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Enhancing protein content and functional properties of gluten-free black glutinous rice flour and tapioca starch pasta fortified with chicken meat

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ABSTRACT

The growing demand for gluten-free foods has increased interest in developing pasta products with improved nutritional value and quality attributes. This study aimed to formulate gluten-free pasta using black glutinous rice flour and tapioca starch fortified with minced chicken meat and to evaluate the effects of chicken meat incorporation on physicochemical properties, antioxidant capacity, texture, nutritional composition, and sensory acceptability. Chicken meat–fortified pasta (CFP) was prepared by replacing black glutinous rice flour and tapioca starch with minced chicken meat at 0, 20, 30, and 40 g /100 g of total flour and compared with conventional wheat pasta (WP). Chicken meat incorporation significantly affected pasta qualities ($p < 0.05$). CFP samples exhibited darker color, higher redness, and lower lightness and yellowness than WP due to the presence of anthocyanins from black glutinous rice flour. Antioxidant activity, total phenolic content, and anthocyanin levels were significantly higher in CFP than in WP but decreased with increasing chicken meat levels as a result of phenolic dilution. Increasing chicken meat content prolonged optimum cooking time and increased water absorption, while reducing cooking loss, volume expansion, and water solubility, indicating improved cooking stability. Texture profile analysis showed that moderate chicken meat incorporation (20 g/100 g) enhanced hardness and gumminess, partially compensating for the absence of gluten, whereas higher meat levels negatively affected cohesiveness, springiness, and chewiness. Proximate analysis revealed progressive increases in protein, fat, ash, and moisture contents with increasing chicken meat levels, with the highest protein content observed at 40 g/100 g of chicken meat sample. Sensory evaluation indicated that all CFP samples were acceptable, with the 20 g/100 g formulation achieving the highest overall acceptability among gluten-free samples. In conclusion, chicken meat–fortified gluten-free pasta based on black glutinous rice flour and tapioca starch is a promising functional food, with 20 g/100 g of chicken meat providing the optimal balance between nutritional enhancement and product qualities.

Keywords: Gluten-free pasta, Chicken meat fortification, Black glutinous rice flour, Tapioca starch, Functional properties

INTRODUCTION

Traditionally, pasta is made from wheat. Pasta is traditionally produced from wheat semolina, water, and eggs, with gluten proteins playing a critical role in determining its structure, cooking quality, and textural properties [1]. The increasing incidence of celiac disease, gluten intolerance, and consumer demand for gluten-free products has spurred the creation of pasta formulations utilizing non-wheat raw materials. Despite extensive research efforts, gluten-free pasta often exhibits inferior cooking quality, poor texture, high cooking loss, and reduced sensory acceptability due to the absence of a gluten network [2, 15]. This structural deficiency remains one of the main technological challenges in gluten-free pasta production.

Among gluten-free raw materials, black glutinous rice (*Oryza sativa* L. var. glutinosa) has attracted attention due to its high starch content and its richness in bioactive compounds such as anthocyanins, phenolics, and flavonoids, which provide antioxidant, anti-inflammatory, and health-promoting properties [4, 5]. Incorporation of black rice flour into noodles and pasta has been reported to enhance antioxidant activity and nutritional value [6–8]. However, previous studies consistently show that replacing wheat flour with black rice flour can adversely affect color brightness, texture, cooking behavior, and structural integrity, mainly due to altered starch gelatinization and the absence of gluten

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[9, 10]. Thus, although black glutinous rice flour is nutritionally advantageous, its application in gluten-free pasta requires additional formulation strategies to improve product quality.

Tapioca starch, which is abundantly produced in Thailand, is another promising gluten-free ingredient due to its neutral flavor, high digestibility, and favorable gelatinization properties. Nevertheless, tapioca starch alone often produces weak and brittle pasta structures, necessitating its combination with other flours or functional ingredients [11]. Previous studies have shown that blending tapioca starch with proteins or hydrocolloids can partially improve the cooking and textural properties of gluten-free pasta [12–14]. However, optimization of tapioca-based composite formulations remains an ongoing research need.

To overcome the structural limitations of gluten-free pasta, hydrocolloids such as xanthan gum are commonly incorporated to mimic gluten functionality by enhancing water retention, dough cohesiveness, and network stability [13, 16–18]. While hydrocolloids improve processing and cooking performance, they do not substantially enhance the nutritional value of pasta. Therefore, adding protein has been suggested as a way to improve both the nutritional value and the technological performance of the food.

Chicken meat is a nutrient-dense, high-quality protein source rich in essential amino acids, vitamins, and minerals, while being relatively low in fat and free from cultural or religious restrictions [20,21]. Prior research has showed that for adding chicken meat to foods that are mostly made of cereal and starch can increase the amount of protein, make the food more stable when cooking, and change the way it feels by changing the way proteins and starches interact with each other [22–26]. However, limited research exists on using minced chicken meat in gluten-free, rice-based pasta systems. Most existing studies on protein-enriched pasta focus on plant proteins, dairy proteins, fish powder, or insect protein [7, 12, 27], leaving a clear gap regarding the functional role of chicken meat in gluten-free pasta formulations based on pigmented rice flour.

Therefore, there is a need to systematically investigate whether chicken meat fortification can simultaneously improve the nutritional quality and technological performance of gluten-free pasta made from black glutinous rice flour and tapioca starch, without compromising sensory acceptability.

The objective of this study was to develop gluten-free chicken meat–fortified pasta using black glutinous rice flour and tapioca starch and to evaluate the effects of varying levels of minced chicken meat (0–40 g/100 g) on color characteristics, cooking quality, antioxidant properties, textural attributes, proximate composition, and sensory acceptability. Conventional wheat pasta was used as a reference control. This study aims to offer empirical evidence regarding the feasibility of using chicken meat as a functional protein ingredient in nutritionally enhanced gluten-free pasta.

Table 1 Formulations of chicken meat-fortified pasta (CFP) based on a 70:30 ratio of black glutinous rice flour to cassava starch.

Ingredients (g/100 g)	Formulation (%)				
	WP	CFP 0	CFP 20	CFP 30	CFP 40
Black glutinous rice flour		39.11	35.18	33.49	31.96
Tapioca starch		17.76	15.08	14.35	13.70
Wheat starch	51.02	-	-	-	-
Whole egg fresh	40.82	-	-	-	-
Xanthan gum	-	2.79	2.51	2.39	2.28
Salt	0.51	0.56	0.50	0.48	0.46
Olive oil	1.53	1.68	1.51	1.44	1.37
Minced chicken breast	-	-	10.05	14.35	18.26
Water requirement (ml, approximately)	6.12	39.11	35.18	33.49	31.96

WP: Wheat pasta; CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/ 100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat.

MATERIALS AND METHODS

2.1 Materials and pasta processing

All ingredients were commercially sourced from local markets in Bangkok, Thailand, except the xanthan gum, which was purchased online. Black glutinous rice flour (Fancy Carp Brand®, Charoenworakit Co., Ltd.) and tapioca starch (Red Cat Brand®, Kriangkrai Co., Ltd.) were used as the main carbohydrate sources for gluten-free pasta. Minced chicken breast was obtained from a local retailer (CP Fresh Mart), while refined salt (Prung Thip®, Thai Refined Salt Co., Ltd.), olive oil (Bertolli®, Deoleo), and xanthan gum (Chemipan Corporation Co., Ltd.) were used as additional ingredients. For all

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gluten-free pasta formulations, ingredient proportions were calculated on a 100 g formulation basis. Minced chicken breast was prepared as a meat emulsion by washing and chopping the chicken breast, followed by blending with sodium pyrophosphate (4 g), olive oil (200 g), and crushed ice (300 g) for 3 min. Conventional wheat pasta (WP) was prepared by hand-mixing all-purpose wheat flour (KITE, United Flour Mill Public Co., Ltd.) and fresh whole eggs with salt and olive oil, with the gradual addition of water until a smooth dough formed.

