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Article

Physicochemical Properties and Nutritional Composition of Chicken Patties with Grey Oyster Mushroom Stems

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***Abstract*— The application of plant-based waste materials as functional food ingredients in meat products has gained popularity owing to their nutritional richness and contributions to the circular economy and environmental protection. As such, mushroom stems are one of the potential ingredients to be used in muscle products as a meat alternative, as they mimic the texture of meat. Therefore, this study aims to determine the physicochemical properties and nutritional composition of chicken patties with grey oyster mushroom stems. In this study, five formulations of chicken patties were prepared with different ratios of chicken meat to the grey oyster mushroom stem: control (65%:0%), A (55%:10%), B (45%:20%), C (35%:30%), and D (25%:40%). The chicken patties were analysed for cooking characteristics, physicochemical properties, and nutritional composition. Results found that the grey oyster mushroom stem-based patties recorded higher (P<0.05) cooking yield and moisture retention as compared to the control. The addition of grey oyster mushroom stems increased (P<0.05) the lightness (L*) due to the white colour of the grey oyster mushroom stems. No significant difference (P>0.05) was observed in all formulations of patties' hardness, chewiness, springiness, and cohesiveness attributes, but the increment of grey oyster mushroom stems in chicken patties decreased the value of all these attributes. Nutritional composition of chicken patty of formulation D (40% grey oyster mushroom stems) recorded significantly the highest (P<0.05) moisture and crude fibre compared to other formulations. In addition, the energy content of chicken patties significantly decreased (P<0.05) proportionally with increasing levels of grey oyster mushroom stems. This study indicated that grey oyster mushroom waste is a promising meat alternative ingredient that has great potential to be used in attaining meat products with enhanced nutritional and sustainability profiles in the current sector.**

Keywords—grey oyster mushroom stems; mushroom stems' patties; plant-based patties; vegetarian patties; hybrid chicken patties

I. INTRODUCTION

A mushroom is a fleshy, spore-bearing fruiting body of a fungus that grows above ground and is recognised by a stem (stipe), cap (pileus), and gills (lamellae) [1]. Mushrooms have been consumed since ancient times and have been acknowledged by many civilizations, including the Greeks, Romans, and Chinese culture, due to their unique flavour and therapeutic properties [2]. In terms of nutrition, mushrooms are low in sodium, fat, calories, and cholesterol while high in β-glucan and dietary fibre (including the cap and stem). Moreover, they are a source of essential fatty acids, mainly in the form of linoleic acid [3]. Mushrooms contain a high amount of proteins and provide all nine essential amino acids that are needed by the human body. As such, they have been explored as a potential alternative for muscle protein. In terms of vitamins and minerals, mushrooms are high in vitamins B1, B2, B12, C, D, and E, as well as copper, iron, manganese, potassium, and zinc [4].

In the past decade, mushroom agriculture has become one of the most successful businesses due to its numerous beneficial properties [5]. The growing health awareness among the population has impacted the worldwide mushroom market [6], which is expected to reach 20.84 million tonnes by 2026 [5]. The increase in demand for edible mushrooms, however, may lead to an increase in the mushroom stem yield, which is commonly treated as waste material and creates major management issues from an economic and environmental standpoint [7]. The stems of the mushrooms are mostly discarded since they are tough to cook and usually end up in landfills [8], and, therefore, could also be categorised as waste materials. In fact, mushroom stems contain more fibres, polysaccharides, amino acid types [9], and antioxidants [10] compared to caps. Indeed, the higher fibrous structure and polysaccharide content of mushroom stems are important to mimic the texture of meat products [11].

Currently, the use of plant-based waste materials as functional food ingredients in muscle food products has been receiving special attention owing to their nutritional richness and contributions to the circular economy and environmental protection [12]. In China, over 100,000 tonnes of mushroom stems are generated per year, and the volume is assumed to be similarly high in other nations [13]. The stems often go to landfills or are used as compost [12]. The increase in human population has decreased the available resources to support the population, which directly impacts the food supply. In 2050, further additions of 2.3 billion people are expected to increase food demand by 70%. The increase in population has led to an increase in food waste and by-products accumulated [14].

