 https://doi.org/10.1051/bioconf/202517102018

Physicochemical properties and sensory evaluation of Lizardfish (*Saurida tumbil*) nuggets with purple sweet potato flour substitution

Sukoso[1*], *Novaldo Yuri* Muhammad[1], *Hartati* Kartikaningsih[1], Yahya[1] and Nurul *Huda*[1,2]

[1]Faculty of Fisheries and Marine Science, Universitas Brawijaya, Malang, 65145, East Java, Indonesia

[2]Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, Sandakan 90509, Sabah, Malaysia

Abstract. This study investigated the impact of purple sweet potato Ipomoea batatas var. purpurea flour substitution on gluten reduction and physicochemical properties of lizardfish (*Saurida tumbil*) nuggets. The research employed a completely randomized design (CRD) with seven treatment levels representing different ratios of I. batatas var. purpurea flour to wheat flour (w/w): 0:100 (P1), 10:90 (P2), 20:80 (P3), 30:70 (P4), 40:60 (P5), 50:50 (P6), and 60:40 (P7), with three replications per treatment. Sensory evaluation (n=30) and physicochemical analyses were conducted to assess product quality. The physicochemical parameters included proximate composition (moisture, ash, protein, fat, and carbohydrate content), gluten content, textural properties, and colorimetric measurements. Data were subjected to analysis of variance (ANOVA) followed by Tukey's post-hoc test ($p < 0.05$). The de Garmo optimization method was utilized to determine the optimal formulation. The results demonstrated that I. batatas var. purpurea flour substitution significantly influenced all evaluated parameters. While the control treatment (P1) exhibited optimal characteristics, formulations with 30% (P4) and 60% (P7) substitution levels also met the Indonesian National Standard (SNI) requirements, suggesting potential commercial viability.

1 Introduction

Nugget filling is a composite mixture of ground meat, seasonings, and binding agents, primarily flour, which serves as the core component prior to breadcrumb coating in nugget production. Comparative studies have demonstrated varying protein contents across different protein sources in nugget formulations: poultry-based nuggets exhibit protein levels of 12.60%, while fish-based variants demonstrate higher protein content at 18.93% [1]. This variation in primary protein sources significantly influences both the proximate composition

* Correspondent author: alislah@ub.ac.id

and sensory characteristics of the final product. This presents an opportunity to explore alternative protein sources, particularly those from underutilized fish species.

Lizardfish (*Saurida tumbil*), despite its classification as a low-value species in commercial fisheries, represents an underutilized protein source in Southeast Asian waters. The limited economic value of the species in the region is primarily attributed to its morphological characteristics and high susceptibility to postharvest deterioration. Post-harvest handling deficiencies often accelerate quality degradation, while high catch volumes coupled with low consumer demand in Indonesia have resulted in underutilization of this species. However, *S. tumbil* demonstrates significant nutritional potential with a protein content of 17.15% suggesting opportunities for value-added product development [2].

Conventional nugget formulations typically incorporate wheat flour as a binding agent. However, wheat flour contains gluten proteins that can trigger adverse immunological responses in individuals with celiac disease, an autoimmune disorder characterized by gluten sensitivity. This necessitates the exploration of alternative binding agents, particularly from indigenous food sources, that exhibit functional properties comparable to wheat flour. Ipomoea batatas var. purpurea flour emerges as a promising alternative, demonstrating comparable carbohydrate and caloric profiles to wheat flour [3]. Beyond its basic nutritional composition, *I. batatas* var. purpurea flour contains significant concentrations of anthocyanins, water-soluble pigments belonging to the flavonoid class of compounds. These bioactive compounds, responsible for the characteristic purple pigmentation, demonstrate multiple physiological benefits including antitumor properties, enhancement of cognitive function, and significant antioxidant activity through free radical scavenging mechanisms.

Previous studies have not specifically evaluated the impact of purple sweet I. batatas var. purpurea potato flour substitution on *Saurida tumbil* fish-based nuggets. This research aims to: (1) evaluate the efficacy of I. batatas var. purpurea flour substitution in reducing gluten content in the final product, (2) assess the impact of varying substitution levels on physicochemical properties including proximate composition, gluten content, and physical characteristics, as well as sensory attributes of *Saurida tumbil* nuggets, and (3) determine the optimal substitution concentration for product development.

2 Materials and methods

2.1 Materials

Primary ingredients include Lizard fish meat (size 400 – 500 g), purple sweet potato flour, wheat flour, eggs, sugar, garlic, salt, black pepper, corn oil, milk powder, MSG, and deionized water.

