



Quality, Nutritional, and Sensory Evaluation of Noodles Enriched with Oyster Mushroom (*Pleurotus sajor-caju*)

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Abstract: Noodles are considered one of the staple foods, especially in Asian countries. Traditional noodles are typically made from wheat flour; however, their nutritional value is relatively low. Previous studies have also explored this topic with an emphasis on improving the nutritional quality of noodles, but the sensory quality was often poorly rated. Therefore, this study focuses on enhancing the nutritional and sensory qualities of noodles, thereby contributing to product diversification through the use of abundant local commodities in line with sustainable development goals. This investigation examined the optimal level of oyster mushroom flour incorporated into noodle formulations at 40, 50, 60, and 70 g, along with a control sample without mushroom flour. The formulation containing 60 g of oyster mushroom flour showed the most favorable nutritional, physical, and sensory characteristics. The selected sample received the highest scores for all sensory attributes. Noodles' elasticity and cooking quality also performed well, with 59.28 g-force, high water absorption, and volume expansion (276.53% and 273.61%), and low cooking loss (2.90%). At the same time, this sample also contained higher levels of nutritional components and bioactive compounds, with 6.07 g protein, 1.94 g cellulose, 0.20 g β -glucan, 0.0051 g QE/100 g flavonoid, and 0.37 g TAE/100 g phenolic. These findings suggest that oyster mushroom flour can be used as a functional ingredient to improve the nutritional and sensory quality of noodles and may support the development of value-added mushroom-based food products.

Keywords: Cooking quality; noodles diversification; nutritional quality; oyster mushroom flour; sensory evaluation.

1. Introduction

Noodles are among the most widely consumed staple foods worldwide, particularly in Asia. This popularity is attributed to their convenience, affordability, and extended shelf life. According to a report by the USDA Foreign Agricultural Service, the annual consumption of global instant noodles reached over 100 billion, among which China, Indonesia, Vietnam, Japan, and India are among the leading countries [1, 2]. This substantial growth stems from accelerated urbanization, modern lifestyles, and the increasing demand for ready-to-eat foods. Along with this expansion come the limitations of maintaining nutritional quality, ensuring food safety, and developing health-friendly products to meet modern consumer trends. Recent studies have concentrated on the intention of improving the quality and nutritional value of

noodles through modifications in flour composition (such as the use of whole wheat flour, whole grains, or plant-based proteins), the application of advanced drying technologies, and the fortification with micronutrients such as dietary fiber, vitamins, and minerals [3, 4].

Oyster mushroom (*Pleurotus spp.*) is one of the most widely consumed edible mushrooms today, which is favored for its high nutritional value, distinctive flavor, and strong adaptability to various cultivation conditions [5, 6]. *Pleurotus sajor-caju* is considered a potential material for the development of functional foods and alternative protein products to replace animal-based sources. Many studies have highlighted the valuable composition of oyster mushrooms, particularly their protein content, which varies from 19-35% (dry matter), and they contain all essential amino acids, such as lysine, leucine, and valine, which are often deficient in cereals [7, 8]. Moreover, with the high fiber content (7-10%), especially β -glucan and chitin, which have various beneficial effects on digestion, blood lipid regulation, and immune system enhancement. Oyster mushrooms also have a low-fat content (2-4%) and consist mainly of unsaturated fatty acids, along with B-group vitamins, vitamin D₂, vitamin C, and minerals such as K, Fe, Zn, and Se, making them an ideal ingredient for nutritional and plant-based products. In addition to their nutritional composition, oyster mushrooms contain a variety of bioactive compounds, notably polysaccharides, phenolic compounds, and flavonoids, which exhibit antioxidant, antimicrobial, anti-inflammatory, hypoglycemic, cholesterol-regulating, and immunomodulatory activities [9-11].