The concept of a circular economy is considered the key element for producing new products using food waste as a raw material. The effect of mushroom stem waste on the physicochemical properties and nutritional composition of meat products has recently attracted researchers' interest. For instance, the application of enaki mushroom stems as a substitute for goat meat in nuggets improved the cooking characteristics and nutritional values, especially in dietary fibres, and ash content [12]. The addition of 0.6% shiitake stipes extracts in fermented sausages was found to significantly reduce ($P<0.05$) lipid oxidation and improve the microbial stability of the sausages [15]. However, the application of mushroom stem waste in meat products is still limited, and the use of mushroom stems in chicken patties has never been explored. Thus, the aim of this study was to determine the cooking characteristics, physicochemical properties, and nutritional composition of chicken patties with underutilised grey oyster mushroom stems.

II. MATERIALS AND METHODS

The chicken breast and other ingredients, including vegetable shortening, potato starch, unripe jackfruit, salt, and spices, were purchased from a supermarket in Nilai, Negeri Sembilan, Malaysia. Meanwhile, the mushroom stems were collected from a mushroom farm (Nas Agro Farm) located at Jenderam Hulu, Selangor, Malaysia. Next, the grey oyster mushroom stems were rinsed using running tap water, followed by the process of air drying using a sieve in order to drain the excessive water. The fresh grey oyster mushroom stems were then ground into small portions to be used in patties formulations.

A. Chicken Patties Formulation and Preparation

The chicken patties were formulated according to Wan Rosli et al. [16] with some modifications. Five formulations of chicken patties were prepared with a percentage of chicken meat to the grey oyster mushroom stem as follows: Control (65%:0%), A (55%:10%), B (45%:20%), C (35%:30%), and D (25%:40%) with the addition of other ingredients (Table I) including 8% of fresh unripe jackfruit as a plant-based meat alternative which also contains high fibres [17] as it could enriched total fibres in patties products. The ingredients were weighed using a weighing scale (Sartorius, German) and mixed together in a food processor (Panasonic, Malaysia). The finished batters were then weighed into 50 g portions and shaped using a burger patty former, labelled, and stored in a freezer (-18 °C) until further analysis.

TABLE I. FORMULATIONS OF CHICKEN PATTIES WITH GREY OYSTER MUSHROOM STEMS

Ingredients (%)	Control	A	B	C	D
Chicken breast	65	55	45	35	25
Grey oyster mushroom stem	0	10	20	30	40
Water	15	15	15	15	15
Unripe jackfruit	8	8	8	8	8
Potato starch	5	5	5	5	5
Veg. shortening	5	5	5	5	5
Salt	1	1	1	1	1
Spices	1	1	1	1	1

B. Cooking Characteristics Analysis

[1] Cooking Procedure: Chicken patties were thawed at 4 °C before cooking for 7 to 8 minutes on a non-stick pan until an internal temperature of 72 ± 1°C was achieved.

[2] Cooking Yields: Chicken patties were weighed and measured before and after frying, according to Murphy et al. [18]. The percentage of cooking yield was calculated as the following equation:

$$\text{Cooking yield (\%)} = [W_1 / W_2] \times 100$$

Where W_1 = Weight of chicken patty after frying;
W_2 = Weight of chicken patty before frying

[3] Cooking Loss: The percentage of cooking loss of chicken patties was determined according to Bouton et al. [19] using the following equation.

$$\text{Cooking loss (\%)} = [(W_1 - W_2) / W_1] \times 100$$

Where W_1 = Weight of chicken patty before frying;
W_2 = Weight of chicken patty after frying

[4] Moisture Retention: The percentage of moisture retention of chicken patties was measured according to Osman and Sukru [20] using the following equation.

$$\text{Moisture retention (\%)} = [\text{Cooking yield (\%)} \times \text{Moisture of cooked chicken patty (\%)}] / 100$$

C. Physicochemical Properties Analysis

[1] pH: The pH of the patties was measured using a digital pH meter (Model Aqua Lab). Briefly, 10.0 g of chicken patties were added with 50 mL of distilled water. The mixtures were homogenised, and the pH was directly taken from the homogenised samples.

