micro minerals. Seaweed flour can be used in meatballs to enrich food fiber and carageenan content, and its polysaccharides can reduce lipid and cholestrol levels, smooth digestion **(Hermanto *et al.*, 2024)**. Additionally, it regulates sugar intake, and potentially controlling diabetes **(Anggraiany *et al.*, 2024)**.

Fishballs made from *Saurida tumbil*, combined with arrowroot tuber flour (*Maranta arundinacea*) and *Eucheuma cottonii* seaweed flour, are developed to optimize the use of seafood as a high-nutritional-value ingredient. This product can serve as an attractive, healthy, and economical alternative snack.

MATERIALS AND METHODS

Chemicals

The ingredients used in making lizardfish meatballs are lizardfish fishmeat, tapioca flour, arrowroot tuber flour, Seaweed flour, shallots, garlic, pepper, salt, and sugar. Materials used for physical and chemical parameter tests included catalyst tablets, boiling stones, 4% boric acid solution, H_3BO_3, concentrated H_2SO_4, H_2O_2, sodium hydroxide-sodium thiosulfate solution, 0.2 N hydrochloric acid standard solution, chloroform, silica gel, water, Nitrogen, protease, HCI, amyloglucosidase, 78% and 95% ethanol, acetone.

Meatballs processing

The process of making lizardfish meatballs substituting tapioca flour with arrowroot tuber flour and seaweed flour in this study follows the method described by **Nugroho *et al.* (2020)**. Fresh lizardfish were separated into meat and spines. The cleaned meat was pulverized using a food processor for approximately 3 minutes. Ice cubes were added, and the mixture was ground again for another 3 minutes. Tapioca flour, arrowroot tuber flour, and seaweed flour were then added according to the formulation, and the mixture was ground until homogeneous. The resulting meatball dough was shaped into rounds and was boiled for approximately 15 minutes, or until the meatballs floated. The proportions of flours used in the formulation—tapioca flour, arrowroot tuber flour, and seaweed flour—are presented in Table (1).

Tabel 1. Formulation of flour comparison used in lizardfish meatballs with arrowroot root flour and seaweed flour

Treatment	Tapioca flour (g)	Arrowroot flour (g)	Seaweed flour (g)
A3B0C0	75	0	0
A0B1C1	0	15	22.5
A0B1C2	0	15	30
A0B2C1	0	22.5	22.5
A0B2C2	0	22.5	30
A0B3C1	0	30	22.5
A0B3C2	0	30	30
A1B1C1	22.5	15	22.5
A1B1C2	22.5	15	30
A1B2C1	22.5	22.5	22.5
A1B2C2	22.5	22.5	30
A1B3C1	22.5	30	22.5
A1B3C2	22.5	30	30
A2B1C1	30	15	22.5
A2B1C2	30	15	30
A2B2C1	30	22.5	22.5
A2B2C2	30	22.5	30
A2B3C1	30	30	22.5
A2B3C2	30	30	30

Meatballs quality test

Organoleptic testing was carried out referring to Indonesian National Standards (SNI 2346:2011). Organoleptic testing is a method of testing using human senses as the main tool for assessing the quality. The parameters assessed were appearance, aroma, texture and taste. Organoleptic tests were carried out to determine the level of accetance of lizardfish meatball product with substitution of tapioca flour by arrowroot tuber flour and seaweed flour. The panelists used in this research were untrained panelist with a total of 30 panelists. The organoleptic test used is the hedonic test. The hedonic test is the most widely used test to measure the level of liking for a product. The hedonic test uses a rating scale for the sample tested, namely 1 = really don't like; 2 = don't like; 3 = kinda don't like; 4 = neutral; 5 = kinda like; 6 = like; 7 = really like **(Herdiana & Widaputri, 2022)**.

Physiscal parameters analysis

Texture testing uses a texture analysis tool. The test procedure was initiated with cutting the Balak fish meatball sample into cubes measuring $2\times2\times2$ cm^3. Next, it was placed on the testing plate under the round probe (6mm thickness), the data cable from the texture analyzer was connected to the computer's CPU, followed by the step of turning on the computer. Then, the probe needle was inserted into the installed sample and adjusted it until it approaches the sample. A computer program was operated to run the probe. Before starting, it was ascertained that the value on the monitor was zero, then the start test menu on the computer was selected so that the probe moves to the Balak fish meatball sample. The test was complete when the probe returned to its original position. The test results were inserted in the form of graphs and numbers.

On the other hand, color testing uses a colorimeter tool. Color measurements are carried out using a colorimeter (Chromameter CR 400). Measurements are carried out by placing the sample in a container. The measuring head is positioned facing the sample, then the test button is pressed until it beeps and the light turns on. The results for the L, a, and b values are displayed on the chromameter. The L value represents the brightness parameter which ranges from 0 (black) to 100 (white). The a value represents the red-green axis, where negative (−a) indicates green and positive (+a) indicates red. The b value represents the blue-yellow axis, where positive (+b) indicates yellow and negative (−b) indicates blue. The results are then converted using the hue degree formula to determine the color hue of the sample: $Hue = \tan^{-1}(b/a)$.