Oyster mushroom flour has attracted increasing attention due to its outstanding nutritional and bioactive properties, making it a potential substitute or supplement for wheat flour in food products. Oyster mushroom flour has a light brown color, distinct flavor, and good blending compatibility with cereal flours, while enhancing the protein, fiber, mineral, and antioxidant compound content of the final product [10, 11]. Previous studies have supplemented oyster mushroom flour into bread, cookies, and functional and diet product formulations, and results revealed that these products have improved nutritional and sensory properties and prolonged shelf-life due to the antioxidant function of the supplemented material [11, 12]. These properties suggest that oyster mushroom flour is a suitable source for the trend toward sustainable food development, particularly in gluten-reduced, nutrient-enriched, or animal protein-substitute products that meet the growing consumer demand for healthy, eco-friendly, and bioactive-rich foods. Therefore, this study aimed to formulate an optimal blend that preserves the nutritional composition and antioxidant capacity of the added oyster mushroom flour while maintaining the product's desired physical and sensory qualities, in alignment with the "nutrition – convenience – sustainability" criteria.

2. Materials and Methods

2.1 Materials

Oyster mushrooms (*Pleurotus sajor-caju*) were selected at a uniform harvest stage, with an average length of 12.5 ± 0.5 cm, width of 6.6 ± 3.5 cm, cap thickness of 1.4 ± 0.5 cm, and weight of 10.48 ± 4.32 g. All samples were of good quality, free from defects, damage, and insect contamination [6]. Those that met the harvest standards were collected and transported to a processing laboratory at An Giang University, Vietnam National University Ho Chi Minh City (Vietnam). Wheat flour No. 13 (Baker's Choice, Long Xuyen, Vietnam) and Semolina flour (Bob Red Mill, Long Xuyen, Vietnam). Tofu (Vi Nguyen brand), iodized salt (Basalco, Bac Lieu), corn starch (Taki Food), and refined sugar (Bien Hoa) were obtained from supermarkets in Long Xuyen City, An Giang Province (Vietnam). Xanthan gum and gluten were supplied by My Au Science and Technology Development Joint Stock Company, Ho Chi Minh City (Vietnam), and other analytical-grade chemicals were sourced from Sinopharm Chemical Reagent Co., Ltd.

2.2 Experimental design

The premix was prepared with fresh oyster mushrooms; they were cleaned and shredded into strips approximately 1.5-2 cm wide, then spread onto an inox tray (40x60 cm²) and dried at 60 °C until reaching a target moisture content of 10% (wet basis). Dried mushrooms were ground into flour and sieved through a 212 μ m mesh (US Standard Mesh No. 70) to obtain the fine flour. Noodles' formulation: This section was set up using a completely randomized design with three replications, as described below. Wheat flour and oyster mushroom flour were 200 g per sample, in which wheat flour was substituted with oyster mushroom flour at

different levels of 40, 50, 60, and 70 g, which corresponded to F1, F2, F3, and F4 samples, respectively; while a control sample was coded with F0 (100% wheat flour). All samples were mixed with 30 g of semolina, 40 g of potato starch, 30 g of gluten, 2 g of salt, 65 g of tofu, 5.8 g of xanthan gum, and 63 g of water; the total amount for each formula was 435.8 g. The specified ratios for 4 formulas are presented in Table 1.

Table 1. Formulation of oyster mushroom noodle

Ingredients	F0 (g)	F0 (%)	F1 (g)	F1 (%)	F2 (g)	F2 (%)	F3 (g)	F3 (%)	F4 (g)	F4 (%)
Oyster mushroom flour	0	0	40	9.18	50	11.43	60	13.77	70	16.06
Wheat flour	200	60.89	160	36.71	150	34.46	140	32.12	130	29.83
Semolina	30	6.88	30	6.88	30	6.88	30	6.88	30	6.88
Potato starch	40	9.18	40	9.18	40	9.18	40	9.18	40	9.18
Gluten	30	6.88	30	6.88	30	6.88	30	6.88	30	6.88
Salt	2	0.46	2	0.46	2	0.46	2	0.46	2	0.46
Tofu	65	14.92	65	14.92	65	14.92	65	14.92	65	14.92
Water	63	14.46	63	14.46	63	14.46	63	14.46	63	14.46
Xanthan gum	5.8	1.33	5.8	1.33	5.8	1.33	5.8	1.33	5.8	1.33
Total	435.8	100	435.8	100	435.8	100	435.8	100	435.8	100