[2] Water Activity: The water activity of cooked chicken patties was determined using an Aqualab Series 4TE water activity meter (Decagon, Pullman, WA, USA) at 25°C.

[3] Colour: Cooked chicken patties' colour's was measured using a colorimeter (LabScan® XE Spectrophotometer Model, HunterLab) based on the $L^*a^*b^*$ colour scale system. The L^* (lightness), a^* (redness), and b^* (yellowness) values were obtained by measuring the patties' surface.

[4] Texture Profile: The texture of cooked chicken patties was measured using a texture analyser (TA-XT Plus Model, Stable Micro System). Each chicken patty was compressed to 75% of its original height with the help of a compression probe (P 75) and analysed for hardness, chewiness, springiness, and cohesiveness attributes.

D. Nutritional Composition Analysis

Cooked chicken patties were analysed for moisture, ash, protein, fat, carbohydrate, and crude fibre according to the methods of the Association of Official Analytical Chemists (AOAC) [21].

[1] Moisture Analysis: The moisture content of cooked chicken patties was determined using a mechanical moisture analyser (MX-50, A&D Company, Limited) based on the principle of thermogravimetric analysis. The percentage of moisture content was obtained by calculating the difference between wet weight and dry weight of the sample.

[2] Ash Analysis: The ash content of cooked chicken patties was determined using conventional dry-ashing. Approximately, 3.0 g of chicken patties were charred on an electric hot plate (Favorit, HS0707V2) until ceased smoke. The crucibles containing charred samples were then placed inside the furnace, which was set up to 550°C. The samples were ignited overnight, cooled in the desiccator, and weighed. The percentage of total ash was calculated using the following equation.

$$\text{Ash (\%)} = [W_1 / W_2] \times 100$$

Where W_1 = Weight of samples after ashing;
W_2 = Weight of samples before ashing

[3] Protein Analysis: The nitrogen content of cooked chicken patties was determined using the Kjeldahl method, which includes digestion, distillation, and titration processes. The protein percentage was expressed as the total nitrogen percentage and multiplied by a factor of 6.25 (nitrogen-protein conversion factor for meat) as per the equation below.

$$\text{Protein (\%)} = \text{Nitrogen (\%) in samples} \times 6.25$$

[4] Fat Analysis: The fat content of cooked chicken patties was carried out automatically using the automatic Soxhlet extraction method (Soxtherm® extractor, Gerhardt). Approximately 2.0 g of each chicken patty was weighed and added to the apparatus, which was operated based on Gerhardt's manual instructions. The residue of extraction was dried in an air-drying oven at 105°C overnight, cooled in a desiccator, and weighed. The fat content of chicken patties was calculated using the following equation.

$$\text{Fat (\%)} = [(W_1 - W_2) / W_0] \times 100$$

Where W_0 = Weight of sample; W_1 = Total weight of extraction beaker with boiling stones and extracted fats; W_2 = Total weight of extraction beaker and boiling stones

[5] Carbohydrate Analysis: The carbohydrate content of cooked chicken patties was obtained by subtracting the protein, fat, moisture, and ash values from 100% and calculated using the following equation.

$$\text{Carbohydrates (\%)} = 100 - [\text{Protein (\%)} + \text{Fat (\%)} + \text{Moisture (\%)} + \text{Ash (\%)}]$$

[6] Crude Fibre Analysis: The crude fibre content was determined using fibre analyser (Gerhardt Fibretherm, German), followed by incineration of the samples in a muffle furnace (Carbolite, England) at 550°C. The crude fibre content was then calculated using the following equation.

$$\text{Crude fibre (\%)} = [(C - A) - (D - E)] \times 100 / B$$

Where A = Weight of FibreBag; B = Weight of sample; C = Weight of crucible and dried FibreBag after digestion; D = Weight of crucible and ash; E = Weight of blank of the empty FibreBag (D – F); F = Weight of crucible

[7] Energy Content: The energy content of cooked chicken patties was determined using the Atwater general factor as per Atwater and Woods [22]. The energy content was calculated using the following equation:

$$\text{Energy value (kcal/g)} = [\text{Carbohydrate (\%)} \times 4] + [\text{Fat (\%)} \times 9] + [\text{Protein (\%)} \times 4]$$

[8] Data Analysis: All data were analysed using Minitab 18 for one-way analysis of variance (ANOVA) followed by the Tukey Test. Results were expressed as mean ± standard deviation, and the statistical significance was established at (P<0.05).