Chemical analysis

Analysis of protein content uses the Kjeldahl method to measure protein levels **(AOAC, 2005)**. Protein levels were analyzed using the micro Kjeldahl method. The protein analysis stages were divided into three stages: digestion, distillation, and titration. The digestion stage began with weighing the sample at 0.2g. The sample was then put into a 100ml volumetric flask, and 10ml of concentrated H_2SO_4 with 2g of catalyst was added. The solution was digested until it became clear, and digestion was continued for 10 minutes. The cooled clear solution was diluted with 3ml of distilled water, then 5ml of 45% NaOH and a few drops of PP indicator were added and then distilled. The distillation results were collected in a 125ml Erlenmeyer flask containing 10ml of 2% boric acid (H_3BO_3) with indicators bromcresol green 0.1% and methyl red 0.1% at a ratio of 2:1. Titration was carried out using 0.01 N HCl until the color of the solution in the Erlenmeyer flask changed to pink.

Water content analysis uses the thermogravimetric method referring to the Indonesian National Standard (SNI 01-2354.1-2006). The principle of analyzing the water content of catfish meatballs using the thermogravimetric method is to evaporate the water contained in the food ingredients through heating, followed by weighing the ingredients until they reach a constant weight.

Analysis of fat content uses the Soxhlet method, referring to the Indonesian National Standard (SNI 01-2354.3-2006). First, the empty round-bottom flask was weighed, followed by weighing 2g of the ground sample that was then placed in a fat sleeve. 150ml of chloroform was added into the round-bottom flask and the fat cartridge was placed into the Soxhlet extractor, then extracted at a temperature of 60°C for 8 hours until the solvent became clear. Next, evaporation was carried out to separate the mixture of fat and solvent in the round-bottom flask, followed by drying in an oven at 105°C for approximately 2 hours. Then the outcome was cooled in a desiccator for 30 minutes and the round-bottom flask containing fat (C) was weighed.

Ash content analysis uses the gravimetric method, referring to the Indonesian National Standard (SNI 01-2354.3-2006). The first step is to put the empty porcelain cup into the ashing furnace, increasing the temperature to 550°C gradually over 8 hours. In the following step, the temperature was lowered to 40°C, and the cup was transferred to a desiccator for 30 minutes, and the empty porcelain cup (A) was weighed. 2g of the ground sample was prepared to be put it in the porcelain cup, then it was oven-dried at 100°C for 24 hours. Next, the crucible was moved to the ashing furnace with increasing the temperature to 550°C for 8 hours until the ash became white (B). After that, the temperature was lowered to 40°C; the porcelain cup was taken out, placed in a desiccator for 30 minutes and weighed again (B) after it cooled down. The ash content percentage was then calculated.

Analysis of carbohydrate content uses the by-difference method **(AOAC, 2005)**, namely the result of reducing 100% by the percentages of water, ash, protein, and fat contents, so that the carbohydrate content depends on the reduction factor. This is because carbohydrates have a significant influence on other nutrients. Carbohydrate levels can be calculated using the formula:
Carbohydrate content (%) = 100% − (Water + Ash + Protein + Fat)%.

The analysis of dietary fiber content was carried out following the procedure of **AOAC (1995)**. A 1g sample was weighed and placed in a 400ml beaker. Then, 50ml of phosphate buffer (pH 6) and 0.1ml of termamyl were added. The beaker was covered with aluminum foil and heated in a boiling water bath for 15 minutes, with shaking every 5 minutes, ensuring that the sample temperature reached 95–100°C. After heating, the sample was cooled to room temperature, and the pH was adjusted to 7.5 ± 0.2 by adding 10ml of 0.275 M NaOH solution. Subsequently, 5g of protease, 10ml of 0.325 M HCl, and 0.3ml of amyloglucosidase were added. The mixture was again covered with aluminum foil and incubated at 60°C for 30 minutes. After incubation, 280ml of 95% ethanol was added, and the mixture was filtered through a crucible coated with 0.1mg of celite mixed with 78% ethanol. The residue in the crucible was washed sequentially with 20ml of 78% ethanol three times, 10ml of 95% ethanol twice, and 10ml of acetone once. The residue was then dried in a vacuum oven at 70°C overnight or in a conventional oven at 105°C until a constant weight was achieved. The percentage of dietary fiber was calculated based on the final dry weight of the residue.