Noodles' preparation: Oyster mushroom flour was blended with wheat flour, semolina, and xanthan gum; the mixture was sieved, then transferred to a Kalite KL960 dough mixer for the first mixing step, lasting approximately 1 minute and 30 seconds. Subsequently, salt, tofu, and water were added, and the mixture was mixed for 5 minutes. The dough was then allowed to rest for 30 minutes. The rested dough was sheeted using a DJJ-200B noodle sheeter, passing through four successive rollings with the sheet thickness gradually reduced from 5 mm to 1 mm. The sheets were then cut into noodle strands approximately 25 cm long and 0.1 cm wide. The noodles were boiled in water at 100°C for 2.5 minutes and dried at 60°C for 4.5 hours. Noodle samples were packed in PET containers for further analyses [13, 14].

2.3 Analysis of physical and cooking properties

2.3.1 Texture analysis: 10 g of each noodle sample was cooked in 100 mL of boiling water, then drained and cooled to 6–8°C before analysis. Elasticity (g-force) of cooked noodles was measured using a texture analyzer (CT3, Brookfield, USA). The measurement was conducted using a wedge-shaped probe with the setup parameters including test speed: 2 mm/g; target type: Stop @ Load; target value: 1000 g; and trigger force: 5 g [13].

2.3.2 Water absorption (WA): 10 g of each noodle sample was cooked in 100 mL of boiling water contained in a 500 mL glass beaker and then evaluated. The amount of absorbed water was calculated using the equation below, where m_2 is the weight of cooked noodles, and m_1 is the weight of noodles before cooking (10 g) [13].

$$WA (\%) = \left(\frac{m_2 - m_1}{m_1} \right) \times 100$$

2.3.3 Cooking loss (CL): 10 g of each noodle sample was cooked in 100 mL of boiling water contained in a 500 mL glass beaker; the cooking water was then transferred into a drying dish and dried to a constant weight at 100–105°C. Cooking loss was the ratio of the dry residue weight in the cooking water (m_d) and the weight of noodles before cooking (m_1) [13].

$$CL (\%) = (m_d / m_1) \times 100$$

2.3.4 Volume expansion (VE): 10 g of each uncooked and cooked noodle sample were immersed in a graduated cylinder containing 50 mL of distilled water. The volume expansion was determined using the equation below, where V_1 and V_2 are the volumes of uncooked and cooked noodles, respectively [13].