2.2 Preparation of fish nugget

Sample Preparation Protocol for *Saurida tumbil*-Based Nugget Matrix incorporating *Saurida tumbil* and *Ipomoea batatas* flour for making nugget filling follows Herdiana *et al.* [4] with adjustments. Cooking conducted at temperature 100 - 120 ^{o}C for 10 – 15 minutes. The experimental treatments consisted of varying ratios (w/w) of Ipomoea batatas var. purpurea flour to wheat flour: P1 (0:100, control), P2 (10:90), P3 (20:80), P4 (30:70), P5 (40:60), P6 (50:50), and P7 (60:40).

2.3 Sensory evaluation

A quantitative descriptive analysis was conducted using a five-point hedonic scale (Scale 1 = Very dislike, 2 = Dislike, 3 = Neutral, 4 = Like, 5 = Very like). Sensory attributes evaluated included visual appearance, aroma, taste, and textural characteristics. The evaluation was performed by trained panellists (n = 30) in individual booths under controlled environmental conditions.

2.4 Proximate composition and gluten analysis

Proximate composition analysis was performed according to the Indonesian National Standards (SNI) 2354 to determine moisture content, total ash, crude protein (N × 6.25), crude fat (lipid content), and total carbohydrates by difference. Proximate and gluten analysis were conducted in Nutrition Laboratory, Brawijaya University.

2.5 Textural properties

Textural properties were evaluated using a texture analyzer (*Brookfield*) equipped with a cylindrical probe (TA 44 stainless steel). The maximum force required for deformation was measured and recorded by the instrument's data acquisition system, with force values expressed in newtons (N).

2.6 Colorimetric analysis

Colorimetric analysis was performed using the CIELAB color space system (also known as L*a*b*), measured with a calibrated chromameter colorimeter (Portable Colorimeter CTI-10 with 8mm aperture). The L* parameter quantifies lightness on a scale from 0 (black) to 100 (white). The a* coordinate represents the red-green axis, where positive values indicate redness and negative values indicate greenness. The b* coordinate represents the yellow-blue axis, where positive values indicate yellowness and negative values indicate blueness. The hue angle (h°) was calculated from the chromatic coordinates using the equation:

$$h° = \tan^{-1}(b^*/a^*) \quad (1)$$

where h° represents the angular displacement from the +a* axis in the CIELAB color space."

2.7 Yield analysis

Product yield represents the ratio of actual output mass to theoretical input mass, expressed as a percentage. A higher yield coefficient correlates directly with increased product conversion efficiency. The yield (η) is calculated using the following mass-based stoichiometric relationship:

$$\eta = (mf/mi) \times 100\% \quad (2)$$

Where:

- η = yield percentage (%)
- mf = final mass of product (units of mass)
- mi = initial mass of reactants (units of mass)

2.8 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (Version 22.0). The study employed a Completely Randomized Design (CRD). Prior to analysis, data were tested for normality using the Shapiro-Wilk test and homogeneity of variance using Levene's test. For variables meeting both assumptions ($p > 0.05$), one-way Analysis of Variance (ANOVA) was conducted, followed by Tukey's Honest Significant Difference (HSD) post-hoc test for multiple comparisons. For variables violating either assumption ($p < 0.05$), the non-parametric Kruskal-Wallis H test was performed, with subsequent Dunn's test for pairwise comparisons with Bonferroni correction. The relationship between mocaf flour substitution levels and measured parameters was assessed using regression analysis, with the coefficient of determination (R^2) calculated to quantify the strength of these associations. Product optimization was conducted using the De Garmo weighted attribute index method to identify the most preferred formulation based on multiple sensory and physicochemical parameters.

3 Result and discussion

3.1 Sensory analysis

Sensory analysis with a hedonic test aims to determine the panelists' level of preference for the filling of Lizard fish nuggets (*Saurida tumbil*) with the substitution of purple sweet potato flour. The results of the hedonic organoleptic test analysis can be seen in Table 1.

Table 1. Test results of sensory analysis of Lizard fish (*Saurida tumbil*) nugget filling with substitution of purple sweet potato flour.

Treatment	Appearance	Aroma	Taste	Texture
P_1(0:100, control)	3.93 ± 0.067^{ab}	3.97 ± 0.176^{a}	3.80 ± 0.145^{a}	3.77 ± 0.067^{ab}
P_2(10:90)	3.73 ± 0.067^{abc}	3.77 ± 0.100^{ab}	3.90 ± 0.153^{ab}	3.91 ± 0.084^{ab}
P_3(20:80)	3.56 ± 0.139^{bcd}	3.53 ± 0.100^{bc}	3.52 ± 0.135^{bc}	3.64 ± 0.069^{bc}
P_4(30:70)	3.44 ± 0.102^{cd}	3.32 ± 0.069^{c}	3.46 ± 0.084^{bc}	3.38 ± 0.084^{cd}
P_5(40:60)	3.20 ± 0.067^{de}	3.20 ± 0.088^{c}	3.17 ± 0.088^{cd}	3.14 ± 0.084^{d}
P_6(50:50)	2.84 ± 0.168^{ef}	2.86 ± 0.102^{d}	2.92 ± 0.102^{de}	2.77 ± 0.153^{e}
P_7(60:40)	2.58 ± 0.278^{e}	2.62 ± 0.069^{d}	2.61 ± 0.084^{e}	2.62 ± 0.139^{e}

Data are shown as the mean ± standard deviation. Same superscript letter within row show there is no significant difference ($p>0.05$).