Chicken meat–fortified pasta (CFP) was formulated using a 70:30 ratio of black glutinous rice flour to tapioca starch on a 100 g basis. Dry ingredients were mixed with minced chicken meat, followed by the addition of olive oil and water to form a homogeneous dough. A completely randomized design was applied with chicken meat levels of 0, 20, 30, and 40 g per 100 g formulation, where CFP 0 served as the gluten-free control. Doughs were sheeted to approximately a 1 mm thickness using a pasta laminator (Pluselectric®, China) and cut into 5 mm-wide fettuccine strands. Minced chicken meat partially replaced black glutinous rice flour and tapioca starch, with corresponding adjustments in water and xanthan gum to maintain dough consistency. Detailed formulations are presented in Table 1.

2.2 Color

The color values of the pasta were assessed using a portable colorimeter (Konica Minolta, Model CR-400, Japan) in reflectance mode, with standard D65 lighting and a 2-degree standard observer angle. The lightness (L^*), redness-greenness (a^*), and yellowness-blueness (b^*) values of each sample were measured using the CIE-LAB color system. For each measurement, the sample was assessed at 10 random points on the surface of the cooked pasta. Three measurements were taken at each point, and the average of all measurements was reported.

2.3 Cooking quality evaluation

2.3.1 Optimum cooking time

One gram of dried pasta was placed in a beaker that was covered with a watch glass and brought to a boil in two hundred milliliters of boiling water. The sample was checked every thirty seconds in order to keep track of the amount of time that was necessary for the pasta to reach its desired level of doneness. It was established that the optimal cooking time was the amount of time required for starch gelatinization, which was demonstrated by the removal of the opaque white core that was contained within the pasta when it was pushed between two glass slides.

2.3.2 Cooking Loss

The amount of solid loss during boiling was assessed by analyzing the cooking water used in the cooking yield measurement. The collected water was dried in a hot-air oven at 105°C until a constant weight was achieved. The remaining solids were then weighed, and cooking loss was calculated using the following equation:

$$\text{Cooking loss (\%)} = \left(\frac{\text{Weight of solids after drying}}{\text{Weight of pasta before cooking}}\right) \times 100 \quad (1)$$

2.3.3 Volume Expansion

During the cooking process, the volume expansion of pasta was measured by using a graduated cylinder that was filled with toluene to a volume that had been determined in advance. First, a sample of uncooked pasta weighing 10 grams was inserted into the cylinder from the top. After gently tapping the cylinder to eliminate any air bubbles, the volume increase was measured and recorded. The same procedure was carried out for the pasta that had been cooked, and the volume expansion was determined by applying the equation that is presented below:

Uncooked pasta volume (mL/100 g) = Increase in volume of uncooked pasta × 10

Cooked pasta volume (mL/100 g) = Increase in volume of cooked pasta × 10

Volume expansion due to cooking

$$= \left(\frac{\text{Volume of cooked pasta}}{\text{Volume of uncooked pasta}}\right) \times 100 \quad (2)$$

2.3.4 Swelling index (%)

The method provided in [28] was utilized in order to accomplish the measurements of the swelling index and water absorption of cooked pasta. In order to acquire the constant weight, the swelling index of cooked pasta was dried in a hot air oven at 105 degrees Celsius. The equation that was used to determine the swelling index is as follows:

Water abortion index (%)

$$= \left(\frac{\text{Weight of cooked pasta-Weight of pasta after drying}}{\text{Weight of pasta after drying}}\right) \quad (3)$$

2.4 Antioxidant properties

A modified method of the procedure described in [8] was utilized to extract the pasta samples. A sample of cooked pasta weighing 5 grams was extracted using 10 milliliters of 80% methanol at a speed of 150 revolutions per minute on an orbital agitator for a period of two hours. After that, the mixture was centrifuged for twenty minutes at a speed of fourteen hundred revolutions per minute, and the supernatant was poured out. A second extraction of the silt was carried out under the identical conditions. The antioxidant activities, such as antioxidant activity, total phenolic compound, and anthocyanin content, were determined by combining the supernatants and using them in the analysis.

2.4.1 Antioxidant activity

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The antioxidant activity was determined using a DPPH radical scavenging assay, with slight modifications based on [8]. A 1.0 mL aliquot of pasta extract was mixed with 1.0 mL of 95% ethanol containing 0.15 mM 2,2-diphenyl-1-picrylhydrazyl (DPPH). The mixture was stirred vigorously and allowed to react for 30 minutes at room temperature in the dark. The absorbance of the resulting solution was measured at 517 nm using a UV-spectrophotometer (Thermo Fisher Scientific, Genesys 180, Massachusetts, USA). The respective solvents were used as blanks in place of the DPPH solution. DPPH radical scavenging activity (%DPPH) was calculated using the following equation.

$$\%DPPH = \left[\frac{(A_{517\ of\ control} - A_{517\ of\ sample})}{A_{517\ of\ control}}\right] \times 100 \qquad (4)$$

2.4.2 Total phenolic compounds

The total phenolic content (TPC) of the samples was determined using the Folin–Ciocalteu spectrophotometric method, as described by [29]. with modifications. A 0.1 mL aliquot of pasta extract was added to 0.5 mL of 10% Folin–Ciocalteu reagent and allowed to react for 8 minutes. Then, 4.5 mL of a 2% sodium carbonate (Na_2CO_3) was added, and the mixture was thoroughly mixed and incubated in the dark at 25 °C for 60 minutes. Absorbance was measured at 760 nm using a UV-spectrophotometer (Thermo Fisher Scientific, Genesys 180, Massachusetts, USA). TPC was quantified using a standard calibration curve of gallic acid (Sigma-Aldrich, Steinheim, Germany) at concentrations ranging from 0 to 100 mg/g, and the results were expressed as gallic acid equivalents (GAE) per 100 g of the sample.

2.4.3 Anthocyanin content

Approximately 2 g of pasta was added to a solvent mixture of 98% ethanol and 1.0 mol/L citric acid in an 80:20 ratio. The mixture was stirred for 3 hours, after which the extract was filtered using qualitative Whatman No. 1 filter paper. The residue was then rinsed with the extraction solvent until the final volume reached 50 mL. To determine anthocyanin content, each sample was diluted in two different buffers–potassium chloride buffer (pH 1.0) and a sodium acetate buffer (pH 4.5)–to a final volume of 3 mL. Cyanidin-3-glucoside (Cy-3-GE) was used as the standard. The absorbance of the samples was measured at 520 nm and 700 nm using a UV-vis spectrophotometer (Thermo Fisher Scientific, Genesys, 180, Massachusetts, USA) with distilled water serving as the blank [30]. The anthocyanin content, expressed as mg of Cy-3-GE per gram of dry-weight sample, was then calculated using the following formula:

$$\text{Anthocyanin content} = \frac{A \times MW \times DF \times 1000}{\varepsilon \times I} \qquad (5)$$

A represents the absorbance difference, calculated as:

$$A = (A_{520nm} - A_{700nm})_{pH1.0} - (A_{520nm} - A_{700nm})_{pH4.5} \qquad (6)$$

Where A is the absorbance, MW is the molecular weight for cyanidin-3-glucoside (449.2 g/mol), DF is the dilution factor, and is the molar absorbance of cyanidin-3-glucoside (26,900 L/(cm×mol)), L is the cell path length (1 cm), and 1000 is the conversion factor from milliliter to liter.

2.5 Texture quality analysis

The Texture Profile Analysis (TPA) with two compression cycles test of the cooked pasta samples was conducted using a TA-XT2i Texture Analyzer (Stable Micro Systems, London, UK) equipped with a 25 kg load cell. For TPA analysis, 20 pasta strands were boiled in 1,000 mL of boiling water for 4 minutes. In order to prevent the fast changes in texture that occur shortly after boiling, the texture of the pasta samples was tested five minutes after they were cooked. The samples of cooked pasta were cut to a length of four centimeters and then put through a compression test that consisted of two cycles. A cylindrical probe with a flat end and a diameter of fifty millimeters (P/50) was utilized, and the pre-test speed, test speed, and post-test speed were all adjusted at a speed of five millimeters per second. With a trigger force of 5 grams, the compression strain was 75% of the size it had been when it was first created. Between the first and second compression cycles, there was a rest period of five seconds followed by the compression cycle. For each sample, the test was carried out in triplicate, and the results were given for the following characteristics: hardness (N), adhesiveness (N·s), springiness, and chewiness characteristics.