$$VE (\%) = \left(\frac{V_2 - V_1}{V_1} \right) \times 100$$

2.4 Chemical properties analysis

The concentration of β -glucan (g/100 g dry matter) was assessed based on the Phenol-Sulfuric method [15]. Briefly, samples were ethanol-precipitated (96%, 4°C, 24 h), filtered, alkaline-treated (1 M NaOH, 60°C, 1 h), reacted with phenol and sulfuric acid, and the absorbance was measured at 490 nm. β -Glucan concentration was quantified using a standard glucan curve $y = 2745.61x + 0.0003^*$ ($R^2=0.9999$). The content of flavonoid (g QE/100 g dry matter) and *phenolic* (g TAE/100 g dry matter) was identified relying on the colorimetric method described by Sumaiyah et al. [16]. Total flavonoid content was determined using the aluminum chloride colorimetric method through the reaction of samples with NaNO_2 , $\text{AlCl}_3 \cdot \text{H}_2\text{O}$, and NaOH to form a stable yellow complex, and absorbance was measured at 510 nm using a UV-Vis spectrophotometer (V730, Jasco, Japan), its content was quantified using a quercetin calibration curve ($y = 8.2634x + 0.0182^*$ ($R^2 = 0.9999$)). Total phenolic content was determined using the Folin-Ciocalteu reagent. Samples were reacted with Folin-Ciocalteu reagent and Na_2CO_3 , and absorbance was measured at 750 nm using a UV-Vis spectrophotometer (V730, Jasco, Japan). The content was quantified using a tannic acid calibration curve: $y = 0.0021x + 0.0064$ ($R^2 = 0.9999$). The total sugar content (g/100 g dry matter) was determined using the DNS method [17]. Briefly, 1 g of noodle and 5 mL of concentrated HCl were added to a 100 mL Erlenmeyer flask, placed in a boiling water bath at 68–70°C for 3 hours, and then cooled to room temperature. Neutralize the mixture with 30% NaOH until the pH reaches 7.0. Add 7 mL of 10% $\text{Pb}(\text{CH}_3\text{COO})_2$, mix thoroughly, and let it stand for 5 minutes. Neutralize the excess $\text{Pb}(\text{CH}_3\text{COO})_2$ by saturated Na_2SO_4 solution, mix thoroughly, and transfer the entire solution to a 100 mL volumetric flask. An aliquot (1 mL) of the extracted solution was placed in a test tube, and 2 mL of the reagent DNS was added. The tubes containing blank, standard glucose solution, and samples were placed in boiling water for 10 minutes. Next, 7 mL of distilled water was added. The solution was analyzed at 575 nm. The concentrations of sucrose and reducing sugar were determined from a standard curve of glucose: $y = 23.885x + 0.126$ ($R^2 = 0.9999$). The protein content (g/100 g dry matter) of the noodle samples was determined using the Lowry assay described by Nielsen [18]. Briefly, 0.1 mL of the solution (after 1 g of sample was digested with 10 mL concentrated H_2SO_4) was mixed with 0.1 mL of 2 N NaOH and heated in boiling water for 10 minutes. After cooling, 1 mL of a reagent (formed from Na_2CO_3 , $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, and $\text{C}_4\text{H}_4\text{O}_6\text{KNa} \cdot 4\text{H}_2\text{O}$) and 0.1 mL of Folin-Ciocalteu reagent were added. The mixture was left at room temperature for 30 minutes, and the absorbance was measured at 750 nm. Protein content was calculated from a standard curve, $y = 0.0041x + 0.0118$ ($R^2 = 0.9999$). Where y represents absorbance and x represents concentration for all standard curves. Cellulose was determined based on its properties as a stable compound that is resistant to decomposition under the action of strong acids and alkalis [19]. The cellulose content (g/100 g dry matter) was quantified by drying the cellulose precipitate (m_2) to a constant weight at a temperature of 100–105 °C after filtration from a mixture consisting of the initial dried noodle sample (m_1) together with concentrated nitric acid and acetic acid at 100 °C for 30 minutes. The cellulose content (C%) was calculated using the following formula:

$$C (\%) = (m_2 * 100) / m_1$$

2.5 Sensory evaluation

The sensory characteristics of the product were measured for color, aroma, taste, and overall preference, following the Quantitative Descriptive Analysis (QDA) method [20]. In summary, forty trained panelists were instructed on how to rate each sensory attribute before evaluating the noodle samples. The degree of each attribute was determined using a detailed descriptive scale from 1 to 5 (Table 2), with 1 representing poor and 5 excellent. The level of preference was measured on a 1-9 Hedonic scale.

2.6 Data analysis

Data were statistically analyzed using Statgraphics Centurion XVI software (U.S.A.). The experiment followed a completely randomized design (CRD) with three replicates per treatment. Analysis of variance (ANOVA) was used to evaluate treatment effects, and mean comparisons were performed using the least significant difference (LSD) test at the 5% significance level. Graphs were prepared using Microsoft Excel.

Table 2. The description of noodle's sensory evaluation

Scale	Color	Aroma	Taste	Texture
5	Bright, uniform light cream to pale brown; very appealing	Strong, very pleasant mushroom aroma	Very delicious; rich umami taste; no off-flavor	Firm, elastic, and smooth; not sticky/mushy; highly desirable
4	Slightly dull but still uniform; acceptable	Noticeable mushroom aroma; pleasant	Good taste; slight reduction in flavor intensity	Slightly less firm; still elastic and acceptable
3	Moderately dull or uneven color	Weak mushroom aroma	Acceptable taste; bland or slightly lacking flavor	Moderately soft; slightly sticky or less elastic
2	Dull, uneven, or slightly discolored	Faint or slightly off aroma	Poor taste; noticeable off-flavor or imbalance	Soft, sticky, or slightly mushy; undesirable
1	Unacceptable color; very dark or uneven	Unpleasant or strong off-odor	Very poor taste; strong off-flavor, not acceptable	Very soft, mushy, or overly sticky; unacceptable

