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Proximate and Starch Profiles of Spent Duck Meat Nuggets: Effects of Rice Bran Flour Substitution

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Abstract

The present study investigated the effect of substituting rice bran flour with tapioca flour on the physicochemical properties of spent duck meat nuggets. Formulations with varying levels of rice bran flour substitution (0%, 5%, 10%, and 15%) were prepared and analyzed for moisture, protein, fat, amylose, and amylopectin contents. The results indicated that increasing the rice bran flour substitution significantly increased the moisture content (48.84%–52.36%), likely due to the water-binding capacity of rice bran fiber. Protein content also increased (9.61% to 14.46%), with higher substitution levels meeting or exceeding regulatory standards, which was attributed to the higher protein content of rice bran compared to that of tapioca flour. Fat content progressively increased (2.39% to 5.97%) with rice bran flour substitution, although all treatments remained within acceptable limits. Amylose content decreased (20.67% to 13.95%) with higher rice bran flour substitution, potentially affecting the texture and water-holding capacity. Conversely, amylopectin content increased (44.02% to 50.98%), which may enhance tenderness but affect texture stability. These findings suggest that partial substitution of tapioca flour with rice bran flour can improve the nutritional profile of spent duck meat nuggets, while maintaining acceptable physicochemical properties. However, further research is needed to optimize the formulation of ideal texture and sensory characteristics.

Keywords: Meat Products; Spent duck meat; Rice bran flour; Proximate composition; Starch profile

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1. Introduction

Spent duck meat refers to meat obtained from female ducks that has reached the end of their egg-laying cycle and is no longer productive for breeding. Globally, duck meat production is heavily concentrated in Asia, accounting for approximately 82–84% of the total output [1]. Duck meat is valued for its high nutritional content, providing a rich source of high-quality protein, essential amino acids, iron, selenium, and niacin [2]. However, compared to chicken, duck meat typically has a redder color, higher fat content, distinctive aroma, and firmer texture, which are factors that can limit consumer acceptance [3]. To enhance its appeal, product diversification into processed forms such as nuggets has been widely explored. Nuggets are restructured meat products prepared from minced meat, seasoning, and fillers, most commonly tapioca flour [4-5]. Tapioca flour derived from cassava serves as an effective binder because of its high starch content, which gelatinizes upon heating to create a cohesive texture [6]. In recent years, there has been a growing interest in replacing traditional fillers with nutrient-dense functional ingredients, such as rice bran.

Rice bran, a byproduct of rice milling, is rich in dietary fiber (8.7–11.4% cellulose; 9.6–12.8% hemicellulose) and bioactive compounds, including γ-oryzanol and tocopherols, which have antioxidant properties [7-10]. The incorporation of rice Bran into meat products has the potential to improve nutritional value, add functional health benefits, and promote sustainable food production [7]. Nonetheless, consumer awareness of the benefits of rice bran remains limited, and its application in duck-meat-based nuggets is underexplored. Despite the nutritional potential of both spent duck meat and rice bran, few studies have examined their combined use in value-added meat products. Existing research on nuggets primarily focuses on chicken or beef, with minimal attention paid to duck meat, particularly spent layers. Moreover, the functional benefits of rice bran as a partial substitute for tapioca flour in such products remain underexplored. To address this gap, present study evaluated the effect of substituting tapioca flour with rice bran flour on the physicochemical characteristics (moisture, protein, fat, amylose, amylopectin content, texture) and sensory attributes (color, aroma, taste, and texture) of spent duck meat nuggets.

2. Materials and Methods

2.1. Materials and Equipment

The ingredients that will be used in this study are: two-year-old spent female duck meat from a farm in Kebonagung Village, Kebonagung District, Demak Regency, Central Java, Indonesia; tapioca flour (Pak Tani Gunung, Indonesia); rice bran flour (Tepung Katul Sari Mata Beras, Indonesia); bread crumbs; powdered garlic; ground pepper; mushroom broth; cooking oil; salt; and eggs.

2.2. Experimental Design

The experimental design employed in this study was a Completely Randomized Design (CRD) with a single factor, specifically varying concentrations of tapioca flour and rice bran flour substitution. This design comprised of four treatments and five replicates. The formulation for substituting tapioca flour with rice bran flour was based on the study by Kandanglangi et al. [3], with the following modifications:

P1 = 70% duck meat: 30% tapioca flour: 0% rice bran flour
P2 = 70% duck meat: 25% tapioca flour: 5% rice bran flour
P3 = 70% duck meat: 20% tapioca flour: 10% rice bran flour
P4 = 70% duck meat: 15% tapioca flour: 15% rice bran flour

The formula for making duck meat nuggets refers to a study by Kandanglangi et al. [3]. The main difference in this study lies in the substitution of tapioca flour with rice bran flour on the proximate and starch profiles of duck nuggets. The formulation for the duck nuggets is shown in Table 1.