Data analysis

This study uses an experimental method, namely processing lizardfish meatballs with varying concentrations of tapioca flour, arrowroot flour, and *E. cottonii* flour. The design used was a non-factorial completely randomized design (CRD), with 18 levels of treatment: tapioca flour (A) at 0, 22.5, and 30g; arrowroot flour (B) at 15, 22.5, and 30g; and seaweed flour (C) at 22.5 and 30g. The study consisted of 3 replications, resulting in 54 experimental units. Data from organoleptic, chemical, and physical tests were analyzed for normality and homogeneity. If the data were normal and homogeneous, they were analyzed using analysis of variance (ANOVA). A *P*-value of less than 0.05 was considered significant **(Mickymaray *et al.*, 2021)**. If $P< 0.05$ indicated a significant difference at the 95% confidence level, the data were further analyzed using Duncan's multiple range test (DMRT) at a 5% significance level using the SPSS 26 program **(Ningsih & Sari, 2023)**.

RESULTS

Organoleptic quality

The results of orgnoleptic analysis of the parameters of Appearance, Aroma, Texture, Taste in log fish meatballs substitution tapioca flour with arrowroot root flour and *E.cottonii* flour can be seen in Table (2).

Tabel 2. The average organoleptic quality of lizardfish meatballs substituted with rowroot flour and seaweed flour with different levels

Treatment	Appearance	Aroma	Texture	Taste
A3B0C0	4.27 ± 0.25	4.48 ± 0.35	4.27 ± 0.25	3.76 ± 0.22
A0B1C1	4.84 ± 0.27	4.61 ± 0.40	4.84 ± 0.27	3.77 ± 027
A0B1C2	4.50 ± 0.36	4.51 ± 0.51	4.50 ± 0.36	3.53 ± 0.36
A0B2C1	5.13 ± 0.20	5.29 ± 0.31	5.13 ± 0.20	3.87 ± 0.25

A0B2C2	4.18 ± 0.23	4.32 ± 0.44	4.18 ± 0.23	3.76 ± 0.15
A0B3C1	4.48 ± 0.56	4.74 ± 0.45	4.48 ± 0.56	4.52 ± 0.20
A0B3C2	4.42 ± 0.37	4.27 ± 0.29	4.42 ± 0.37	4.14 ± 0.17
A1B1C1	4.89 ± 0.26	4.16 ± 0.14	4.89 ± 0.26	3.82 ± 0.10
A1B1C2	4.10 ± 0.15	4.23 ± 0.10	4.10 ± 0.15	3,78 ± 0.20
A1B2C1	5.46 ± 0.10	5.52 ± 0.15	5.46 ± 0.10	5.12 ± 0.15
A1B2C1	5.01 ± 0.17	4.90 ± 0.22	5.01 ± 0.17	4.47 ± 0.17
A1B3C1	4.33 ± 0.14	5.03 ± 0.20	4.33 ± 0.14	4.36 ± 0.24
A1B3C2	4.80 ± 0.19	4.40 ± 0.41	4.80 ± 0.19	3.81 ± 0.20
A2B1C1	4.48 ± 0.34	4.84 ± 0.27	4.48 ± 0.34	4.57 ± 0.24
A2B1C2	4.32 ± 0.30	4.81 ± 0.29	4.32 ± 0.30	4.21 ± 0.29
A2B2C1	4.74 ± 0.38	4.77 ± 0.41	4.74 ± 0.38	4.88 ± 0.12
A2B2C2	4.18 ± 0.40	4.73 ± 0.33	4.18 ± 0.40	4.68 ± 0.25
A2B3C1	4.42 ± 0.37	4.66 ± 0.14	4.42 ± 0.37	4,68 ± 0.23
A2B3C2	4.04 ± 0.16	4.14 ± 0.32	4.04 ± 0.16	3,98 ± 0.12

*Notes: Scale of score: 1 = really don’t like, 2 = don’t like, 3 = rarely don’t like, 4 = neutral, 5 = rarely like, 6 = like, 7 = really like.

Appearance affects consumer acceptance, although it does not absolutely determine the level of consumer preference. The uniformity and integrity of a product can attract panelists and increase preference compared to products that are irregular or not intact **(Rochima *et al.*, 2015)**. According to **Nurhuda *et al*. (2017)**, the appearance of good fish balls should be smooth, round, uniform in size, clean, bright, and not dull. The average hedonic value for the appearance parameter in the acceptance test of lizardfish meatballs with tapioca flour substituted with arrowroot tuber flour and seaweed flour is presented in Table (1).

Table (1) shows that the highest mean hedonic value for appearance was observed in the A1B2C1 treatment (tapioca flour 15g, arrowroot flour 22.5g, and seaweed flour 22.5g), with a score of 5.46 ± 0.10. The middle average value was found in the A0B3C1 treatment (tapioca flour 0g, arrowroot flour 30g, and seaweed flour 22.5g) with a score of 4.48 ± 0.56, while the lowest mean value for appearance was recorded in the A2B3C2 treatment (tapioca flour 30g, arrowroot flour 30g, and seaweed flour 30g) with a score of 4.04 ± 0.16. These results indicate that the substitution of 22.5g (30%) arrowroot flour made the lizardfish meatballs more preferred based on appearance, while remarkably the substitution of 22.5g (30%) *E. cottonii* seaweed flour produced the most preferred sample in terms of appearance. However, increasing the amount of seaweed flour tended to make the lizardfish meatballs appear darker and less preferred by panelists.