3. Results and Discussion

3.1 Effect of supplemented amount of oyster mushroom flour on the sensory value and cooking quality of noodles

3.1.1 Elasticity of noodles

Elasticity of noodles containing different levels of oyster mushroom flour is presented in Figure 1. As the level of oyster mushroom flour in the formula increased, noodle elasticity decreased progressively. In particular, the elasticity of the control formula (without mushroom flour) was 116.11 g-force; at fortification levels of 40, 50, 60, and 70 g mushroom flour, the elasticity of noodle samples was 109.61, 78.64, 59.28, and 56.56 g-force, respectively. An analysis of noodle elasticity is a quality control measure to ensure consistent, high-quality noodle production [14]. The incorporation of oyster mushroom flour into the formulation partially replaces wheat flour; consequently, the amount of wheat flour is reduced. In noodles production, the elasticity and flexibility of noodles mainly depend on the gluten content in wheat flour, which consists of the protein fractions gliadin and glutenin [21]. A study by Zhang et al. [22] reported that the elasticity of noodles declined with increasing mungbean flour addition, due to its gluten-free nature. Shere et al. [23] also stated that the elasticity of noodles significantly lowered when formulating with a high amount of pureed carrot supplementation. The results reveal that ingredients with high levels of sugar and dietary fiber can reduce the elasticity of the final product. This phenomenon can be explained by the competition for water among the components in the dough. Both sugar and fiber have a high affinity for water; therefore, they absorb and retain some of the moisture essential for the hydration of gluten-forming proteins, gliadin and glutenin, resulting in a weaker, less cohesive structure [23]. An incomplete gluten network reduces the dough's characteristic elasticity and chewiness, making the noodles more fragile, softer, and less resilient when stretched [21]. In addition, the addition of oyster mushroom flour increased dietary fiber content, causing mechanical disruption within the gluten matrix and further contributing to the reduction in elasticity.

3.1.2 Sensory evaluation

The sensory evaluation results showed that incorporating oyster mushroom flour significantly affected the color, aroma, taste, and texture of the noodles, with significant differences among formulations ($P \leq 0.05$). The color of the noodle samples changed substantially at different levels of mushroom flour fortification. Table 3 shows that the evaluation scores for the color attribute were lowest for the control sample (2.66) and highest at the 60 g mushroom flour addition level (4.66). The addition of oyster mushroom flour enhanced the yellow color of the noodles, thereby improving the color score in the sensory evaluation. However, excessive supplementation resulted in darker noodle strands. Specifically, when the amount of mushroom flour was increased to 70 g, the color score tended to decrease. (4.11). The differences in flavor and taste also followed the trend of color: the control sample received the lowest score (1.33) for flavor, and the sample fortified with 60 g of mushroom flour recorded the highest (4.33). The addition of oyster mushroom

flour enhanced the product's aroma compared to the control sample. However, with the addition of more mushroom flour, the product tended to develop a slightly strong or pungent mushroom odor. The combination of wheat flour with other ingredients and oyster mushroom flour enhanced the sensory score for the taste, reaching 3.66 and 3.88 in samples supplemented with 70 g and 60 g of oyster mushroom flour, respectively, compared to 1.33 points in the control sample without mushroom flour. This improvement can be attributed to the partial substitution of wheat flour with mushroom flour, which contributed to the development of the characteristic umami flavor in the noodles.