2.3. Duck Nugget Preparation

The duck meat nuggets used in this study were prepared following a modified procedure adapted from Kandanglangi et al. [3]. The process commenced with the preparation of the raw materials wherein fresh duck meat was meticulously cleaned. Additional ingredients, including tapioca flour, rice bran flour, salt, ground pepper, garlic powder, chicken eggs, and flavor enhancers, were also prepared. Each component was weighed according to the treatment formulation. Subsequently, the cleaned duck meat was blended with ice until smooth consistency was attained. The resulting duck meat paste was then transferred to a larger mixing bowl for the mixing stage, during which tapioca flour, rice bran flour, water, and seasonings were incorporated and mixed until homogeneous dough was formed. Subsequently, the mixture was transferred into trays greased with margarine and steamed at 90°C for approximately 30 min. Following the steaming process, the trays were removed and allowed to cool to ambient temperature, after which the nugget mass was demolded and manually sectioned into desired shapes. Each nugget was coated with beaten eggs and breadcrumbs. The breaded nuggets were packaged in food-grade containers (27 × 19 × 5 cm) and stored at 5°C for a minimum duration of 12 h to ensure proper setting. Prior to analysis, the nuggets were deep-fried in hot oil at 100°C for approximately 5 min until a golden-brown hue was attained and excess oil was drained.

2.4. Data collection and analysis

a. Moisture Content

Moisture content was determined using the oven-drying method described by Horwitz and Latimer [11]. Approximately 5 g of the finely ground sample was placed in a pre-weighed porcelain dish and dried in a hot air oven at 105°C for 3–4 h until a constant weight was achieved. Moisture content was calculated based on the weight loss during drying using Eq. (1).

b. Crude Protein Content

The crude protein content was measured using the Kjeldahl method described by Bakhtra [12]. About 0.5–1.0 g of the sample was digested in concentrated sulfuric acid (H_2SO_3) with a catalyst mixture (usually potassium sulfate and copper sulfate). After complete digestion, the sample was distilled with sodium hydroxide (NaOH), and the released ammonia was trapped in a boric acid solution and then titrated with standardized hydrochloric acid (HCl). The nitrogen content was calculated and converted to protein content by multiplying by a factor of 6.25.

c. Crude Fat Content

Fat content was analyzed using the Soxhlet extraction method as outlined by Kalor et al. [13]. Approximately 2–3 g of the dried sample was wrapped in filter paper and extracted with petroleum ether for 6–8 h in a Soxhlet apparatus. After extraction, solvent was evaporated and the residue was weighed to determine the fat content.

d. Amylose Content

Amylose content was measured following the method of Sitinjak et al. [14]. A weighed amount of sample (typically 100 mg) was treated with ethanol and 1N NaOH, then heated to gelatinize the starch. The solution was cooled and reacted with iodine (KI) solution. The resulting blue complex was measured spectrophotometrically at 620 nm. Amylose concentration was determined by comparing the absorbance with a standard curve prepared using pure amylose.

e. Amylopectin Content

Amylopectin content was estimated indirectly using the method of Sitinjak et al. [14], based on the difference between total starch and amylose content. After determining the total starch content using similar spectrophotometric methods, amylopectin content was calculated using Eq. (5).

2.5. Statistical Analysis

All experimental measurements were conducted in triplicate (n = 3), and the results were expressed as mean ± standard deviation (SD). To assess the significance of differences among the treatment groups, the data were subjected to Analysis of Variance (ANOVA). Upon identifying significant effects ($p < 0.05$) through ANOVA, Duncan's Multiple Range Test (DMRT) was used as a post-hoc test to ascertain specific differences between treatment means. This methodology facilitated precise pairwise comparisons and identification of statistically distinct groups. Statistical analyses were performed using SPSS software.