3.1.1 Appearance

The visual assessment of *Saurida tumbil*-based nugget matrices incorporating varying concentrations of Ipomoea batatas flour revealed an inverse relationship between consumer acceptability and the proportion of purple sweet potato flour incorporation. Sensory evaluation indicated a significant preference ($p < 0.05$) for matrices exhibiting golden-yellow hues compared to those with darker chromatic properties. The observed color modification can be attributed to the presence of anthocyanin pigments naturally occurring in Ipomoea batatas. These water-soluble flavonoid compounds maintained their chromatic stability throughout thermal processing, specifically during the steaming phase of matrix preparation. This thermal stability of anthocyanins aligns with findings reported by Falahudin *et al.* [5], who demonstrated the efficacy of sweet potato-derived anthocyanins as stable natural food colorants. The progressive darkening of the nugget matrices correlates directly with increased concentrations of Ipomoea batatas flour, characterized by: A shift from golden-yellow (control) to deeper purple hues; retention of anthocyanin pigmentation post-thermal processing and Uniform color distribution throughout the matrix. This transformation in chromatic properties, while demonstrating successful incorporation of natural pigments, inversely affected consumer acceptance scores, suggesting a preference threshold for color intensity in processed fish products.

3.1.2 Aroma

The sensory assessment indicated that aroma acceptability of Lizard fish (*Saurida tumbil*) nuggets exhibited an inverse correlation with increasing concentrations of purple sweet potato (*Ipomoea batatas* L.) flour substitution. Sensory evaluation revealed that panelists showed significant preference ($p < 0.05$) for treatments containing lower concentrations of purple sweet potato flour, where the characteristic volatile compounds of the fish base material remained dominant. Higher concentrations of purple sweet potato flour resulted in the masking of desirable fish aromatics and the predominance of sweet potato volatile compounds, leading to decreased sensory acceptance scores. These findings corroborate with Sormin *et al.* [6], who demonstrated that the intensity of fish nugget aroma compounds was inversely proportional to the concentration of purple sweet potato flour incorporation.

3.1.3 Taste

The sensory evaluation of taste profiles in *Saurida tumbil* nuggets revealed an inverse relationship between taste acceptability and the concentration of purple sweet potato flour substitution. Sensory panel assessments indicated a higher preference for formulations with lower concentrations of purple sweet potato flour, where the characteristic umami notes of *S. tumbil* remained predominant. As the proportion of purple sweet potato flour increased in the formulation, the inherent sweetness of the flour progressively masked the distinctive fish taste profile, leading to decreased palatability scores from panelists. These findings align with Falahudin *et al.* [5], who reported optimal sensory acceptance in formulations with minimal purple sweet potato flour incorporation, attributing this to the balanced taste profile where the savory characteristics of the fish protein matrix were complemented, rather than overwhelmed, by the subtle sweetness of the purple sweet potato flour. Conversely, higher concentrations of purple sweet potato flour resulted in a pronounced sweetness that significantly altered the desired organoleptic properties of the fish nuggets, diminishing the characteristic taste of *S. tumbil*.

3.1.4 Texture

Textural analysis of *Saurida tumbil* nuggets demonstrated a negative correlation between textural properties and purple sweet potato flour concentration in the formulation. Sensory evaluation indicated higher acceptability scores for products with lower purple sweet potato flour incorporation, characterized by enhanced chewiness and optimal textural resilience. The progressive increase in purple sweet potato flour concentration resulted in diminished textural attributes, particularly reduced chewiness, which negatively impacted overall sensory acceptance. These findings corroborate with Falahudin *et al.* [5], who documented a significant inverse relationship between purple sweet potato flour concentration and textural quality parameters. Their research established that elevated levels of purple sweet potato flour adversely affected the nuggets' mechanical properties, specifically reducing chewiness, which consequently lowered consumer acceptance scores in sensory evaluations.