2.6 Proximate composition

The chemical composition of the control pasta and the selected pasta was performed according to the standard methods of AOAC [31], ash (923.03), lipid (922.06), protein (984.13, nitrogen factors of 6.25); total fiber content (991.43, kit K-TDFR-200 A). Total carbohydrates were calculated by difference. Determinations were made in triplicate.

2.7 Sensory evaluation

The sensory panel consisted of sixty untrained consumers familiar with pasta products. The panel included 19 men and 41 women, aged between 20 and 51 years. Sensory evaluation of cooked pasta samples was conducted at the Faculty of Home Economics Technology, Rajamangala University of Technology Phra Nakhon, Bangkok, Thailand. The pasta samples were cooked under optimum cooking time (OCT) conditions in boiling water without salt, then drained and kept warm until testing. Each sample was coded and presented on white plastic plates. Panelists were provided with water to cleanse their palates between evaluations. Untrained panelists assessed their liking of the pasta

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samples with respect to color, flavor, taste, texture, and overall preference using a 9-point hedonic scale. The study was approved by the Rajamangala University of Technology Phra Nakhon Research Ethics Committee (Approval number, IRB-COE-008-2024) on March 13, 2024.

2.8 Statistical analysis

All experiments were performed in triplicate (n = 3) unless otherwise stated. Data were expressed as means ± standard deviation (SD). Statistical analyses were conducted using the IBM SPSS software (version 23). Significant differences among samples were determined by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at a significance level of $p < 0.05$. Different superscript letters in tables and figures indicate statistically significant differences between means.

RESULTS AND DISCUSSION

3.1 Color of pasta

Chicken meat fortification and raw material composition significantly affected the color parameters (L^*, a^*, and b^*) of cooked pasta ($p < 0.05$), as shown in Table 2 and Figure 1. A clear visual and instrumental distinction was observed between wheat pasta (WP) and chicken-fortified pasta (CFP) produced using black glutinous rice flour and tapioca starch. The WP sample exhibited the highest lightness, together with low redness and high yellowness, which is characteristic of conventional wheat-based pasta (Figure 1a). The bright and yellow appearance of WP is mainly attributed to the presence of carotenoid pigments in wheat flour and the absence of dark-colored phenolic compounds. In contrast, all CFP samples showed significantly lower L^* values, indicating a much darker appearance compared to WP ($p < 0.05$). This substantial reduction in lightness confirms that the substitution of wheat flour with black glutinous rice flour and tapioca starch markedly darkened the pasta matrix.

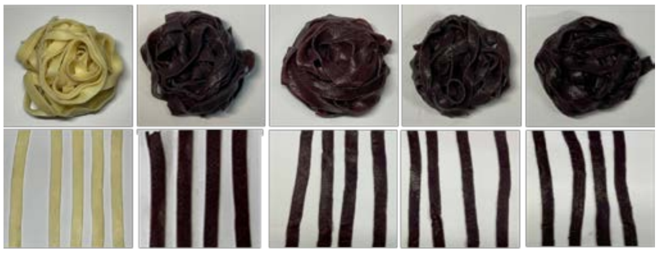

Figure 1 Cooked chicken-fortified pasta (CFP) prepared with varying proportions of black glutinous rice flour and tapioca starch. (a) Wheat pasta (WP); (b) pasta containing 0 g/100 g chicken meat (CFP 0); (c) pasta containing 20 g/100 g chicken meat (CFP 20); (d) pasta containing 30 g/100 g chicken meat (CFP 30); and (e) pasta containing 40 g/100 g chicken meat (CFP 40).

Table 2 Color index of chicken fortified pasta made by black glutinous rice flour and tapioca starch.

Color values	Lightness (L^*)	Redness (a^*)	Yellowness (b^*)
WP	78.46^{a}±0.37	-1.55^{d}±0.13	18.03^{a}±0.44
CFP 0	34.48^{d}±0.18	9.64^{a}±0.85	1.17^{b}±0.12
CFP 20	38.82^{b}±0.55	7.09^{c}±0.85	1.04^{b}±0.12
CFP 30	37.13^{c}±0.57	7.77^{b}±0.50	0.67^{c}±0.29
CFP 40	35.09^{e}±0.43	7.68^{b}±0.89	0.72^{c}±0.13

WP: Wheat pasta, CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat.
^{a,b,c} Different letters in the same column show significant differences among the values ($p<0.05$).

Among the CFP samples, L^* values ranged from 35.09 to 38.82. CFP 20 exhibited the highest lightness, while CFP 40 showed the lowest. Increasing the minced chicken meat content from 20% to 40% resulted in a significant decrease in L^* values ($p < 0.05$), indicating darker pasta. This decrease in lightness was visually evident in Figure 1, where pasta strands became progressively darker with increasing chicken meat content. The dark purple–black color of the CFP samples is primarily attributed to anthocyanins present in black glutinous rice flour, which are responsible for red, purple, and black hues in pigmented rice varieties [32]. The purple–red coloration observed in chicken-fortified pasta was primarily attributed to the high anthocyanin content of black glutinous rice flour. Anthocyanins are water-soluble flavonoid pigments responsible for red, purple, and blue hues in pigmented rice varieties, and their color expression is strongly influenced by the food matrix and processing conditions [33-34]. In the present study, these pigments dominated the visual appearance of the pasta, producing an intense dark purple color regardless of chicken meat addition.

Xanthan gum (XG) and tapioca starch likely contributed to color stability during processing and cooking by improving the structural integrity of the pasta matrix and limiting pigment leaching into the cooking water. Hydrocolloids such as XG are known to enhance water retention, stabilize biopolymer networks, and reduce pigment degradation or migration

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in starch-based systems [35]. Similarly, tapioca starch forms a translucent gel upon gelatinization, which may help preserve anthocyanin intensity and maintain uniform color distribution. At lower inclusion levels, minced chicken meat had a limited influence on pasta color compared to black glutinous rice flour, resulting in strong purple color characteristics. However, higher levels of chicken meat led to a darker and less vivid appearance, which can be attributed to the pale-yellow color of cooked chicken proteins and intensified protein–carbohydrate interactions, including Maillard browning reactions during thermal processing (Martins et al., 2001; Hou, 2010). The increase in $L^*$of partially substituting wheat flour with black glutinous rice flour has also been reported by Subanmanee et al [8] and pasta enriched with anthocyanin-rich black rice bran by [28].

The addition of chicken meat resulted in a considerable rise in the redness (a^*) values of chicken-fortified pasta that was prepared from black glutinous rice flour and cassava starch. The value of the hue known as a^*ranged from 1,91 to 2,85. The a^*value of redness in pasta fortified with 40% minced chicken meat was 2.85 times greater than the value of redness in pasta fortified with 20-30% chicken meat and the control pasta. According to the findings of the research that was conducted in line with [7], the redness a^*value of gluten-free pasta was measured to be higher when 20% cricket powder was added as a supplement. According to [36], when the concentration of coloring pigment was increased, there was a corresponding increase in the value of redness, while there was a corresponding decrease in the value of brightness.

Yellowness (b^*) values showed the most pronounced contrast between WP and CFP samples. WP exhibited a significantly higher b^*value (18.03), reflecting the characteristic yellow color of wheat-based pasta, which is primarily attributed to carotenoid pigments naturally present in wheat flour [37]. In comparison, CFP samples recorded very low b^* values ranging from 0.67 to 1.17 ($p < 0.05$). As the chicken meat content increased from 0% to 40%, the b^*value decreased slightly, indicating reduced yellowness. This reduction highlights the dominant role of black glutinous rice flour in imparting a purple hue due to its high anthocyanin content, which effectively masked the pale-yellow color of cooked chicken meat [33-34]. The decrease in b^* values may also be associated with protein–polysaccharide interactions occurring during pasta processing and cooking, which can suppress yellow coloration in pigmented starch-based systems and promote color darkening [38-39].