3. Results and discussion

3.1. Moisture Content of Duck Nugget

Based on the results of the variance analysis in Appendix 2, the substitution of tapioca flour with rice bran flour had a significant effect ($p<0.05$) on the moisture content of the duck meat nuggets. The results of the follow-up Duncan Multiple Range Test (DMRT) for the moisture content of duck meat nuggets at the 5% level are shown in Table 2. Table 2 presents the average moisture content of duck meat nuggets across various treatments, ranging from 48.84% to 52.36%. The highest moisture content was recorded in treatment P4 (52.36%), whereas the lowest was observed in P1 (48.84%). DMRT analysis at the 5%

significance level revealed no significant difference between P1 and P2. However, P3 and P4 exhibited significant differences, and both were significantly different from P1 and P2. The observed increase in moisture content with higher levels of rice bran flour substitution can be attributed to compositional differences between the binding agents.

Tapioca flour, which is high in starch, forms a dense gel structure upon heating, thereby limiting its water retention [15]. In contrast, rice bran flour is rich in dietary fiber, including cellulose and hemicellulose, which are hygroscopic and are capable of binding substantial amounts of water within the matrix [16]. This property enhances water retention in the product, resulting in a higher measured moisture content. Similar findings were reported by [17], who demonstrated that the addition of rice bran fiber to beef burgers significantly increased moisture retention during cooking because of the water-holding capacity of the fibers. Furthermore, the primary data from this study indicated that rice bran flour has a moisture content of 7.02%, which may contribute additional bound water to the final product. According to Duka et al. [18], rice bran typically contains 13–18% total dietary fiber, which enhances its water-binding properties, thereby increasing the final moisture content of the food product. Notably, all nugget formulations in this study exhibited moisture contents below the Indonesia National Standard (SNI) No. 6683-2014 maximum limit of 60%, ensuring compliance with the Indonesian National Standard for nuggets.

3.2. Protein Content of Duck Nuggets

The ANOVA results indicated that the substitution of tapioca flour with rice bran flour significantly affected the protein content of duck meat nuggets (p<0.05). Subsequent analysis using DMRT at the 5% significance level revealed significant differences between the treatments. The average protein content of the duck meat nuggets is shown in Table 3. Table 3 shows that the protein content of duck meat nuggets varied from 9.61% (P1) to 14.46% (P4), with all treatments exhibiting significant differences ($p < 0.05$). The data indicated a discernible trend: an increased substitution of tapioca flour with rice bran flour resulted in elevated protein content. This is attributable to the substantially higher protein content of rice bran flour (10.11 g/100 g, primary data) compared to that of tapioca flour (1.1 g/100 g) [19]. Consequently, replacing tapioca with rice bran increased the proportion of protein-rich components in the formulation. Furthermore, the combination of animal protein from spent duck meat and plant-based protein from rice bran may enhance the overall protein quality owing to complementary amino acid profiles.

The processing methods employed in this study, particularly steaming, are relatively mild and preserve protein content, consistent with the findings of Serdaroğlu and Değırmencioğlu [20], who reported minimal protein loss in steamed meat products. The present findings are consistent with those of Dwiloka et al. [21], who noted an increase in protein content in chicken nuggets with the substitution of rice bran flour, and with, who reported (nalogous effects in biscuits fortified with rice bran flour. According to SNI 6683-2014, the minimum protein requirement for nuggets is 12%. The study found that treatments P2 (12.47%) and P4 (14.46%) met the required standards, whereas treatments P1 (9.61%) and P3 (11.67%) did not. This indicates that substituting tapioca flour with rice bran flour, either in part or in full, can enhance the nutritional composition to fulfill or exceed regulatory protein standards.

3.3. Fat Content of Duck Nuggets

The ANOVA results show that ($p<0.05$) duck meat nuggets have a significant effect on fat content, followed by a Duncan Multiple Range Test (DMRT) to determine whether there are differences among the treatments presented in Table 4. Table 4 presents the fat content of the duck meat nuggets, which varied from 2.39% (P1) to 5.97% (P4). Statistical analysis revealed no significant difference between treatments P1 and P2, whereas treatments P3 and P4 exhibited progressively higher fat content ($p < 0.05$). This increase was directly associated with the substitution of tapioca flour with rice bran flour. Rice bran flour contains a higher fat content (2.34 g/100 g) compared to tapioca flour (0.4 g/100 g) and is rich in unsaturated fatty acids, such as oleic and linoleic acids, as well as bioactive lipids like γ-oryzanol [22-24]. The elevated fat content in P4 can also be attributed to the proportionally greater influence of duck meat fat, as the carbohydrate binder (tapioca) is reduced.