The level of brightness is influenced by the addition of *E. cottonii* seaweed flour, which contains carrageenan, a complex mixture of several polysaccharides **(Winarno, 1996)**. When exposed to heat, carrageenan can cause darkening in color. Protein denaturation during processing is not only caused by heating but is also influenced by the addition of salt. In this study, a salt concentration of 2.5% was used. High salt concentrations can denature lizardfish protein, resulting in a darker color. Salt can promote lysis (release of cell fluid), which leads to protein denaturation.

Aroma can be defined as an attribute perceived through the sense of smell. Aroma plays an important role in food products because it strongly influences consumer acceptance **(Yadav *et al*., 2024)**. The average hedonic values for the aroma parameter in the acceptance test of lizardfish meatballs with the substitution of arrowroot flour and *E. cottonii* seaweed flour are presented in Table (1).

Table (1) shows that the highest mean hedonic value for aroma was obtained in the A1B2C1 treatment (15g tapioca, 22.5g arrowroot flour, and 22.5g *E. cottonii* flour), with a value of 5.52 ± 0.15. The middle value was found in the A2B3C1 treatment (22.5g tapioca, 30g arrowroot flour, and 22.5g seaweed flour), with a score of 4.66 ± 0.14, and the lowest value was observed in the A2B3C2 treatment (30g tapioca, 30g arrowroot flour, and 30g seaweed flour), with a score of 4.14 ± 0.32. These results show that panelists preferred the aroma of lizardfish meatballs from the A1B2C1 treatment (22.5g arrowroot flour and 22.5g seaweed flour), whereas the A2B3C2 sample was the least preferred.

At this concentration, the fishy odor of the meatballs could still be masked by the aroma of seasonings such as garlic, shallots, and white pepper. Differences in panelists' preferences affected the hedonic scores for aroma. The use of arrowroot flour did not cause a significant change in aroma, while the use of *E. cottonii* seaweed flour led to a less preferred aroma. This was likely due to the distinctive seaweed odor masking other ingredients. **Nadia *et al*. (2023)** also reported that the addition of *E. cottonii* flour affected the aroma of tuna jerky, where higher concentrations of seaweed flour produced a stronger seaweed aroma and reduced the fish aroma. The organoleptic test results showed that tuna jerky with 2.5% seaweed flour had the most preferred aroma, as the seaweed scent was mild and not overpowering.

Texture is a characteristic of food that results from the combination of several physical properties, including size, shape, structure, and composition, which can be perceived by the senses of touch, taste, and sight. Texture evaluation was conducted by pressing the surface of the meatballs to assess compactness, elasticity, and density. Texture is sometimes more important than aroma, taste, or color because it strongly affects consumer perception of food. Good fish meatballs should be compact, elastic, not sticky or lumpy, free from thorns or bones, not mushy, watery, or brittle **(Nazilah *et al*., 2023)**. The average hedonic values for texture in lizardfish meatballs substituted with tapioca, arrowroot, and *E. cottonii* flours are presented in Fig. (3).

Table (1) shows that the highest average hedonic texture value was observed in the A1B2C1 treatment (22.5g tapioca, 22.5g arrowroot flour, 22.5g seaweed flour), with a score of 5.46 ± 0.10. The middle value was found in A2B2C2 (30g tapioca, 22.5g arrowroot flour, 30g seaweed flour), while the lowest value was recorded in A3B0C0 (control), with a score of 4.27 ± 0.25. The substitution of *E. cottonii* seaweed flour significantly affected the texture of the meatballs. *E. cottonii* seaweed flour contains carrageenan, which interacts with charged macromolecules such as proteins, thereby increasing viscosity, promoting gel formation, and improving texture stability. However, excessive carrageenan addition can make the texture too hard. Gel formation by carrageenan occurs through cross-linking of polymer chains, forming a strong three-dimensional network. Therefore, excessive addition may produce an overly firm gel, resulting in an undesirable hard texture **(Widati *et al.*, 2021)**.

In the A2B3C2 sample (30% tapioca, 30% arrowroot flour, and 30% *E. cottonii* seaweed flour), the lowest texture preference was observed. This may be due to the increased compactness, density, and elasticity caused by higher flour content. This finding aligns with **Widati *et al.* (2021)**, who stated that the more flour added, the more water interacts with it, resulting in a harder texture.