As can be observed from the variations in L^*, a^*, and b^* values demonstrate that, the color of cooked pasta was significantly influenced by both the replacement of wheat flour with black glutinous rice flour and the increasing proportion of chicken meat (20–40%). The darker appearance of CFP samples can also be linked to non-enzymatic browning reactions, such as the Maillard reaction, which occur during cooking between reducing sugars and proteins [36]. Protein-enriched noodles have been reported to show large variations in color due to Maillard reaction products and protein-associated pigments, as described by [40]. These reactions likely contributed to the darker and less yellow appearance of chicken-fortified pasta compared to conventional wheat pasta.

3.2 Cooking quality of pasta

The cooking quality parameters of wheat pasta (WP) and chicken meat–fortified pasta (CFP) were significantly affected by formulation differences ($p < 0.05$), as shown in Table 3. Substitution of the starch-based matrix (black glutinous rice flour and tapioca starch) with increasing levels of minced chicken meat (0–40 g/100 g) markedly influenced cooking time, cooking loss, volume expansion, water absorption index (WAI), and water solubility index (WSI). As the chicken meat content increased, the optimum cooking time, water absorption index, and water solubility index increased. In contrast, cooking loss and volume expansion decreased with higher chicken meat incorporation.

WP exhibited a significantly shorter optimum cooking time compared to all CFP samples. Among CFP formulations, cooking time increased progressively with higher chicken meat incorporation, with CFP 40 showing the longest cooking time. The prolonged cooking time in CFP samples may be attributed to competitive hydration among starch, xanthan gum, and chicken proteins, which limited starch swelling and delayed gelatinization. The presence of myofibrillar proteins likely surrounded starch granules and restricted water penetration, particularly at higher protein levels, resulting in slower starch gelatinization during heating [41]. Similar increases in cooking time have been reported in poultry-based noodles [42] and chicken meat–enriched instant noodles [43].

Cooking loss differed significantly between WP and CFP samples ($p < 0.05$). WP exhibited a relatively high cooking loss, whereas CFP samples showed significantly lower values ranging from 4.17% to 6.63%, with the lowest cooking loss observed in CFP 40. The reduction in cooking loss with increasing chicken meat content suggests the formation of a more cohesive and continuous protein-based network, which enhanced structural integrity and reduced the leaching of soluble starch components into the cooking water. In pasta systems, cooking loss is primarily associated with the solubilization and diffusion of loosely bound, gelatinized starch molecules, particularly amylose, during thermal processing [27]. Stronger starch–protein interactions can limit starch granule

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swelling and restrict amylose migration, thereby reducing cooking loss.

The presence of chicken myofibrillar proteins likely contributed to network reinforcement by surrounding starch granules and forming protein–starch complexes that improved resistance to disintegration during boiling. Similar reductions in cooking loss have been reported in protein-enriched pasta and noodles formulated with animal and plant proteins, including chicken meat, fish powder, whey protein, and soy flour, where enhanced protein matrices improved cooking stability [25, 42]. In addition, high amylose retrogradation has been shown to strengthen the starch network, leading to firmer noodle structures and lower cooking losses by stabilizing gelatinized starch during cooking [44-45]. Furthermore, the inclusion of xanthan gum likely played a complementary role by increasing dough cohesiveness and entrapping starch granules within a hydrocolloid-supported matrix, thereby limiting starch leaching. Hydrocolloids are known to improve cooking quality in gluten-free pasta by mimicking the structural function of gluten and enhancing network formation [46]. However, insufficient hydrocolloid concentrations may result in incomplete network development, leading to elevated cooking losses in starch-based gluten-free pasta systems [47].

Volume expansion was highest in WP and CFP 20 and decreased significantly ($p < 0.05$) with increasing chicken meat content, reaching the lowest value in CFP 40. The reduced volume expansion observed in CFP samples may be attributed to the partial replacement of starch with protein, which limited starch gelatinization and swelling during cooking. The formation of a continuous protein network can restrict water accessibility to starch granules and reduce granule disintegration, thereby suppressing volumetric expansion [40]. In addition, increased protein content may dilute the overall starch fraction, further decreasing the extent of starch swelling and expansion. Similar reductions in volume expansion have been reported in pasta enriched with anthocyanin-rich black rice bran [28] and in chicken-based noodles formulated with increasing levels of meat, where protein–starch interactions constrained starch hydration and gelatinization [25].

The water absorption index (WAI) increased significantly ($p < 0.05$) with higher levels of chicken meat incorporation, ranging from 1.22 g/g in CFP 0 to 1.79 g/g in CFP 40, while WP exhibited a lower WAI value. The increase in WAI can be attributed to the higher availability of polar and charged amino acid side chains in chicken proteins, which provide additional hydrophilic sites for water binding. Furthermore, protein denaturation during cooking, disruption of starch granules, and swelling of dietary fiber components may collectively enhance water absorption capacity in protein-enriched pasta systems [48-49]. An elevated WAI is generally associated with improved hydration, increased viscosity, and enhanced textural properties of cooked pasta and noodle products [46].

Table 3 Cooking quality of chicken fortified pasta (CFP) made from black glutinous rice flour and tapioca starch.

Sample	Cooking time (min)	Cooking losses (%)	Volume Expansion (%)	Water absorption index (g/g)	Water solubility index (%)
WP	$7.65^d±0.03$	$7.29^a±0.13$	$249.53^a±2.87$	$1.47^d±0.05$	$0.089^b±0.002$
CFP 0	$5.55^e±0.03$	$4.45^d±0.03$	$107.21^e±1.96$	$1.22^e±0.10$	$0.094^a±0.004$
CFP 20	$9.17^c±0.03$	$6.63^b±0.10$	$213.47^b±2.18$	$1.59^c±0.08$	$0.076^c±0.002$
CFP 30	$10.55^b±0.05$	$5.51^c±0.073$	$185.21^c±1.55$	$1.63^b±0.02$	$0.072^c±0.003$
CFP 40	$11.16^a±0.02$	$4.17^e±0.04$	$159.44^d±2.13$	$1.79^a±0.02$	$0.062_d±0.002$

WP: Wheat pasta, CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat.
[a,b,c] Different letters in the same column show significant differences among the values ($p<0.05$).

In contrast, the water solubility index (WSI) decreased progressively with increasing chicken meat content, with CFP 40 exhibiting the lowest solubility. WP and CFP 0 showed significantly higher WSI values, indicating greater leaching of soluble components into the cooking water. The reduction in WSI at higher protein levels suggests improved structural integrity and reduced starch solubilization, likely due to stronger protein–starch interactions, formation of protein–starch complexes, and dilution of the carbohydrate fraction [25, 50]. Similar inverse relationships between WAI and WSI have been reported in protein-enriched noodles and gluten-free pasta systems, where increased protein content enhanced water retention while limiting solubilization losses during cooking [36,40]. Overall, these results demonstrate that chicken meat fortification substantially modified the cooking behavior of pasta, yielding products with enhanced water absorption, improved cooking stability, and reduced solubility compared to conventional wheat pasta.

3.3 Antioxidant properties

The antioxidant activity, total phenolic compound (TPC) content, and anthocyanin content of wheat pasta (WP) and chicken meat–fortified pasta

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(CFP) differed significantly among formulations ($p < 0.05$), as shown in Table 4 and Figure 1. WP exhibited the lowest antioxidant activity and TPC content, with anthocyanins not detected. This result is expected, as refined wheat flour contains negligible amounts of anthocyanin pigments and low levels of phenolic compounds [50]. Although WP contained fresh egg, which is a source of nutritive and non-nutritive bioactive compounds with antioxidant potential [49], its contribution was insufficient to markedly enhance the antioxidant capacity compared with CFP samples.

In contrast, all CFP formulations exhibited significantly higher antioxidant activity, TPC, and anthocyanin content than WP ($p < 0.05$), primarily due to the inclusion of black glutinous rice flour. CFP 0 showed the highest antioxidant activity, TPC, and anthocyanin content, reflecting the strong contribution of anthocyanins and phenolic compounds naturally present in black glutinous rice. These bioactive compounds are known to possess strong free radical–scavenging activity and are responsible for the characteristic purple coloration observed in CFP samples (Figure 1) [4-5].