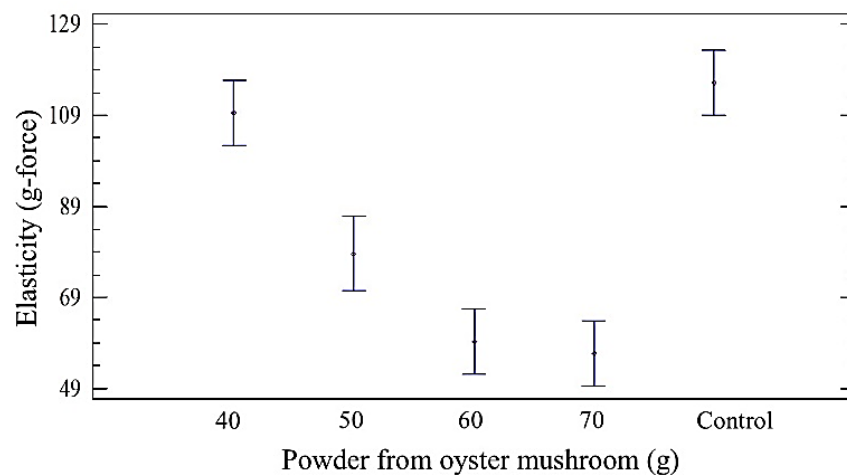


Figure 1. Elasticity of noodles containing different levels of oyster mushroom flour

Table 3. Effects of different levels of oyster mushroom flour on the sensory evaluation of noodles

Oyster mushroom flour (g)	Sensory scores			
	Color	Flavor	Taste	Texture
0 (control)	2.66 ^d ± 0.18	1.33 ^e ± 0.08	1.33 ^e ± 0.08	1.66 ^e ± 0.03
40	3.44 ^c ± 0.21	2.33 ^d ± 0.15	2.00 ^d ± 0.15	2.33 ^d ± 0.11
50	3.88 ^b ± 0.21	3.00 ^c ± 0.19	2.77 ^c ± 0.18	3.00 ^c ± 0.13
60	4.66 ^a ± 0.22	4.33 ^a ± 0.21	3.88 ^a ± 0.21	4.22 ^a ± 0.22
70	4.11 ^{ab} ± 0.21	3.66 ^b ± 0.20	3.33 ^b ± 0.20	3.66 ^b ± 0.14
Level of significance (P)	0.0000	0.0000	0.0000	0.0000

Mean values (n = 3) with different superscripts in the same column are significantly different at the 95% confidence level according to the LSD test.

The texture of noodles scores differed significantly among formulations ($P \leq 0.05$) (Table 3). It was also affected by the level of oyster mushroom flour substitution; the sensory score for texture was significantly higher in samples with higher substitution levels. Specifically, the sample with 60 g of mushroom flour scored 4.22 points, and the lowest reference was still the control sample at 1.66 points. The samples with a higher proportion of wheat flour, especially those without oyster mushroom flour or with a low supplementation level (40 g), may have resulted in an excessively firm and tough texture after steaming. However, excessive replacement of wheat flour reduced gluten content, resulting in reduced elasticity and chewiness and lower texture scores. In particular, the formulation with the highest level of substitution had a lower score (3.66) than the formulation containing 60 g of oyster mushroom flour (4.22). Although instrumental analysis showed a decrease in elasticity with increasing levels of oyster mushroom flour, the sensory evaluation indicated that the formulation containing 60 g achieved the highest texture score. This may be attributed to the fact that sensory texture perception involves multiple attributes, including softness, chewiness, and overall mouthfeel, rather than elasticity alone. Therefore, the 60 g formulation likely provided a more balanced and acceptable texture despite the reduction in instrumental elasticity.

3.1.3 Cooking quality of noodles

Table 4 shows the evaluation of cooking quality, including cooking loss, water absorption, and volume expansion, which was carried out at different levels of mushroom flour fortification.

Table 4. Effects of oyster mushroom flour incorporation on the physical properties of noodles

Oyster mushroom flour (g)	Water absorption (%)	Cooking loss (%)	Volume expansion (%)
0 (control)	154.40 ^c ± 10.24	2.40 ^b ± 0.05	152.22 ^c ± 10.12
40	186.17 ^c ± 12.31	2.07 ^b ± 0.07	155.56 ^c ± 10.03
50	260.33 ^{ab} ± 20.19	2.19 ^b ± 0.04	193.52 ^{bc} ± 12.41
60	276.53 ^a ± 20.24	2.90 ^{ab} ± 0.08	273.61 ^a ± 20.34
70	230.00 ^b ± 15.16	4.56 ^a ± 0.14	243.61 ^{ab} ± 20.11
Level of significance (P)	0.0000	0.1073	0.0185

Mean values (n = 3) with different superscripts in the same column are significantly different at the 95% confidence level according to the LSD test.