Taste is one of the most important parameters determining consumer acceptance of a product. Even if other attributes such as appearance and texture are good, a product will be rejected if the taste is not acceptable. The taste assessment was conducted by tasting the meatballs and evaluating their flavor profile. Good fish meatballs should have a dominant fish flavor corresponding to the species used, complemented by well-balanced spices without excessive saltiness or any off-flavor **(Yendro & Widyaningrum, 2023)**. The average hedonic values for taste in lizardfish meatballs with the substitution of tapioca, arrowroot, and seaweed flours are shown in Table (1).

Table (1) shows that the highest mean hedonic taste score was obtained in the A1B2C1 treatment (22.5g tapioca, 22.5g arrowroot flour, and 22.5g seaweed flour), with a value of 5.12 ± 0.15. The intermediate score was recorded in A0B3C2 (0 g tapioca, 30 g arrowroot flour, and 30 g seaweed flour) with a value of 4.14 ± 0.17, and the lowest score was observed in A0B1C2 (0g tapioca, 15g arrowroot flour, and 30g seaweed flour) with a value of 3.53 ± 0.36. These results indicate that the panelists preferred the taste of Lizardfish meatballs from the A1B2C1 treatment. The pleasant flavor is thought to result from the protein content in the fish meatballs, which during boiling undergoes hydrolysis to produce amino acids such as glutamic acid that enhance umami taste **(Octafiani *et al.*, 2023)**.

Consumers typically evaluate taste first when deciding whether a product is acceptable. Good flavor attracts consumer attention and plays a major role in determining food preference. However, taste perception is complex because it varies among individuals. In general, taste can be categorized as salty, sweet, bitter, or spicy, and it is one of the main determinants of food quality **(Chen *et al*., 2023)**.

Physical quality – Color

The color test was conducted using a colorimeter to measure the color parameters of lizardfish meatballs. The samples were placed in transparent plastic Petri plates with a diameter of 9cm, and measurements were performed directly in those plates. The *a* value indicates redness or greenness, the *b* value indicates yellowness or blueness, and the *L* value indicates brightness, ranging from 0 (black) to 100 (white) **(Altan *et al.*, 2023)**.

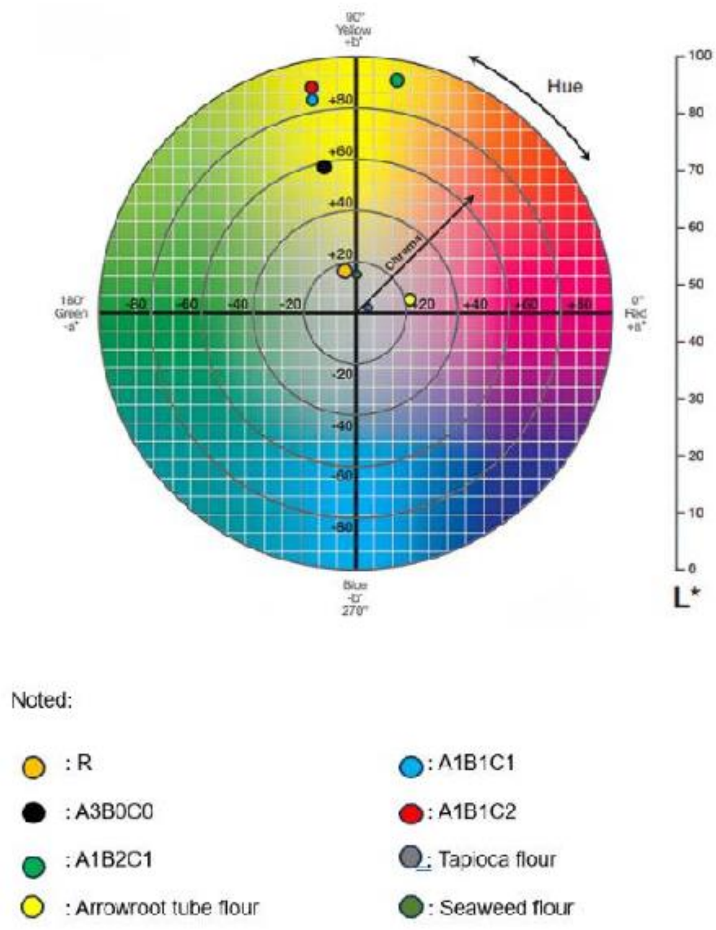

Fig. 1. Color values chart of lizardfish meatballs

Based on the color values chart in Fig. (1), it is known that the best treatment A1B2C1 (substitution of tapioca flour 22.5g, arrowroot tuber flour 22.5g, and seaweed flour 22.5g) has a yellowish red color indicated by a green dot to the right of the line b on the Color values chart. While the other 4 samples of balak fish meatballs, namely treatment (R, A3B0C0, A1B1C1, and A1B1C2) have a yellowish green color indicated by a dot on the left of line b on the Colour values chart. The color difference in the A1B2C1 treatment sample is influenced by the addition of arrowroot tuber flour which is more than the other treatments. The results of the arrowroot tuber flour color test show that arrowroot tuber flour has an a * value of 15.52 and * b of 2.66 when viewed on the color values chart, it can be seen that arrowroot tuber flour has a color that is closest to red compared to tapioca flour and seaweed flour.