However, a decreasing trend in antioxidant activity, TPC, and anthocyanin content was observed as the level of chicken meat increased from 20% to 40%. This reduction can be attributed to the partial replacement of black glutinous rice flour with chicken meat, which diluted the concentration of rice-derived phenolic compounds and anthocyanins in the formulation. Similar trends have been reported by Subanmanee et al. [8], who observed reductions in antioxidant activity, TPC, and anthocyanin content in pasta when black glutinous rice flour partially replaced wheat flour. Likewise, Sethi et al. [28] reported a decrease in DPPH scavenging activity, FRAP values, and anthocyanin content as the proportion of black rice bran in pasta formulations decreased.

Although chicken meat contains endogenous bioactive compounds and has been reported to exhibit measurable antioxidant activity and phenolic content [51], its antioxidant contribution was relatively small compared to that of black glutinous rice flour. Therefore, increasing chicken meat levels did not compensate for the reduction in rice-derived phenolics. Additionally, xanthan gum did not contribute to antioxidant activity, as it functions primarily as a structural hydrocolloid without inherent bioactive properties [52]. These results demonstrate that the antioxidant properties of CFP were mainly governed by the level of black glutinous rice flour rather than chicken meat content. Nevertheless, even at the highest chicken meat level (CFP 40), antioxidant activity and phenolic content remained significantly higher than those of WP. This indicates that gluten-free chicken meat–fortified pasta made from black glutinous rice flour and tapioca starch can serve as a functional food with enhanced antioxidant potential while simultaneously providing improved protein content.

Table 4 Antioxidant activities, total phenolic compounds and anthocyanin content of cooked chicken fortified pasta (CFP) made from black glutinous rice flour and tapioca starch at different percentages of meat.

Sample	Antioxidant activities (%DPPH)	Total phenolic compounds (mg GAE/100 g)	Anthocyanin content (Cyanidin-3-O-glucoside; mg/g)
WP	$38.93^{e}±0.45$	$0.78^{e}±0.12$	ND
CFP 0	$57.44^{a}±0.31$	$1.64^{a}±0.08$	$2.35^{a}±0.03$
CFP 20	$54.52^{b}±0.82$	$1.56^{b}±0.11$	$2.18^{b}±0.02$
CFP 30	$48.06^{c}±0.65$	$1.48^{c}±0.07$	$2.05^{c}±0.02$
CFP 40	$46.28^{d}±0.63$	$1.42^{d}±0.09$	$2.13^{b}±0.04$

WP: Wheat pasta, CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat. ND is not detected.
^{a,b,c} Different letters in the same column show significant differences among the values ($p < 0.05$)

3.4 Texture quality analysis

Texture is one of the most decisive quality attributes influencing consumer acceptance of pasta products, particularly in gluten-free formulations where the absence of gluten compromises structural integrity. The texture profile analysis (TPA) parameters of cooked pasta samples, including wheat pasta (WP) and chicken-fortified gluten-free pasta (CFP), are presented in Table 5.

Hardness values varied significantly ($p < 0.05$) among formulations, ranging from 135.89 to 226.76 N. The WP sample exhibited relatively high hardness, reflecting the well-developed gluten network formed by wheat proteins, which provides mechanical strength and firmness to conventional pasta products [47, 53]. Among the gluten-free samples, CFP20 recorded the highest hardness value, significantly exceeding both WP and other formulations. This suggests that moderate incorporation of chicken meat (20 g/100 g) may initially enhance the structural rigidity of the pasta matrix through protein–hydrocolloid interactions. CFP0, which contained no chicken meat but included 3.0% xanthan gum, exhibited the lowest hardness (135.89 N). Xanthan gum is commonly used in gluten-free formulations to mimic gluten functionality

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by forming a viscoelastic gel network; however, without sufficient protein reinforcement, the resulting matrix may remain comparatively weak [54]. As chicken meat content increased beyond 20%, hardness declined (CFP30 and CFP40), likely due to dilution of starch granules and excessive moisture introduced by minced meat. Similar trends have been reported in fish- and meat-enriched pasta, where myofibrillar proteins disrupt the continuous starch matrix, weakening the three-dimensional structure and reducing firmness [25,55]. These findings indicate that while chicken meat enhances nutritional value, excessive inclusion compromises textural strength.

Adhesiveness values were significantly higher (more negative) in chicken-fortified pasta than in WP ($p < 0.05$). WP showed the lowest adhesiveness, consistent with its compact gluten network that limits starch leaching during cooking. In contrast, CFP0 exhibited the highest adhesiveness, indicating greater surface stickiness. This phenomenon is associated with the leaching of starch granules into cooking water, which subsequently form a viscous layer on the pasta surface [47]. As the proportion of chicken meat increased, adhesiveness progressively decreased, suggesting reduced starch availability and altered surface characteristics. The partial replacement of starch with meat proteins appears to mitigate excessive stickiness by limiting starch swelling and diffusion.

Cohesiveness reflects the internal bonding strength of the pasta matrix during deformation. WP demonstrated the highest cohesiveness value, confirming the superior integrity of gluten-based pasta [56]. All chicken-fortified samples exhibited significantly lower cohesiveness (0.81–0.84), indicating weaker internal bonds. The reduction in cohesiveness with chicken incorporation may be attributed to limited interactions between meat proteins and starch granules, resulting in a less uniform matrix. These findings align with previous studies on protein-enriched gluten-free pasta, where added animal proteins disrupted starch continuity and reduced matrix stability [25, 55].

Table 5 Texture profile analysis of cooked free gluten pasta with black glutinous rice flour and tapioca starch.

Texture attributes	Formulation (%Ratio of black glutinous rice flour and tapioca starch)				
	WP	**CFP 0**	**CFP 20**	**CFP 30**	**CFP 40**
Hardness (N)	$174.76^{b}\pm17.07$	$135.89^{d}\pm7.50$	$226.76^{a}\pm11.28$	$170.46^{b}\pm14.41$	$168..03^{c}\pm12.62$
Adhesiveness (N.J)	$-0.52^{d}\pm0.09$	$-1.47^{a}\pm0.14$	$-1.09^{b}\pm0.12$	$- 0.68^{c}\pm0.10$	$-0.63^{c}\pm0.08$
Cohesiveness	$0.92^{a}\pm0.01$	$0.81^{b}\pm0.02$	$0.84^{b}\pm0.01$	$0.84^{b}\pm0.03$	$0.82^{b}\pm0.03$
Springiness (%)	$93.46^{a}\pm7.19$	$79.40^{b}\pm0.06$	$77.36^{b}\pm0.08$	$70.70^{c}\pm0.07$	$66.80^{d}\pm0.06$
Gumminess (N)	$161.33^{b}\pm15.68$	$110.62^{e}\pm3.46$	$172.08^{a}\pm17.23$	$144.02^{c}\pm16.44$	$138.22^{d}\pm9.62$
Chewiness (N)	$150.67^{a}\pm11.84$	$87.98^{e}\pm4.32$	$134.03^{b}\pm7.22$	$101.41^{c}\pm8.02$	$92.28^{d}\pm7.10$

WP: Wheat pasta, CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat
a,b,c Different letters in the same row show significant differences among the values ($p< 0.05$).

Springiness describes the ability of pasta to recover its original shape after compression and is closely related to elasticity. WP exhibited the highest springiness, significantly outperforming all gluten-free samples ($p < 0.05$). This result highlights the fundamental role of gluten in conferring elastic recovery to pasta structures [57]. Chicken-fortified pasta showed a progressive decline in springiness with increasing meat content, reaching the lowest value in CFP40. The absence of gluten proteins in black glutinous rice flour and tapioca starch, coupled with the limited elastic properties of meat proteins, likely contributed to this reduction [58]. Similar reductions in springiness have been reported in gluten-free pasta formulations enriched with non-gluten proteins [47, 53].

Gumminess, defined as the force required to disintegrate semi-solid foods during mastication [59], differed significantly among samples ($p < 0.05$). CFP20 exhibited the highest gumminess, surpassing WP, which suggests enhanced resistance to deformation at moderate chicken inclusion levels. However, gumminess decreased markedly with further increases in chicken meat content, reaching the lowest value in CFP0 and CFP40. The observed reduction may be attributed to diminished starch-protein interactions and the absence of gluten, which collectively weaken the structural resistance of the pasta matrix.