During the evaluation, the highest cooking loss was recorded in the sample with 70 g of mushroom flour added (4.56%); however, the differences among all samples were not significant. Cooking loss is one of the fundamental parameters used to predict noodle cooking quality. These values represent the amount of solid matter lost into the cooking water [13]. Compared with previous studies, it was found that the cooking losses of all noodle formulas were below the technological limit of $\leq 8\%$ [24,25]. Therefore, the incorporation of oyster mushroom flour at different levels did not affect the cooking loss. The increase in noodle volume showed a statistically significant difference at the 5% level among the formulations with different levels of oyster mushroom flour supplementation. The volume expansion of the control sample (without oyster mushroom flour) and the sample supplemented with 40 g of oyster mushroom flour exhibited the lowest values, at 152.22% and 155.56%, respectively ($P > 0.05$). Whereas, the formula containing 60 g of oyster mushroom flour showed the highest volume expansion of 273.61%. A high level of volume expansion is a desirable attribute in noodle products and is generally preferred by consumers [14]. According to Kang et al. [26], the degree of noodle volume expansion during cooking is mainly influenced by starch gelatinization and protein hydration. In fact, oyster mushroom flour contains 16.22% protein [6,7], while wheat flour contains about 13%. Therefore, the higher protein content of oyster mushroom flour may partly explain the greater water absorption capacity observed when higher levels of mushroom flour were incorporated into the noodle formulation. Furthermore, a strong correlation has been reported between water absorption and noodle volume expansion, indicating that noodles with higher water uptake tend to exhibit greater expansion during cooking [26]. Water absorption is the amount of water retained by noodles during cooking, an important characteristic that determines overall cooking quality [23]. The results shown in Table 4 clearly demonstrate that noodles supplemented with 60 g of oyster mushroom flour exhibited the highest values of both water absorption and volume expansion.

3.2 Effects of supplemented amount of oyster mushroom flour on the nutritional value of noodles

3.2.1 Chemical compositions of noodles

The protein, total sugar, and cellulose contents of noodles at different levels of mushroom flour fortification are presented in Table 5. The protein and cellulose content of noodles rose with the increase in the amount of mushroom flour added. At levels of 60 g and 70 g of mushroom flour fortification, noodles exhibited remarkable protein and cellulose contents of 6.07 g and 6.41 g, and 1.94 g and 2.14 g/100 g dry matter (without statistical difference). According to previous studies, the protein content of oyster mushroom flour is higher than that of wheat flour [6, 7]. Therefore, partial substitution of wheat flour with oyster mushroom flour increased the protein content of noodles. The protein content can reflect a product's nutritional value and may significantly influence its structural properties.

Table 5. Chemical compositions of noodles at different levels of oyster mushroom flour fortification

Oyster mushroom flour (g)	Chemical compositions (g/100 g dry matter)		
	Protein	Total sugar	Cellulose
0 (control)	3.05 ^d ± 0.03	75.53 ^a ± 1.52	0.70 ^d ± 0.02
40	3.84 ^c ± 0.05	64.66 ^b ± 1.65	1.53 ^c ± 0.05
50	4.69 ^b ± 0.08	56.75 ^b ± 1.37	1.76 ^b ± 0.04
60	6.07 ^a ± 0.06	44.61 ^c ± 1.10	1.94 ^{ab} ± 0.04
70	6.41 ^a ± 0.05	35.55 ^c ± 1.32	2.14 ^a ± 0.06
Level of significance (P)	0.0000	0.0000	0.0000

Mean values (n = 3) with different superscripts in the same column are significantly different at the 95% confidence level according to the LSD test.