The a value expresses the chromatic color of red-green mixtures with +a (positive) values for red and -a (negative) values for green. The notation b denotes the chromatic color of a blue-yellow mixture with a +b (positive) value for yellow and a b (negative) value for blue. Lightness or L- value indicates the brightness of a product **(Ly *et al.*, 2020)**. The greater the L- value of a product, the brighter the color. The range of values is from 0 (black) to 100 (white) **(Milovanovic *et al.*, 2020)**. The greater the lightness value (closer to 100) means the brighter the appearance of the product while the smaller the lightness value (closer to 0) indicates the darker the appearance of the product.

Chewness

The results of the chewiness analysis of lizardfish meatballs on protein conten can be seen in the Fig. (6).

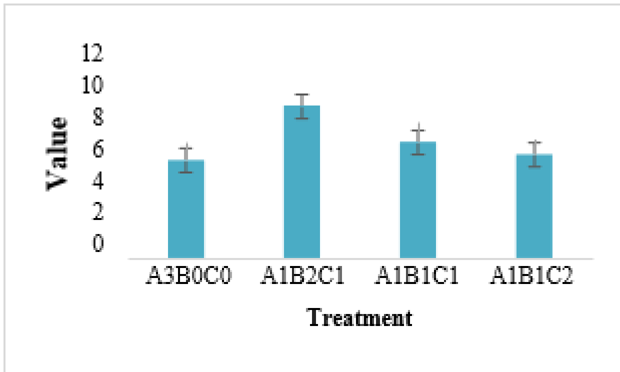

Fig. 2. Graph of test of the chewiness value of *Saurida tumbil* fish meatballs with substitution of tapioca flour with arrowroot tuber flour and seaweed flour

The results of the ANOVA test of the level of elasticity of *Saurida tumbil* fishmeatballs with the substitution of tapioca flour with arrowroot tuber flour and *E.cottonii* flour in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) are significantly different (P>0.05) from the negative control treatment (A3B0C0). Thus, it can be concluded that the substitution of tapioca flour with arrowroot tuber flour and *E.cottonii* flour has a significant effect on the elasticity of the balak fish meatballs produced.

In this study, the average elasticity value of *Saurida tumbil* fishmeatballs ranged from 6.22 - 9.71 with the highest elasticity value in the A1B2C1 treatment (best reatment) of 9.71 and the lowest elasticity value in the A3B0C0 treatment (negative control) of 6.22. The addition of *E.cottonii* seaweed flour substitution concentration which has carrageenan content plays a role in increasing the elasticity value of the balak fish meatball products produced. This is in accordance with the statement of **Nurhayati *et al.* (2024)**, the higher the concentration of carrageenan use, the higher the chewiness of Tuna meatballs because carrageenan is able to form a chewy texture due to the formation of a three-dimensional mesh after heating. However, the substitution of *E.cottonii* seaweed flour with too high aconcentration can result in a harder and brittle texture. This is in line with the statement of **Djamaluddin *et al.* (2024)**, who clarified that the addition of

E.cottonii flour with a higher concentration will cause the texture to become harder and brittle, and will cause the jerky to be disliked by panelists.

Chemical quality

The results of the proximate analysis of lizardfish meatballs with substitution tapioca flour by arrowroot tuber flour and seaweed flour can be seen in the Table (3).

Tabel 3. The average chemical quality of lizarfish meatballs substituted with arrowroot flour and seaweed flour with different levels

Treatment	A3B0C0	A1B2C1	A1B1C1	A1B1C2
Carbohydrate	$28.03 \pm 0.40^{*a}$	$28.53 \pm 1.29^{*a}$	$27.41 \pm 0.57^{*a}$	$28.37 \pm 0.35^{*a}$
Protein	$8.53 \pm 0.20^{*a}$	$11.07 \pm 0.15^{*b}$	$9.28 \pm 0.35^{*c}$	$12.88 \pm 0.41^{*d}$
Fat	$2.11 \pm 0.15^{*a}$	$2 \pm 0.17^{*a}$	$2.27 \pm 0.16^{*a}$	$2.43 \pm 0.20^{*a}$
Water	$59.34 \pm 0.66^{*c}$	$54.66 \pm 1.20^{*a}$	$57.77 \pm 0.47^{*b}$	$60.55 \pm 0.76^{*c}$
Ash	$0.96 \pm 0.15^{*b}$	$0.54 \pm 0.09^{*a}$	$0.57 \pm 0.15^{*a}$	$1.15 \pm 0.20^{*b}$
Fiber	$0.5 \pm 0.19^{*a}$	$2.11 \pm 0.11^{*b}$	$3.3 \pm 0.22^{*c}$	$5.29 \pm 0.15^{*c}$

^{*a},^{*b}, ^{*c}, ^{*d} Different superscripts in the same row indicate significant differences at *P*>0.05.