Chewiness, a composite parameter derived from hardness, cohesiveness, and springiness, followed trends similar to gumminess. WP showed the highest chewiness, reflecting its dense and elastic gluten network [60]. Among the gluten-free samples, CFP20 again exhibited relatively high chewiness, while CFP0 recorded the lowest value. Increasing chicken meat levels beyond 20% resulted in a significant reduction in chewiness, likely due to increased cooking loss and starch leaching, which diminish elastic resistance [60]. Although CFP40 maintained a comparatively rigid structure, its reduced cohesiveness and springiness led to lower overall chewiness.

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Collectively, these results demonstrate that WP consistently outperformed gluten-free formulations in terms of cohesiveness, springiness, and chewiness due to the presence of gluten. However, strategic incorporation of chicken meat at moderate levels improved certain textural attributes, such as hardness and gumminess, suggesting a partial compensation for the absence of gluten. Excessive chicken meat inclusion, however, weakened the pasta matrix by disrupting starch continuity and increasing moisture content. These findings highlight the importance of optimizing protein type and concentration in gluten-free pasta formulations to balance nutritional enhancement with desirable textural quality.

3.5 Proximate composition

The chemical composition of wheat pasta (WP) and chicken-fortified gluten-free pasta (CFP) formulations is presented in Table 6, and significant differences ($p < 0.05$) were observed among samples for all measured parameters. WP exhibited the lowest moisture content compared with CFP formulations, reflecting the stronger gluten network formed by wheat proteins, which limits water uptake and retention during processing and cooking [47,53]. In contrast, moisture content increased progressively with increasing chicken meat incorporation, reaching the highest values in CFP30 and CFP40. This trend can be attributed to the high water-holding capacity of muscle proteins and the presence of hydrophilic groups in myofibrillar proteins, which enhance moisture retention in meat-enriched pasta systems [25, 55]. CFP0, formulated without wheat flour, egg, or chicken meat, showed moderately higher moisture than WP due to the combined effects of starch gelatinization and the water-binding capacity of xanthan gum, despite the absence of animal proteins.

Ash content differed significantly among formulations, with CFP40 exhibiting the highest value, followed by WP and CFP30, while CFP0 showed the lowest ash content. The increase in ash with chicken meat addition reflects the contribution of minerals naturally present in poultry meat, including phosphorus, potassium, and iron [61]. WP showed relatively high ash content due to the mineral contribution from wheat flour and egg, whereas the reduced ash level in CFP0 is consistent with its starch-dominant composition and limited mineral sources.

Protein content varied markedly among samples and increased significantly with higher chicken meat levels. CFP40 exhibited the highest protein content, surpassing WP, highlighting the effectiveness of chicken breast as a high-quality protein source. Similar increases in protein content have been reported in meat- and fish-fortified pasta products [25, 55]. CFP0 showed the lowest protein content, reflecting the inherently low protein levels of black glutinous rice flour and tapioca starch and the absence of gluten, egg, or animal protein. These results demonstrate that chicken meat incorporation substantially enhances the nutritional profile of gluten-free pasta, particularly in terms of protein enrichment.

Crude fat content also increased significantly with increasing chicken meat inclusion, ranging from 1.21% in CFP0 to 3.43% in CFP40. The elevated fat content in CFP formulations is primarily associated with intramuscular lipids present in chicken meat, while the relatively low-fat content of WP and CFP0 reflects the limited contribution from wheat flour, starches, and olive oil alone [62]. Crude fiber content exhibited an inverse trend, decreasing progressively with increasing chicken meat levels. WP and CFP0 showed the highest fiber contents, attributable to cereal-derived components, while higher meat substitution diluted fiber concentration in CFP30 and CFP40. Similar dilution effects have been observed in protein-enriched pasta products [47, 62].

In general, the results show that substituting black glutinous rice flour and tapioca starch for wheat flour changes the chemical makeup of pasta to large extent. Adding chicken meat gradually increases the protein, fat, ash, and moisture content while lowering the crude fiber content. These changes in composition show the balance between adding nutrients and replacing ingredients. They show that adding chicken meat is a beneficial way to improve the nutritional quality of gluten-free pasta, even though it has a big effect on its physicochemical properties.

Table 6 Chemical composition of control pasta and chicken fortified pasta made from black glutinous rice flour and tapioca starch.

Sample	Moisture content (%)	Ash (%)	Protein content (%)	Crude fat (%)	Crude fiber (%)
WP	$55.18^{c}\pm1.34$	$2.45^{b}\pm0.06$	$16.04^{ab}\pm0.31$	$1.59^{d}\pm0.08$	$0.26^{a}\pm0.12$
CFP 0	$58.12^{c}\pm0.62$	$1.91^{d}\pm0.07$	$4.21^{d}\pm0.29$	$1.21^{e}\pm0.07$	$0.25^{a}\pm0.05$
CFP 20	$60.27^{b}\pm0.21$	$2.03^{c}\pm0.08$	$11.863^{c}\pm0.49$	$2.54^{c}\pm0.06$	$0.21^{b}\pm0.06$
CFP 30	$68.37^{a}\pm0.65$	$2.31^{b}\pm0.06$	$14.705^{b}\pm0.29$	$2.99^{b}\pm0.09$	$0.18^{c}\pm0.03$
CFP 40	$69.11^{a}\pm0.66$	$2.86^{a}\pm0.09$	$18.895^{a}\pm0.54$	$3.43^{a}\pm0.11$	$0.14^{d}\pm0.08$

WP: Wheat pasta, CFP 0: Control pasta, without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat.
[a,b,c] Different letters in the same column show significant differences among the values ($p < 0.05$).

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3.6 Sensory evaluation

The sensory evaluation results of wheat pasta (WP) and chicken meat–fortified gluten-free pasta (CFP) are presented in Table 7 and show trends closely aligned with the instrumental texture profile (Table 5) and chemical composition data (Table 6). All samples received mean scores above the minimum threshold for liking of pasta attributes, indicating that the incorporation of chicken meat did not reduce overall preference. Significant differences ($p < 0.05$) were observed among formulations for all sensory attributes. WP consistently received the highest scores for appearance, smell, taste, texture, and overall preference. This can be attributed to its balanced chemical composition and well-developed gluten network, which contributed to cohesive, springy, and chewy texture, as confirmed by texture profile analysis. Additionally, the moderate moisture and fat contents of WP enhanced the familiar mouthfeel and flavor perception, which are known to positively influence panelists' preference [25, 54].

Among the chicken-fortified samples, CFP 20 exhibited sensory scores most comparable to WP, particularly for appearance and color, which were not significantly different ($p > 0.05$). This is consistent with the moderate moisture content and protein level of CFP 20 (Table 6), resulting in relatively high hardness, gumminess, and chewiness values compared with CFP 30 and CFP 40 (Table 5). These instrumental properties translated into a firmer, more pasta-like texture perceived by panelists. The acceptable visual attributes of CFP 20 suggest that the color imparted by black glutinous rice flour and the inclusion of chicken meat at this level did not negatively affect appearance, despite deviations from traditional wheat pasta. However, odor, taste, and overall preference scores of CFP 20 were significantly lower than those of WP ($p < 0.05$), likely due to differences in flavor development associated with the absence of wheat gluten and egg and the relatively mild meat flavor, as reported in previous studies on meat-enriched pasta and noodles [25, 62].

Increasing the chicken meat content to 30% and 40% led to a significant decline ($p < 0.05$) in most sensory attributes, particularly texture and overall preference. These reductions correspond with the instrumental texture results, which showed decreased cohesiveness and springiness and increased moisture and fat contents at higher meat inclusion levels. Such compositional changes likely produced a softer, less elastic structure and a denser mouthfeel, negatively affecting panelists' preference. The decline in appearance and color scores at elevated chicken meat levels may be attributed to intensified enzymatic browning, lipid oxidation, and Maillard reactions during processing and cooking, which are more pronounced in protein- and lipid-rich systems [61-62]. Similar sensory trends have been reported in refined wheat flour–based noodles and gluten-free pasta fortified with chicken meat or meat powders [25, 61-62].