The total sugar content of noodles showed an opposite trend, decreasing with increasing levels of oyster mushroom flour supplementation. The samples containing 60 g and 70 g of mushroom flour exhibited the lowest total sugar content at 44.61 g and 35.55 g per 100 g dry matter, respectively. In the control sample, the total sugar content was 75.53 g/100 g dry matter. This result is consistent with the findings of Bui et al. [19], who reported that the total sugar content in noodles ranges from 70% to 75%. According to previous studies on oyster mushrooms' compositions [6, 7], the total sugar content of oyster mushroom flour is 24.84 g/100 g dry matter. Therefore, replacing wheat flour with oyster mushroom flour reduced the sugar content of the noodles. Oyster mushrooms retain a certain amount of cellulose, which is considered a potential source of fiber due to the presence of non-starch polysaccharides [27]. Results also reveal that cellulose content tended to increase gradually with the further addition of oyster mushroom flour to the noodles' formula, but the samples with 60 g and 70 g of fortified mushroom flour did not differ statistically in cellulose content ($P > 0.05$). The study by Sobota et al. [28] also showed that adding vegetable flours to noodle formulations increases the noodles' fiber content.

3.2.2 Bioactive compounds in noodles

Conventional noodle products made from wheat flour available on the market generally contain none or only very minor amounts of bioactive compounds. Therefore, the fortification or development of noodle products enriched with bioactive compounds is considered innovative and meets consumer expectations. The quantification of phenolic, flavonoid, and β -glucan in noodles formulated with oyster mushroom flour addition is shown in Table 6.

Table 6. Bioactive compounds content of noodles containing different levels of oyster mushroom flour

Oyster mushroom flour (g)	Phenolic (g TAE/100 g dry matter)	Flavonoid (g QE/100 g dry matter)	β -glucan (g/100 g dry matter)
0 (control)	0.07 ^c ± 0.001	0.0005 ^c ± 0.0000	0.06 ^d ± 0.000
40	0.35 ^b ± 0.001	0.0046 ^b ± 0.0000	0.18 ^c ± 0.002
50	0.36 ^b ± 0.001	0.0051 ^a ± 0.0000	0.18 ^c ± 0.002
60	0.37 ^a ± 0.001	0.0051 ^a ± 0.0000	0.19 ^b ± 0.003
70	0.37 ^a ± 0.001	0.0051 ^a ± 0.0000	0.20 ^a ± 0.003
F	15.13	48.99	30.60
P	0.0000	0.0000	0.0000

Mean values (n = 3) with different superscripts in the same column are significantly different at the 95% confidence level according to the LSD test.

β -glucan in the control sample was the lowest (0.06 g/100 g dry matter). However, its content increased with the addition of oyster mushroom flour to the formula. In particular, β -glucan rose from 0.18 to 0.20 g per 100 g dry matter as the fortified level increased from 40 g to 70 g. β -glucan is a major polysaccharide found in many edible mushrooms and possesses numerous functional and biological activities, including anticancer, antioxidant, and anti-infective properties [29]. The β -glucan content increased by 3–3.5 times compared with the control sample (without oyster mushroom flour supplementation). In addition, the changes in phenolic

and flavonoid content of noodles also followed the trend of β -glucan. Phenolic and flavonoid content reached the peak at 0.37 g TAE and 0.0051 g per 100 g dry matter when adding 60 g and 70 g mushroom flour. Noodles are primarily made from wheat flour and may include additional ingredients to enhance their quality [19]. According to Melinda et al. [30], oyster mushrooms have great potential as a natural source of secondary metabolites, including phenolics, flavonoids, and glucans. Therefore, incorporating oyster mushroom flour into noodles enhances their bioactive compounds and antioxidant activity.

4. Conclusions

This study evaluated the effect of oyster mushroom flour fortification on the quality and nutritional composition of noodles. The results indicated that adding 60 g of oyster mushroom flour produced noodles with the most favorable sensory attributes, including color, aroma, taste, and texture. This formulation also showed enhanced nutritional and bioactive properties, with protein (6.07 g), cellulose (1.94 g), total sugar (44.61 g), β -glucan (0.19 g), flavonoid (0.0051 g QE/100 g), and phenolic content (0.37 g TAE/100 g) higher than the control. These findings demonstrate that partial substitution of wheat flour with oyster mushroom flour can improve the functional and nutritional characteristics of noodles. Further studies are recommended to investigate storage stability and other quality parameters.

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