3.1.5 Treatment optimization

Treatment optimization was conducted using the de Garmo effectiveness index method, incorporating organoleptic parameters through hedonic scaling. This analytical approach was employed not only to identify the optimal formulation but also to determine intermediate and suboptimal treatments based on sensory evaluation scores. The selected treatments subsequently underwent comprehensive physicochemical characterization, including proximate composition analysis, gluten content determination, and physical property assessment. Statistical analysis revealed that treatment P1 (0:100 ratio) demonstrated superior performance across all evaluated parameters, achieving the highest effectiveness index (NP) of 0.95. The sensory attribute scores for P1 were: appearance (3.93 ± SE), aroma (3.97 ± SE), taste (3.80 ± SE), and texture (3.77 ± SE). Treatment P4 (30:70 ratio) exhibited intermediate performance with an effectiveness index of 0.60, corresponding to sensory scores of: appearance (3.44 ± SE), aroma (3.32 ± SE), taste (3.46 ± SE), and texture (3.38 ± SE). Treatment P7 (60:40 ratio) showed the lowest performance metrics, with an effectiveness index of 0.00 and corresponding sensory evaluation scores of: appearance (2.58 ± SE), aroma (2.62 ± SE), taste (2.61 ± SE), and texture (2.62 ± SE).

3.2 Proximate composition and gluten analysis

Proximate analysis is a standardized analytical methodology for determining the fundamental nutritional constituents of food materials, including moisture content, crude protein, total lipids, ash content, and carbohydrates by difference. This analytical approach enables quantitative characterization of the major macronutrient components and provides essential data for nutritional profiling and quality assessment of food matrices. The analytical results from the proximate composition determination are presented in Table 2.

Table 2. Proximate composition and gluten analysis of *Saurida tumbil*-based nuggets incorporated with *Ipomoea batatas* var. purpurea flour as partial substitute.

Parameter (%)	Treatment			
	P0 (Commercial))	P1 (0:100)	P4 (30:70)	P7 (60:40)
Moisture	63.07±0.263^{a}	60.09±0.491^{b}	55.52±0.742^{c}	54.80±0.223^{c}
Ash	1.82±0.133^{a}	1.73±0.142^{a}	1.77±0.078^{a}	1.90±0.072^{a}
Protein	31.26±0.246^{a}	27.11±0.178^{b}	24.05±0.329^{c}	22.64±0.081^{d}
Fat	0.68±0.189^{a}	0.63±0.021^{a}	0.55±0.102^{a}	0.48±0.148^{a}
Carbohydrate	3.17±0.202^{a}	10.43±0.471^{b}	18.11±0.251^{c}	20.18±0.372^{d}
Gluten	2.15±0.112^{b}	3.35±0.100^{a}	0.24±0.062^{c}	0.14±0.049^{c}

Data are shown as the mean ± standard deviation. Same superscript letter within row show there is no significant difference (p>0.05).

3.2.1 Moisture Content

The analysis revealed that treatment P1 (0:100 ratio) yielded the highest moisture content among all treatments. Moisture content serves as a critical determinant of processed food products' shelf stability and durability. An inverse relationship exists between moisture content and product stability: lower water content inhibits microbial proliferation, thereby extending shelf life, while elevated moisture content accelerates microbial growth and subsequent product deterioration [6]. The product's moisture content was influenced by the constituent ingredients' inherent moisture levels: Lizard fish (74.39%), wheat flour (11.27%), and purple sweet potato flour (3.59%).

The incorporation of purple sweet potato flour facilitates water absorption through its starch matrix. According to Falahudin *et al.* [5], increasing the substitution ratio of purple sweet potato flour enhanced water-binding capacity, resulting in a corresponding decrease in the final product's moisture content. The experimental results indicated that the observed water content exceeded the acceptable threshold established by SNI 7758-2013 standards, which specify a maximum water content of 60% for fish nuggets. This non-compliance with quality requirements suggests the need for formulation optimization.

3.2.2 Ash content

Quantitative analysis demonstrated that treatment P7 (60:40 ratio) exhibited the highest ash content among all treatments. Ash content serves as a quantitative indicator of inorganic constituents present in food matrices, though it should be noted that this measurement may not precisely correspond to total mineral content due to potential losses through volatilization and thermal decomposition during the combustion process [7]. The elevated ash content in Lizard fish nugget filling can be attributed to the mineral composition of its primary constituents: Lizard fish meat (1.73%) and purple sweet potato flour (2.46%). In contrast, wheat flour contributed minimally to the total ash content with 0.81%. The progressive increase in ash content correlates with the incremental substitution of purple sweet potato flour, which possesses a superior mineral profile compared to conventional flour alternatives.

Falahudin *et al.* [5] characterized the predominant minerals in purple sweet potatoes as potassium, sodium, phosphorus, calcium, magnesium, and iron. The systematic increase in purple sweet potato flour substitution across treatments resulted in a corresponding elevation of total mineral content in the final product. The experimental results indicated that the ash content remained within acceptable parameters as defined by SNI 7758-2013 quality standards, which specify a maximum threshold of 2.5% for fish nuggets.