The results of the proximate analysis of lizardfish meatballs for protein content can be seen in Table (3). Based on the results of proximate testing of the protein parameter in lizardfish meatball samples with the substitution of tapioca flour with arrowroot tuber flour and seaweed flour, the negative control treatment (A3B0C0) had a protein content of 8.53%, the best treatment (A1B2C1) had 11.07%, the middle treatment (A1B1C1) had 9.28%, and the highest protein content was found in the A1B1C2 treatment with 12.88%. The ANOVA results showed that the protein content of lizardfish meatballs with tapioca flour substituted by arrowroot tuber flour and seaweed flour in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) differed significantly (*P*<0.05).

Based on Table (3), the average protein content of lizardfish meatballs with the substitution of tapioca, arrowroot, and seaweed flours was 10.44%. The treatment with 22.5g tapioca, 15g arrowroot flour, and 30g seaweed flour produced the highest average value, while the lowest protein content was found in the negative control treatment (A3B0C0) with 75g tapioca, 0g arrowroot flour, and 0g seaweed flour. This indicates that the substitution of arrowroot and seaweed flours significantly affected the protein content of the resulting lizardfish meatballs. This finding is consistent with that of **Tarigan (2020)**, who reported that increasing seaweed concentration in fish meatballs can raise protein content. This is due to the carrageenan in *Eucheuma cottonii* seaweed, which contains numerous sulfate groups. These groups enhance the ability to neutralize protein charges, thereby improving protein binding. Furthermore, the carrageenan in *E. cottonii* functions as a water binder, minimizing protein loss during processing. According to SNI 01-7266-2014, the minimum protein content in fish meatballs is 7%. Therefore, the lizardfish meatballs produced in this study, with an average protein content above 7%, meet the SNI standard.

The results of the proximate analysis of lizardfish meatballs for fat content are presented in Table (2). Based on the proximate test results for the fat parameter, the negative control treatment (A3B0C0) had 2.11%, the best treatment (A1B2C1) had 2.00%, the middle treatment (A1B1C1) had 2.27%, and the highest fat content was found in the A1B1C2 treatment at 2.43%. The ANOVA test results for fat content showed no significant differences (P>0.05) between the selected treatments (A1B2C1, A1B1C1, and A1B1C2) and the negative control (A3B0C0). Therefore, no further test was required, and it can be concluded that the substitution of tapioca flour with arrowroot tuber flour and seaweed flour did not significantly affect the fat content of the lizardfish meatballs produced.

The variation in fat content among treatments is influenced by the fat levels of the raw ingredients. According to **Nurhayati *et al.* (2024)**, different food ingredients contain different amounts of fat. Higher-fat raw materials yield products with higher fat contents. The low fat content in the A1B2C1 treatment is due to the higher substitution of arrowroot tuber flour, which has a fat content of only 0.53%, compared to tapioca flour (3.39%) and seaweed flour (0.88%). This agrees with **Khalimi *et al.* (2023)**, who stated that tubers generally contain very low fat percentages.

The results of the proximate analysis of Lizardfish meatballs for water content are presented in Table (2). The ANOVA test showed that water content in lizardfish meatballs with tapioca flour substituted by arrowroot tuber flour and seaweed flour in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) was significantly different (P<0.05) from the negative control (A3B0C0). This indicates that the substitution of tapioca flour with arrowroot and seaweed flours significantly affected the water content of the lizardfish meatballs produced.

The Duncan multiple range test (DMRT) results showed that the water content of the A1B2C1 treatment differed significantly from A1B1C1, A3B0C0 (negative control), and A1B1C2 treatments. The A1B1C1 treatment also differed significantly from A3B0C0 and A1B1C2. Based on the test results, the highest water content was observed in the A1B1C2 treatment (60.55%), followed by A3B0C0 (59.34%), A1B1C1 (57.77%), and A1B2C1 (54.66%) as the lowest.

The findings indicate that the water content of lizardfish meatballs increased with higher concentrations of *E. cottonii* seaweed flour substitution. This agrees with **Tarigan (2020)**, who reported that the water content of snapper meatballs increased with greater *E. cottonii* addition due to its naturally high water content. Moreover, *E. cottonii* seaweed has strong water-binding properties, contributing additional moisture to the product. Similarly, **Saloko *et al*. (2024)** found that increasing *E. cottonii* concentrations raised the water content of fish-based products.

The results of the proximate analysis of lizardfish meatballs for ash content are shown in Table (2). The ANOVA test results revealed that ash content in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) differed significantly ($P<0.05$) from the negative control (A3B0C0). Thus, the substitution of tapioca flour with arrowroot and seaweed flours significantly influenced the ash content of the meatballs.