Overall preference followed a pattern similar to texture perception, highlighting the strong influence of structural integrity and compositional balance on panelists' preference. CFP 30 and CFP 40 contained higher protein and fat than CFP 20 (Table 6), but these nutritional benefits were offset by less favorable texture and taste. Among the chicken-fortified formulations, CFP 20 achieved the most balanced sensory profile, providing enhanced nutritional value while maintaining desirable texture, flavor, and visual attributes. The relatively favorable performance of CFP 20 can be attributed to optimal interactions among starch, xanthan gum, and chicken meat proteins, which improved binding capacity and emulsion stability without excessively disrupting the starch-based matrix. These findings align with previous studies demonstrating that moderate protein enrichment, combined with hydrocolloids such as xanthan gum, can partially mimic gluten functionality and improve the sensory quality of gluten-free pasta products [7, 15, 56].

Table 7 Sensory attributes of cooked gluten-free pasta with black glutinous rice flour and tapioca starch

Sensory attributes	**Formulation (%Ratio of black glutinous rice flour and tapioca starch)**			
	WP	**CFP 20**	**CFP 30**	**CFP 40**
Appearance	6.64^{a}±0.48	6.71^{a}±0.46	6.42^{b}±0.54	6.70^{a}±0.46
Color	6.28^{ab}±0.70	6.48^{a}±0.50	6.22^{b}±0.62	6.16^{b}±0.62
Odor	6.66^{a}±0.48	6.12^{b}±0.48	5.94^{b}±0.65	5.92^{b}±0.49
Taste	6.50^{a}±.0.51	6.26^{b}±0.53	6.32^{ab}±0.47	6.18^{b}±0.39
Texture	6.86^{a}±0.64	6.62^{b}±0.53	6.22^{c}±0.55	6.16^{c}±0.55
Overall preference	7.16^{a}±0.55	6.70^{b}±0.46	6.64^{b}±0.53	6.50^{b}±0.74

WP: Wheat pasta without chicken meat 0 g/100 g; CFP 20: pasta with 20 g/100 g chicken meat; CFP 30: pasta with 30 g/100 g chicken meat; CFP 40: pasta with 40 g/100 g chicken meat.
^{a,b,c} Different letters in the same row show significant differences among the values ($p < 0.05$).

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CONCLUSIONS

In this study, gluten-free pasta formulated from black glutinous rice flour and tapioca starch was successfully fortified with minced chicken meat, resulting in products with enhanced nutritional and functional properties. Incorporation of black glutinous rice flour significantly improved antioxidant activity, total phenolic content, and anthocyanin levels compared with wheat pasta, while chicken meat addition increased protein, fat, ash, and moisture contents. Increasing chicken meat levels improved cooking stability by reducing cooking loss and water solubility and increasing water absorption, but also prolonged cooking time. Texture analysis showed that moderate chicken meat incorporation (20 g/100 g) improved hardness and gumminess and yielded sensory acceptability closest to that of wheat pasta, whereas higher levels (30–40 g/100 g) negatively affected cohesiveness, springiness, and chewiness. Overall, a formulation containing 20 g/100 g chicken meat provided the best balance between improved nutritional value, desirable cooking and textural properties, and consumer acceptance, demonstrating its potential for the development of protein-enriched, functional gluten-free pasta.

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REFERENCE

1. Sissons M. Development of novel pasta products with evidence-based impacts on health-A review. Foods. 2022;11(1):123.
2. Scarton M, Clerici MTPS. Gluten-free pastas: Ingredients and processing for technological and nutritional quality improvement. Food Sci Technol. 2022;42:65622.
3. da Silva Ramos NJ, Rocha EBM, Gusmão TAS, Nascimento A, Lisboa HM, de Gusmão RP. Optimizing gluten-free pasta quality: The impacts of transglutaminase concentration and kneading time on cooking properties, nutritional value, and rheological characteristics. LWT. 2023;189:115485.
4. Poonia A, Pandey S. Bioactive compounds, nutritional benefits and food applications of black rice: A review. NFS. 2021;52(3):466-82.
5. Phonsakhan W, Kong-Ngern K. A comparative proteomic study of white and black glutinous rice leaves. Electron J Biotechnol. 2015;18(1):29-34.
6. Kong S, Kim DJ, Oh SK, Choi IS, Jeong HS, Lee J. Black rice bran as an ingredient in noodles: chemical and functional evaluation. J Food Sci. 2012;77(3):C303-7.
7. Musika J, Kapcum C, Itthivadhanapong P, Musika T, Hanmontree P, Piayura S. Enhancing nutritional and functional properties of gluten-free Riceberry rice pasta supplemented with cricket powder using D-optimal mixture design. Front Sustain Food Syst. 2024;8:1417045.
8. Subanmanee N, Sarasuk C, Wongtom R, Khampaen W. Changes in the physical, chemical and sensory properties of pasta made by partially substituting wheat flour with black glutinous rice flour. AJFAND. 2024;24(8):24138-60.
9. Raungrusmee S, Shrestha S, Sadiq MB, Anal AK. Influence of resistant starch, xanthan gum, inulin and defatted rice bran on the physicochemical, functional and sensory properties of low glycemic gluten-free noodles. LWT. 2020;126:109279.
10. Sirichokworrakit S, Phetkhut J, Khommoon A. Effect of partial substitution of wheat flour with riceberry flour on quality of noodles. Procedia Soc Behav Sci. 2015;197:1006-12.
11. Yilmaz MT, Yildiz Ö, Yurt B, Toker OS, Karaman S, Baştürk A. A mixture design study to determine interaction effects of wheat, buckwheat, and rice flours in an aqueous model system. LWT. 2015; 61(2):583-9.
12. Messia MC, Cuomo F, Falasca L, Trivisonno MC, De Arcangelis E, Marconi E. Nutritional and technological quality of high protein pasta. Foods. 2021;10(3):589.
13. Milde LB, Chigal PS, Olivera JE, González KG. Incorporation of xanthan gum to gluten-free pasta with cassava starch. Physical, textural and sensory attributes. LWT. 2020;131:109674.
14. Rachman A, Brennan MA, Morton J, Brennan CS. Gluten-free pasta production from banana and cassava flours with egg white protein and soy protein addition. Int J Food Sci Technol. 2020:55 (8):3053-60.
15. Cai J, Chiang JH, Tan MYP, Saw LK, Xu Y, Ngan-Loong MN. Physicochemical properties of hydrothermally treated glutinous rice flour and xanthan gum mixture and its application in gluten-free noodles. J Food Eng. 2016;186:1-9.
16. Sanguinetti AM, Secchi N, Del Caro A, Fadda C, Fenu PA, Catzeddu P, et al. Gluten-free fresh filled pasta: The effects of xanthan and guar gum on

DOI: 10.60101/jarst.2026.262683

changes in quality parameters after pasteurisation and during storage. LWT. 2015;64(2):678-84.

17. Susanna S, Prabhasankar P. A study on development of Gluten free pasta and its biochemical and immunological validation. LWT. 2013;50(2):613-21.

18. Norma VM, García-Zepeda R A, Mitzy Belén O H, Morales-Guerrero JC. Gluten-free pasta as an alternative in the diet of patients with celiac disease. J Food Sci. 2024;89(6):3384-99.

19. Olson R, Gavin-Smith B, Ferraboschi C, Kraemer K. Food fortification: The advantages, disadvantages and lessons from sight and life programs. Nutr. 2021;13(4):1118.

20. Smith DP, Northcutt JK, Steinberg EL. Meat quality and sensory attributes of a conventional and a Label Rouge-type broiler strain obtained at retail. Poult Sci. 2012;91(6):1489-95.

21. Hailemariam A, Esatu W, Abegaz S, Urge M, Assefa G, Dessie T. Nutritional composition and sensory characteristics of breast meat from different chickens. Appl Food Res. 2022;2(2):100233.

22. Cakmak H, Altinel B, Kumcuoglu S, Tavman S. Chicken meat added bread formulation for protein enrichment. Food Feed Res. 2013;40(1):33-42.

23. Cakmak H, Altinel B, Kumcuoglu S, Kisla D, Tavman S. Production of crispy bread snacks containing chicken meat and chicken meat powder. An Acad Bras Ciênc. 2016;88(4):2387-99.