3.2.3 Protein content

The protein content analysis revealed highest values in treatment P1 (0:100), characterized by the absence of purple sweet potato flour substitution. A negative correlation was observed between purple sweet potato flour concentration and protein content in nugget fillings. This relationship can be attributed to two primary factors: the inherent protein content of raw materials and the substitution effect of wheat flour. The primary protein sources in the formulation were Lizard fish meat and wheat flour, containing 22.17% and 12.15% protein content, respectively. Wheat flour additionally contributes 17.48% gluten protein. In contrast, purple sweet potato flour contains significantly lower protein content (1.78%) and lacks gluten proteins. Consequently, increasing the proportion of purple sweet potato flour in the wheat flour substitution progressively reduced the total protein content of the nugget filling [7].

These findings align with previous research by Sormin *et al.* [6], who demonstrated that fish meat content significantly influences the protein content of fish nugget filling. In their experiment, the higher the percentage of purple sweet potato added to tuna nugget, the smaller the protein content of the product. Despite the observed reduction in protein content with increased purple sweet potato flour substitution, all treatments maintained protein levels above the minimum requirement of 5% specified by SNI 7758-2013 quality standards for fish nuggets.

3.2.4 Fat Content

Analysis revealed maximum fat content in treatment P1 (0:100), reflecting the compositional influence of raw materials. The lipid profile of the nugget filling demonstrates an inverse relationship with purple sweet potato flour substitution levels. The primary lipid contributors in the formulation include Lizard fish (0.65% fat), wheat flour (1.54% fat), and purple sweet potato flour (0.43% fat) [8]. Thermal processing during boiling or steaming operations induced a reduction in total fat content. This phenomenon can be attributed to thermal degradation of lipid structures at elevated temperatures, leading to molecular restructuring and potential losses. The magnitude of fat reduction was positively correlated with the proportion of purple sweet potato flour substitution in the formulation. All experimental treatments maintained fat content levels within the acceptable range specified by SNI 7758-2013 quality standards, which stipulate a maximum threshold of 15% for fish nuggets.

3.2.5 Carbohydrate content

The experimental results indicated that treatment P7 (60:40 ratio) exhibited the highest carbohydrate content. This elevation in carbohydrate levels in the fish nugget matrix can be attributed to the cumulative contributions from multiple raw materials: Lizard fish (1.06% carbohydrates), wheat flour (72.21% carbohydrates), and purple sweet potato flour (80.23% carbohydrates). A positive correlation was observed between the proportion of purple sweet potato flour substitution and the total carbohydrate content in the lizard fish nugget formulation. The elevated carbohydrate concentration in treatment P7 is primarily attributed to the substantial carbohydrate content of the binding agents - purple sweet potato flour and wheat flour [5]. The data demonstrated that increasing the proportion of purple sweet potato flour resulted in a corresponding increase in the carbohydrate content of the final product.

While the Indonesian National Standard for fish nuggets does not specify maximum permissible carbohydrate levels, all formulations containing purple sweet potato flour substitution complied with SNI 01-6683-2002 standards for chicken nuggets, which stipulates a maximum carbohydrate content of 25%.

3.2.6 Gluten analysis

Gluten quantification analysis was performed to determine the relative concentration of storage proteins, specifically glutenin and gliadin complexes, in the flour matrices. These protein complexes, predominantly found in Triticum aestivum (wheat), form a viscoelastic network that confers characteristic rheological properties to dough systems. The quantitative analysis of gluten content across formulations is presented in Table 2. Analysis of gluten concentration revealed an inverse correlation between purple sweet potato flour incorporation and gluten content, with treatment P7 (60:40) exhibiting the lowest gluten concentration. This observation aligns with findings by Tuhumury *et al.* [7], who documented that progressive substitution of wheat flour with purple sweet potato flour results in proportional reduction of gluten network formation. Treatment P1 (negative control) demonstrated maximum gluten content, attributed to its higher wheat flour concentration and consequently elevated protein content. The functional properties of gluten are derived from its constituent proteins: gliadin, which contributes extensibility, and glutenin, which provides elasticity. These proteins form a viscoelastic network that significantly influences the textural properties of the final product, particularly its rheological characteristics and organoleptic attributes [9]. The protein composition, specifically the gluten complex, serves as the primary determinant of textural properties in flour-based matrices. During hydration, the glutenin and gliadin proteins present in wheat form an interconnected gluten network through disulfide bonds and non-covalent interactions [10]. This viscoelastic gluten matrix confers extensibility and gas retention properties to the dough system. Insufficient gluten development results in reduced gas-holding capacity, leading to smaller alveoli (gas cells) formation within the dough structure. The limited expansion of the gluten network during fermentation and baking consequently produces a final product with diminished elasticity and altered textural properties [11].

3.3 Textural and colorimetric properties

3.3.1 Textural elasticity

Elasticity, defined as the mechanical property characterizing a material's ability to recover its original configuration following deformation under applied stress, represents a critical quality parameter in food systems. The textural resilience, specifically firmness, serves as a key instrumental indicator for quality assessment and significantly influences consumer acceptance of food products. The quantitative results of texture profile analysis (TPA), focusing on resilience measurements, are presented in Table 3.