The DMRT results indicated that the ash content in the A1B2C1 (best treatment) and A1B1C1 (middle treatment) samples differed significantly from the A3B0C0 (negative control), while A1B1C2 (worst treatment) did not differ significantly from the control. The A1B1C2 treatment had the highest ash content (1.15%), followed by A3B0C0 (0.96%), A1B1C1 (0.57%), and A1B2C1 (0.54%). The increase in ash content with higher *E. cottonii* concentrations may be attributed to its carrageenan content, which contains mineral salts. This is consistent with the outcome of **Asikin *et al.* (2023)**, who reported that higher carrageenan concentrations increased the ash content of the barracuda fish meatballs. Similar findings were also reported by **Tarigan (2020)** and **Sukoso *et al.* (2025)**, who found that seaweed addition increased ash levels in snapper meatballs due to the minerals present in seaweed.

The results of the proximate analysis of lizardfish meatballs for carbohydrate content are presented in Table (2). Based on the results, the carbohydrate content in the negative control treatment (A3B0C0) was 28.03%; the best treatment (A1B2C1) was 28.53%; the middle treatment (A1B1C1) was 27.37%; and the A1B1C2 treatment was 28.37%. The ANOVA results showed that the carbohydrate content in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) did not differ significantly ($P>0.05$) from the negative control (A3B0C0). Therefore, no further test was conducted. It can be concluded that substituting tapioca flour with arrowroot tuber flour and seaweed flour did not significantly affect the carbohydrate content of the lizardfish meatballs.

The carbohydrate content in these meatballs originates from the addition of tapioca, arrowroot, and seaweed flours, as well as other ingredients such as spices. This agrees with **Chan *et al*. (2023)**, who noted that the carbohydrate contribution in food formulations is influenced by added ingredients containing carbohydrates. Additionally, the carbohydrate level calculated by difference can vary depending on the levels of other proximate components such as fat, protein, fiber, water, and ash **(Hidayat & Insafitri, 2021; Ismail *et al.*, 2025)**. If other nutrient components have higher values, the carbohydrate value decreases, and vice versa.

The results of the proximate analysis of the lizardfish meatballs for fiber content are presented in Table (2). The ANOVA test results showed that fiber content in the lizardfish meatballs with tapioca flour substituted by arrowroot tuber flour and *E. cottonii* seaweed flour in the selected treatments (A1B2C1, A1B1C1, and A1B1C2) was significantly different ($P<0.05$) from the negative control (A3B0C0). Thus, it can be concluded that the substitution of tapioca flour with arrowroot and *E. cottonii* seaweed flour significantly affected the fiber content of the resulting lizardfish meatballs.

The DMRT results showed that the fiber content in A1B2C1 (best treatment), A1B1C1 (middle treatment), and A1B1C2 (worst treatment) differed significantly from the A3B0C0 control. The highest fiber content was found in A1B1C2 (5.29%), followed by A1B1C1 (3.3%), A1B2C1 (2.11%), and A3B0C0 (control). Increasing the concentration of *E. cottonii* seaweed flour in the formulation increased the fiber content of the lizardfish meatballs. This supports **Yudiastuti *et al*. (2022)**, who stated that higher seaweed concentrations lead to greater dietary fiber content.

The increase in fiber content is attributed to the naturally high fiber content of *E. cottonii* seaweed flour, which contains approximately 28.93% fiber. Seaweed is rich in polysaccharides such as carrageenan, most of which are indigestible fibers. Dietary fiber comprises various components including polysaccharides, oligosaccharides, and lignin derived from plant cell walls **(An *et al.*, 2022; Mas'ud *et al.*, 2025)**.

CONCLUSION

The conclusions obtained in this research are as follows: Based on the hedonic organoleptic tests for appearance, aroma, texture, and taste parameters, there was a significant difference (P<0.05) between the negative control treatment (A3B0C0) and all treatments in which tapioca flour was substituted with arrowroot tuber flour and *E. cottonii* flour. Based on the results of the physical tests, the color and elasticity parameters also showed significant differences (P<0.05) between the control treatment (R) and the negative control (A3B0C0) compared with the selected treatments A1B2C1, A1B1C1, and A1B1C2. The results of the proximate and fiber analyses indicated that there were significant differences (P<0.05) between the selected treatments (A1B2C1, A1B1C1, and A1B1C2) and the negative control (A3B0C0) for protein, moisture, ash, and dietary fiber contents. However, there were no significant differences (P>0.05) in carbohydrate and fat contents. These results show that the A1B1C2 treatment (containing 22.5g tapioca flour, 15g arrowroot tuber flour, and 30g *E. cottonii* flour) produced the best nutritional composition, with carbohydrate content of 28.37%, protein 12.88%, fat 2.43%, moisture 60.55%, ash 1.15%, and dietary fiber 5.25%.

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