24. Liu Y, Chen K, Zeng Q, Wang P, Zhang Y. The impact of dietary fibers on the construction and molecular network of extrusion-based 3D-printed chicken noodles: Unlocking the potential of specialized functional food. Food Chem. 2025;463:141065.

25. Verma AK, Pathak V, Singh VP. Quality characteristics of value-added chicken meat noodles. J Nutr Food Sci. 2014;4(1):1.

26. Lee C, Choi G, Cho S. Physicochemical and sensory characteristics of gluten-free noodles added with chicken breast meat: a comparative study with wheat flour noodle. Food Sci Biotechnol. 2024;33(6):1351-58.

27. Gopalakrishnan J, Menon R, Padmaja G, Sajeev MS, Moorthy SN. Nutritional and functional characteristics of protein-fortified pasta from sweet potato. FNS. 2011;2(9):944-55.

28. Sethi S, Nanda SK, Bala M. Quality assessment of pasta enriched with anthocyanin-rich black rice bran. J Food Process Preserv. 2020;44(12):e14952.

29. Mohamad A, Shah NNAK, Sulaiman A, Adzahan NM, Aadil RM. Characterization of rice noodles fortified with different levels of stabilized rice bran. Food Res. 2024;8(7):16-27.

30. Pang Y, Ahmed S, Xu Y, Beta T, Zhu Z, Shao Y, et al. Bound phenolic compounds and antioxidant properties of whole grain and bran of white, red and black rice. Food Chem. 2018;240:212-21.

31. AOAC. Official methods of analysis (17th ed). The Association of Official Analytical Chemists. 2000

32. Chen T, Xie L, Wang G, Jiao J, Zhao J, Yu Q, et al. Anthocyanins-natural pigment of colored rice bran: Composition and biological activities. Food Res Int 2024;175:113722.

33. ElShamey EA, Yang X, Yang J, Pu X, Yang L, Ke C, et al. Occurrence, Biosynthesis, and Health Benefits of Anthocyanins in Rice and Barley. Int J Mol Sci. 2025;26(13):6225

34. Sompong R, Siebenhandl-Ehn S, Linsberger-Martin G, Berghofer E. Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China, and Sri Lanka. Food Chem. 2011;124(1):132-40.

35. Kraithong S, Rawdkuen S. Effects of food hydrocolloids on quality attributes of extruded red Jasmine rice noodle. PeerJ. 2020;8:e10235.

36. Chhikara N, Kushwaha K, Jaglan S, Sharma P, Panghal A. Nutritional, physicochemical, and functional quality of beetroot (*Beta vulgaris L.*) incorporated Asian noodles. Cereal Chem. 2019;96(1):154-61.

37. Sofi SA, Singh J, Chhikara N, Panghal A, Gat Y. Quality characterization of gluten free noodles enriched with chickpea protein isolate. Food Biosci. 2020;36:100626.

38. Chang HC, Chen HH, Hu HH. Textural changes in fresh egg noodles formulated with seaweed powder and full or partial replacement of cuttlefish paste. J Texture Stud. 2011;42(1):61-71.

39. Martins SIFS, Jongen WMF, van Boekel MAJS. A review of Maillard reaction in food and implications to kinetic modelling. Trends Food Sci Technol. 2001;11(9–10):364-73.

40. Pal GK, Kumar SB, Prabhasankar P, Suresh PV. Inclusion of poultry-based food ingredients in the formulation of noodles and their effects on noodle quality characteristics. J Food Meas. Charact. 2017;11:939-47.

DOI: 10.60101/jarst.2026.262683

41. Pongpichaiudom A, Songsermpong S. Evaluation of microstructure and quality characteristics of microwave-dried instant noodles enriched with chicken meat, egg yolk, and seaweed. J Food Meas Charact. 2018;12:22-34.

42. Tian Y, Zhang L, Xu X, Xie Z, Zhao J, Jin Z. Effect of temperature-cycled retrogradation on slow digestibility of waxy rice starch. Int J Biol Macromol. 2012;51(5):1024-27.

43. Tam LM, Corke H, Tan WT, Li J, Collado LS. Production of bihon-type noodles from maize starch differing in amylose content. Cereal Chem. 2004;81(4):475-80.

44. Liu XL, Mu TH, Sun HN, Zhang M, Chen JW. Influence of potato flour on dough rheological properties and quality of steamed bread. J Integr Agric. 2016;15(11):2666-76.

45. Liu Y, Xu M, Wu H, Jing L, Gong B, Gou M, et al. The compositional, physicochemical and functional properties of germinated mung bean flour and its addition on quality of wheat flour noodle. J. Food Sci Technol. 2018;55:5142-52.

46. Nimalaratne C, Lopes-Lutz D, Schieber A, Wu J. Free aromatic amino acids in egg yolk show antioxidant properties. Food Chem. 2011;129(1):155-61.

47. Marti A, Pagani MA. What can play the role of gluten in gluten free pasta? Trends in Food Science and Technology. 2013;31(1):63-71.

48. Abdel-Aal ESM, Young JC, Rabalski I. Anthocyanin composition in black, blue, pink, purple, and red cereal grains. J Agric Food Chem. 2006;54(13):4696-704.

49. Okarini IA, Purnomo H, Aulanni'am AA, Radiati LE. Proximate, total phenolic, antioxidant activity and amino acids profile of Bali indigenous chicken, spent laying hen and broiler breast fillet. Int J Poult Sci. 2013;12(7):415-20.

50. Widelska G, Wójtowicz A, Kasprzak K, Dib A, Oniszczuk T, Olech M, et al. Impact of xanthan gum addition on phenolic acids composition and selected properties of new gluten-free maize-field bean pasta. Open Chem. 2019;17(1):587-98.

51. Hua Y, Cui SW, Wang Q. Gelling property of soy protein–gum mixtures. Food Hydrocoll. 2003;17(6):889-94.

52. Ainsa A, Roldan S, Marquina PL, Roncalés P, Beltrán JA, Calanche Morales JB. Quality parameters and technological properties of pasta enriched with a fish by-product: A healthy novel food. J Food Process. Preserv. 2022;46(2):e16261.

53. Barak S, Mudgil D, Khatkar BS. Effect of compositional variation of gluten proteins and rheological characteristics of wheat flour on the textural quality of white salted noodles. Int J Food Prop. 2014;17(4):731-40.

54. Bouasla A, Wójtowicz A. Gluten-free rice instant pasta: Effect of extrusion-cooking parameters on selected quality attributes and microstructure. Processes. 2021;9(4):693.

55. Larrosa V, Lorenzo G, Zaritzky N, Califano A. Improvement of the texture and quality of cooked gluten-free pasta. LWT. 2016;70:96-103.

56. Halim Y, Angelina B, Hardoko H, Handayani R. Characteristics of dried noodle analogue made from sorghum flour and rice flour added with konjac glucomannan. In IOP Conference Series: Earth and Environmental Science. IOP Publishing. 2023;1200(1):012032.

57. Szczesniak AS. Texture is a sensory property. Food Qual. Prefer. 2002;13(4):215-25.

58. Sozer N, Dalgıç AC, Kaya A. Thermal, textural and cooking properties of spaghetti enriched with resistant starch. J Food Eng. 2007;81(2):476-84.

59. Zayas JF. Functionality of Proteins in Food, 1st ed.; Springer: Berlin/Heidelberg, Germany, 1997.

60. Kumar S, Khanna N, Vaquil RD, Yadav S. Development and evaluation of quality of noodles enriched with chicken meat powder. Int J Curr Microbiol App Sci. 2019;8(8):2282-9.

61. Verma AK, Pathak V, Umaraw P, Singh VP. Quality characteristics of refined wheat flour (maida) based noodles containing chicken meat stored at ambient temperature under aerobic conditions. Nutr Food Sci. 2015;45(5):753-65.

62. Litaay C, Indriati A, Mayasti NKI, Tribowo RI, Andriana Y, Andriansyah RCE. Physical, chemical, and sensory quality of noodles fortification with anchovy (*Stolephorus sp.*) flour. JFST. 2022;42:e75421.

DOI: 10.60101/jarst.2026.262683