Table 3. Textural elasticity and colorimetric parameters of *Saurida tumbil* nugget fillings formulated with *Ipomoea batatas* var. purpurea flour at various substitution levels.

Treatment	Elasticity (gf)	Sampel			
		L*	a**	b***	°Hue
Flour	-	92.74	0.24	14.69	89.06
Ipomoea batatas Flour	-	52.68	12.19	3.98	18.08
P0 (Commercial)	1082.07±3.593^{a}	76.68	-3.55	15.75	102.71
P1 (0:100)	790.06±1.621^{b}	74.12	-2.50	11.85	101.92
P4 (30:70)	731.75±3.194^{c}	55.41	0.51	7.14	85.91
P7 (60:40)	668.82±3.060^{d}	45.27	3.02	6.44	64.87

Data are shown as mean ± standard deviation. Same superscript letter within column show there is no significant difference (p>0.05).

The *Saurida tumbil* nugget filling in treatment P1 (negative control) exhibited superior elasticity scores, attributed to its elevated protein content. During nugget production, proteins serve as critical structural components that enhance product elasticity. The myofibrillar proteins, predominantly actin and myosin, demonstrate significant gel-forming capabilities [112]. These muscle proteins function as binding agents between comminuted meat particles and additional ingredients, facilitating the formation of a cohesive matrix [13].

The considerable protein content of the raw material (*S. tumbil*, 22.17%) contributes to the characteristic textural properties of the nugget filling through its multifunctional properties: water binding capacity, gel formation potential, and emulsification properties. The inverse relationship between purple sweet potato flour (Ipomoea batatas var. purpurea) substitution and elasticity can be attributed to the differential protein compositions of the flours utilized. Wheat flour, the primary protein contributor in the control formulation, contains 12.15% total protein and 17.48% gluten proteins. In contrast, I. batatas var. purpurea flour exhibits significantly lower protein content (1.78%) and lacks gluten proteins entirely. Consequently, treatment P1 demonstrated superior gel strength characteristics.

3.3.2 Colorimetric L (lightness) analysis*

Color attributes serve as critical organoleptic parameters that significantly influence consumer preference and product acceptance. This study examined the chromatic properties of *Saurida tumbil* nugget fillings using objective colorimetric measurements. According to Utari *et al.* [14] instrumental color analysis was employed to obtain quantitative colorimetric data, thereby eliminating the variability inherent in subjective visual assessments. The hue angle (h°) values were measured to determine the precise chromatic characteristics of the product. Instrumental colorimetric analysis of *Saurida tumbil* nugget fillings revealed that treatment P1 (0:100 ratio) exhibited the highest L* value of 74.12, indicating maximum luminosity in the sample matrix. Conversely, treatment P7 (60:40 ratio) demonstrated the lowest L* value of 45.27, indicating increased light absorption. This inverse relationship between anthocyanin concentration and L* values align with findings reported by Falahudin *et al.* [5], which established that anthocyanin pigments in Ipomoea batatas function as effective natural chromophores in food systems.

The observed decrease in L* values correlates with increased anthocyanin concentration, as these pigments enhance light absorption properties of the matrix. This phenomenon is further supported by the measured L* value of 52.68 in isolated purple sweet potato flour, indicating moderate light absorption characteristics. The data demonstrate a negative correlation between purple sweet potato flour concentration and L* values in the final product, suggesting that incremental increases in purple sweet potato flour content result in proportional decreases in matrix luminosity.

3.3.3 Hue values (°Hue)

Colorimetric analysis of hue values (°Hue) and chromatic spectrum characterization revealed distinct color variations among different formulations of *Saurida tumbil* nugget fillings with variable proportions of purple sweet potato flour substitution. Spectrophotometric measurements indicated that treatments P0 (positive control) and P1 (0:100) exhibited yellow chromatic characteristics (K), while treatments P4 (30:70) and P7 (60:40) demonstrated yellowish-red hues (MK). The wheat flour control sample displayed yellowish-red coloration (MK), whereas pure purple sweet potato flour manifested red chromaticity (M).

These observed chromatic variations align with the findings reported by Falahudin *et al.* [5], who attributed the color transitions to the presence of anthocyanin pigments in purple sweet potato flour. Quantitative analysis by Tang *et al.* [15] demonstrated that purple sweet potato flour contains relatively low carotenoid concentrations (2.85 units) compared to its anthocyanin content (15.7 units), accounting for the predominance of red hues over yellow coloration. The final chromatic profile is further modulated by supplementary ingredients in the formulation matrix, including wheat flour, egg proteins, and corn oil, which contribute additional carotenoid compounds to the overall color characteristics of the product.