Duck meat contains approximately 28.60 g fat/100 g [25], which is considerably higher than chicken meat. This observation aligns with the findings of Kusmayadi and Sundari [26], who reported that fat from duck meat becomes dominant when the proportion of low-fat binders is reduced. In accordance with SNI 6683-2014, permissible maximum fat content in the nuggets was 20%, indicating that all treatments in this study adhered to the standard. This trend aligns with findings of Echeverria et al. [27], who demonstrated that an increased proportion of rice bran flour in nugget formulations results in elevated fat content owing to inherently higher lipid levels of rice bran. From a nutritional perspective, moderate increase in fat content observed in treatments with higher rice bran content may be advantageous, as rice bran lipids are predominantly unsaturated and have been associated with cardiovascular health benefits [28].

3.4. Amylose Content of Duck Nuggets

The ANOVA results indicated a statistically significant effect ($p<0.05$) of substituting tapioca flour with rice bran flour in duck nuggets on amylose content, as presented in Table 5. The amylose content of the duck meat nuggets (Table 5) varied from 13.95% (P4) to 20.67% (P1), and all treatments exhibited significant differences ($p < 0.05$). The highest amylose content was observed in P1, which utilized 30% tapioca flour without any substitution with rice bran flour, whereas lowest recorded in P4, which comprised equal proportions of tapioca and rice bran flours (15% each). The observed decrease in amylose content with increasing substitution of rice bran flour is attributed to compositional differences between tapioca flour and rice bran flour. Tapioca flour contains 10.9–41% amylose [29], whereas rice bran flour contains approximately 13.54% amylose [30]. Given that rice bran is primarily composed of fiber, protein, and lipids rather than starch, increasing its proportion in the formulation results in dilution of the overall amylose content. This trend was corroborated by Damayanti et al. [31], Rahmawati et al [32], who reported that incorporation of rice bran into starchy food products reduced starch-derived amylose. From a functional perspective, a reduction in amylose content can significantly affect the physicochemical properties of the nuggets. Piga et al. [33] reported that diminished amylose levels lead to decreased gelatinization capacity and gel firmness, thereby altering the texture & water-holding capacity of processed meat products.

Table 1: Composition of Nugget Ingredients

Composition	Treatment			
	P1	**P2**	**P3**	**P4**
Duck meat, g	70	70	70	70
Tapioca Flour, g	30	25	20	15
Rice Bran Flour, g	0	5	10	15
Garlic, g	3	3	3	3
Salt, g	1	1	1	1
Ground Pepper, g	1	1	1	1
Mushroom broth, g	2	2	2	2
Egg, g	20	20	20	20

Table 2: Moisture content of duck nuggets

Treatments	Moisture content (wt.%)
P1	48.84 ± 0.51^{a}
P2	49.07 ± 0.58^{a}
P3	51.00 ± 0.37^{b}
P4	52.36 ± 0.16^{c}

Note: Numbers followed by different notations indicate a significant difference ($p<0.05$)

Table 3: Protein content of duck nuggets

Treatments	Ash content (%)
P1	9.61 ± 0.16^{a}
P2	12.47 ± 0.12^{b}
P3	11.67 ± 0.15^{c}
P4	14.46 ± 0.30^{d}

Note: Numbers followed by different notations indicate a significant difference ($p<0.05$)

Table 4: Fat content of duck nuggets

Treatments	Fat content (wt.%)
P1	2.39 ± 0.21^{a}
P2	2.50 ± 0.11^{a}
P3	3.43 ± 0.16^{b}
P4	5.97 ± 0.49^{c}

Note: Numbers followed by different notations indicate a significant difference ($p<0.05$)

Table 5: Amylose content of duck meat nuggets

Treatments	Amylose content (wt.%)
P1	20.67 ± 0.36^{d}
P2	16.22 ± 0.21^{c}
P3	14.98 ± 0.29^{b}
P4	13.95 ± 0.47^{a}

Note: Numbers followed by different notations indicate a significant difference ($p<0.05$)

Table 6: Amylopectin content of duck nuggets

Treatments	Amylopectin content (wt.%)
P1	44.02 ± 0.38^{a}
P2	48.67 ± 0.19^{b}
P3	49.85 ± 0.18^{c}
P4	50.98 ± 0.42^{d}

Note: Numbers followed by different notations indicate a significant difference ($p<0.05$)

Furthermore, Nawaz et al. [34] elucidated that interaction between proteins (derived from duck meat and rice bran) and amylose can result in formation of amylose–protein complexes. These complexes not only reduce measurable amylose levels, but may also influence starch digestibility and product firmness. Consequently, while substitution of tapioca with rice bran flour enhances protein and fat content, as evidenced by other parameters, it incurs drawback of reduced amylose levels, which may adversely affect texture formation in duck meat nuggets.