3.4 Evaluation of optimal treatment parameters in accordance with Indonesian National Standards (SNI).

The optimal treatment was determined through the de Garmo decision-making methodology, incorporating multiple parameters: organoleptic properties, proximate composition, gluten content, and physical characteristics. Following comprehensive analytical calculations across all measured parameters, treatment P1 (negative control) demonstrated superior performance. The quantitative values for each parameter in relation to SNI specifications are presented in Table 4.

Table 4. Physicochemical and sensory properties of optimized *Saurida tumbil* nugget formulation compared to standard quality parameters.

Characterization	Best Nugget Filling Analysis Results (P1)	Indonesia National Standard of Fish Nuggets (SNI 7758-2013)
Appearance	3.93 ± 0.67	Min 7.0
Aroma	3.97 ± 0.176	Min 7.0
Taste	3.80 ± 0.145	Min 7.0
Texture	3.77 ± 0.067	Min 7.0
Water Content	60.09 ± 0.491	Max 60.0
Ash	1.73 ± 0.142	Max 2.5
Protein	27.11 ± 0.178	Min 5.0
Fat	0.63 ± 0.021	Max 15.0
Carbohydrate	10.43 ± 0.471	-
Gluten	3.35 ± 0.100	-
Elasticity	790.06 ± 1,621	-

Analysis revealed that Treatment P1 (control without additives) exceeded the maximum permissible moisture content (>60.0%) specified by the National Standardization Agency for fish nugget quality standards. However, all other physicochemical parameters for Treatment P1 were within acceptable ranges: ash content (≤2.5%), protein content (≥5.0%), and lipid content (≤15.0%). These values comply with the established national quality criteria for processed fish products (Table 5).

Table 5. Comparative analysis of quality parameters between fish nugget formulations P4 and P7.

Characterization	Nugget Filling Analysis Results (P4)	Nugget Filling Analysis Results (P7)	Indonesia National Standard of Fish Nuggets (SNI 7758-2013)
Appearance	3,44 ± 0.102	2.58 ± 0.278	Min 7.0
Aroma	3.32 ± 0.069	2.62 ± 0.069	Min 7.0
Taste	3.46 ± 0.084	2.61 ± 0.0.084	Min 7.0
Texture	3.38 ± 0.084	2.62 ± 0.139	Min 7.0
Water Content	3,20 ± 0.742	54.80 ± 0.223	Max 60.0
Ash	1.77 ± 0.078	1.90 ± 0.072	Max 2.5
Protein	24.05 ± 0.329	22.64 ± 0.081	Min 5.0
Fat	±	0.48 ± 0.251	Max 15.0
Carbohydrate	±	20.18 ± 0.372	-
Gluten	±	0.14 ± 0.049	-
Elasticity	±	668.82 ± 3.060	-

Additional formulations, designated as P4 (30:70 ratio) and P7 (60:40 ratio), were evaluated against quality parameters established by the National Standardization Agency. Both formulations complied with the Indonesian National Standard (SNI) specifications.

3.5 Yield

The meat yield of *Saurida tumbil* (final weight/initial weight × 100%) was determined to be 47.79%, calculated from 4,788 g of filleted meat obtained from 10,017 g whole fish. For the nugget filling preparation, a yield of 95.45% was achieved, where 210 g of final product was obtained from an initial mixture of 220 g.

4 Conclusion

This study demonstrated that varying concentrations of purple sweet potato (Ipomoea batatas L.) flour substitution in *Saurida tumbil* (lizardfish) nugget fillings significantly influenced their organoleptic properties, proximate composition, gluten content, and physical characteristics ($p < 0.05$). The control formulation (P1; 0:100 ratio of purple sweet potato flour to conventional flour) exhibited optimal characteristics across measured parameters. Notably, the incorporation of purple sweet potato flour effectively reduced gluten content while enhancing the nutritional profile. Future research directions should explore flavor-enhancing additives to improve consumer acceptability and conduct comprehensive nutritional analyses, particularly focusing on fatty acid profiles and mineral content of these modified nugget formulations. Additionally, clinical trials are recommended to validate the product's safety and efficacy for celiac disease patients.

Acknowledgments

This work was supported by the Professor Grant Program (Grant No. 3708/UN10.F06/KS/2024) from the Faculty of Fisheries and Marine Sciences, Brawijaya University, Indonesia. The authors express their sincere appreciation to the institution for providing essential research facilities and technical infrastructure. We would also like to acknowledge the valuable support of the laboratory staff during the experimental phase. No funding conflicts or competing interests were reported by the authors.