3.5. Amylopectin content of duck nuggets

The ANOVA results indicated a statistically significant effect ($p<0.05$) of substituting tapioca flour with rice bran flour on the amylopectin content in duck meat nuggets, as detailed in Table 6. The amylopectin content of the duck meat nuggets (Table 6) varied from 44.02% (P1) to 50.98% (P4), and all treatments exhibited significant differences ($p < 0.05$). The lowest amylopectin content was observed in P1 (30% tapioca flour, no rice bran flour), whereas the highest was observed in P4 (15% tapioca flour + 15% rice bran flour). A discernible trend was identified; increasing the substitution of rice bran flour led to elevated amylopectin levels. This trend can be attributed to the starch composition of the ingredients. Rice bran flour contains approximately 84.25% amylopectin (Primary Data, 2025), which is significantly higher than the approximately 78% found in tapioca flour [35]. Replacing tapioca flour with rice bran flour increased amylopectin content in the final product.

Similar findings were reported by Ma'ruf et al. [36], who observed that starches with lower amylose content naturally have higher amylopectin fractions owing to the inverse relationship between these two components. From a functional standpoint, amylopectin is pivotal for determining nugget tenderness and water retention. In contrast to amylose, which forms firm gels, amylopectin contributes to softer and more cohesive textures. The increased amylopectin content in formulations with higher rice bran flour may enhance tenderness while potentially diminishing structural firmness. However, Scot and Awika [37] suggested that excessive amylopectin can reduce retrogradation and product firmness during storage, potentially impacting the shelf life. In conclusion, substituting tapioca flour with rice bran flour significantly elevates amylopectin content, which may improve tenderness, but must be balanced to maintain desirable texture stability in duck meat nuggets.

3.6. Future direction of the research

The replacement of tapioca flour with rice bran flour in duck meat nugget formulations resulted in notable alterations in their compositional profiles, as indicated by an increase in fat and amylopectin content and a decrease in amylose content. The elevated fat levels associated with higher rice bran inclusion can be attributed to its naturally higher lipid concentration, particularly unsaturated fatty acids and bioactive compounds, whereas the reduction in amylose content is due to its lower starch proportion compared to tapioca. Conversely, the amylopectin fraction increased, reflecting the inverse relationship between amylose and amylopectin, potentially enhancing tenderness and moisture retention, albeit with a possible compromise between gel stability and storage firmness. These compositional changes are consistent with previous findings that starch and protein interactions can influence functional properties, such as texture, retrogradation, and water-binding capacity. From a product development perspective, the challenge lies in optimizing rice bran substitution to leverage its nutritional and sensory benefits without compromising its structural integrity during storage. Future research should explore hydrocolloid or protein fortification strategies to counterbalance reduced amylose-related gel strength, investigate consumer sensory acceptance at different substitution levels, and evaluate storage stability under varying temperature and humidity conditions to determine the optimal formulation for both quality and shelf life.

4. Conclusions

Substitution of tapioca flour with rice bran flour significantly influenced the physicochemical properties of the nuggets. The moisture content increased with higher levels of rice bran flour substitution, likely due to the water-binding capacity of rice bran fiber; however, all formulations remained within acceptable moisture limits. Protein content also increased with the substitution, with treatments P2 and P4 meeting or exceeding regulatory protein standards, which was attributed to the higher protein content of rice bran compared to that of tapioca flour. Fat content progressively increased with rice bran flour substitution, although all treatments remained within acceptable limits, likely because of the higher fat content of rice bran and the potential influence of duck meat fat. As rice bran flour substitution increased, the amylose content decreased, which may have affected the texture and water-holding capacity of the nuggets. Conversely, amylopectin content increased with higher rice bran flour substitution, potentially enhancing tenderness but possibly affecting texture stability. These findings suggest that partially substituting tapioca flour with rice bran flour can improve nutritional profile of spent duck meat nuggets while maintaining acceptable physicochemical properties. However, further research is needed to optimize the formulation for ideal texture and the sensory characteristics. Future studies should explore the effects of modified nuggets on sensory attributes, shelf life, and consumer acceptability.

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