References

1. N. A. A. Sari, E. Permadi, R. B. Lestari, Kualitas nutrisi *nugget* ayam broiler dengan penambahan tepung kulit pisang kepok (*Musa acuminata*). Jurnal Peternakan Borneo: Livestock Borneo Research, **2(1),** 38-45 (2023). https://dx.doi.org/10.26418/jpb.v1i1.0000
2. M. A. Nugraha, Rozi. The effect of giving commercial feed, beloso trash fish (*Saurida tumbil*), kurisi trash fish (*Nemipterus nematophorus*), and mixed trash fish on growth of cantang grouper (*Epinephelus fuscoguttatus-lanceolatus*) in floating net cage. IOP Conference Series.: Earth and Environmental Science. **441**. 012069 (2020). https://doi.org/10.1088/1755-1315/441/1/012069
3. E. Ginting, R, Yulifianti, M.J.M. Jusuf, Ubi jalar sebagai bahan diversifikasi pangan lokal [Sweet Potatoes as Ingredients of Local Food Diversification]. Jurnal Pangan. **23(2),** 194-207 (2014). https://doi.org/10.33964/jp.v23i2.63
4. N. Herdiana, S. Susilawati, D. Koesoemawardani, E. Rahayu, Substitusi tepung ubi jalar ungu (Ipomea batatas L) dan tapioka sebagai bahan pengisi pembentuk tekstur nugget ikan lele. AgriTECH. **43(2),**127-133 (2023). https://doi.org/10.22146/agritech.69714
5. A. Falahudin, U.I.L.R. Rahmah, T. Ismail, T. Karakteristik fisik dan organoleptik *nugget* ayam petelur afkir dengan substitusi tepung ubi jalar ungu (*Ipomoea batatas*). Agrivet: Jurnal Ilmu-Ilmu Pertanian dan Peternakan (Journal of Agricultural Sciences and Veteriner). **10(2**), 238-244 (2022). https://doi.org/10.31949/agrivet.v10i2.3960
6. R. B. D. Sormin, F. Gasperz, S. Woriwun, S. Karakteristik nugget ikan tuna (*Thunnus* sp.) dengan substitusi ubi ungu (*Ipomoea batatas*). AGRITEKNO: Jurnal Teknologi Pertanian. **9(1**), 1-9 (2020). https://doi.org/10.30598/jagritekno.2020.9.1.1

7. H. C. Tuhumury, L. Ega, N. Keliobas, Pengaruh substitusi tepung ubi jalar ungu terhadap karakteristik kue kering. *AGRITEKNO:* Jurnal Teknologi Pertanian. **7(1),** 30-35 (2018). https://doi.org/10.30598/jagritekno.2018.7.1.30
8. S. Rahman, A Dwiani, A. Pengaruh substitusi jamur Tiram (Pleurotus ostreatus) dan tepung terigu terhadap mutu kimia nugget. Jurnal Ilmiah Inovasi. **20(3**), 30-34 (2020). https://doi.org/10.25047/jii.v20i3.2364
9. U. Hasanah, M. Ulya, U. Purwandari, Pengaruh penambahan tempe dan tepung tapioka terhadap karakteristik fisikokimia dan hedonik nugget nangka muda (Artocarpus heterophyllus LMK). Jurnal Pangan dan Agroindustri. **8(3),** 154-162 (2020). https://doi.org/10.21776/ub.jpa.2020.008.03.5
10. A. A. J., Setyadi, R. Ninsix, Pengaruh substitusi tepung ubi jalar ungu (*Ipomoe batatas var. Ayamurasaki*) terhadap karakteristik bolu yang dihasilkan. Jurnal Teknologi Pertanian. **8(2)**, 107-111 (2019). https://doi.org/10.32520/jtp.v8i2.942
11. D. Triastuti, Sifat fisikokimia dan sensori mie basah dengan substitusi tepung ubi jalar ungu. Scientific Timeline. **1(2),** 070-085 (2021)
12. Y. Ardianti, S. Widyastuti, S. W. Rosmilawati, D. Handito, Pengaruh penambahan karagenan terhadap sifat fisik dan organoleptik bakso ikan tongkol (*Euthynnus affinis*). Agroteksos. **24(3)**, 159-166 (2018).
13. L. Amalia, S. R. Bilqisthy, M. Mardiah, A. Jumiono, Karakteristik fisiko kimia dan organoleptik bakso daging sapi, bakso daging tikus, dan bakso daging sapi campur daging tikus dengan penambahan bahan pengenyal dan bumbu. Karimah Tauhid. **3(3),** 3975-3989 (2024).
14. K.S.T. Utari, E. N. Dewi, R. Romadhon, Sifat fisika kimia fish snack ekstrusi ikan nila (*Oreochromis niloticus*) dengan penambahan grit buah lindur (*Bruguiera gymnorrizha*). Jurnal Pengolahan dan Bioteknologi Hasil Perikanan, **5(4),** 33-42 (2016).
15. Y. Tang, W. Cai, B. Xu, Profiles of phenolics, carotenoids and antioxidative capacities of thermal processed white, yellow, orange and purple sweet potatoes grown in Guilin, China. Food Science and Human Wellness. **4(3),** 123-132 (2015). https://doi.org/10.1016/j.fshw.2015.07.003