III. RESULTS AND DISCUSSIONS

A. *Cooking Properties of Patties*

Table II shows the cooking properties of chicken patties with underutilised grey oyster mushroom stems. Results found that the grey oyster mushroom stem-based patties exhibited a higher cooking yield (P<0.05), which ranged from 90.68 to 93.24% as compared to the control (87.45%). Similarly, nuggets added with grey oyster mushroom stems exhibited a significantly (P<0.05) higher cooking yield than the control nugget [11]. Moreover, the addition of white jelly mushrooms to pork patties significantly (P<0.05) increased the cooking yield [23]. According to Wan Rosli et al. [16], dietary fibres in mushrooms increase cooking yield due to their high tendency to retain fat and moisture in the matrix. Indeed, the increase in cooking yield is beneficial from a technological, sensorial, and economic viewpoint [3].

Cooking loss is defined as the total quantity of dry matter lost during optimal cooking conditions. Meanwhile, cooking loss or shrinkage in meat products indicates the denaturation of protein caused by heat induction, which alters the function of the structural proteins actomyosin complex and collagen, resulting in undesirable results that are closely associated with sensory characteristics such as juiciness and toughness of meat products [24]. In this study, the cooking loss of chicken patties significantly reduced (P<0.05) with an increased level of grey oyster mushroom stems. This is probably due to the higher dietary fibre content of mushrooms, which enhances the oil absorption and water retention properties of the meat emulsion [12]. Meanwhile, the highest cooking loss (12.55%) in control in this study was probably due to meat protein denaturation, which causes more moisture loss during the cooking process and might be correlated with the loss of emulsion stability of the hydrophobic interaction between fats and moisture in the product [11]. This suggests that grey oyster mushroom stems can be substituted in chicken patties as they improve the cooking loss property, resulting in better water retention.

The moisture retention of grey oyster mushroom stem-based patties ranged from 62.04 to 69.54%, higher (P<0.05) than the control (58.59%). The increment in grey oyster mushroom stem content in the chicken patty formulations significantly increased (P<0.05) moisture retention proportionally. The dietary fibre content in mushrooms tends to increase the cooking yield because of their strong ability to keep moisture and fat in the matrix [16]. A similar trend in moisture retention was observed in a study by Husain and Huda-Faujan [11]. The addition of grey oyster mushroom stems improved moisture retention, which could be attributed to the high level of polysaccharides in grey oyster mushroom stems, which can form a tridimensional matrix within the meat product.

B. *Physicochemical Properties of Patties*

The pH value of grey oyster mushroom stem-based patties increased from 6.11 to 6.21 as the level of grey oyster mushroom stems increased but significantly (P<0.05) lower than the control patties (Table III). These results were in line with the findings of Banerjee et al. [12]. The increase in the pH of the grey oyster mushroom stem-based patties could be due to the abundance of basic amino acids in mushrooms in comparison to acidic amino acids and the mushroom proteins' natural buffering capacity [12]. Chicken breast contains the most abundant essential amino acids, lysine, arginine, and leucine [25], and arginine and lysine are categorised as basic amino acids. Additionally, mushrooms contain all three types of basic amino acids. However, wild grey oyster mushroom stems contain significantly higher (P<0.05) of lysine compared to the cap but have similar arginine content in both parts [26]. In a comparison of the cap and stem of *Morchella esculenta* (a wild edible mushroom in Bulgaria), it was also found that the stems contain 31.92% and 56.98% higher basic amino acid lysine and arginine, respectively [27].

In fact, the pH of fresh chicken breast fillets was 5.88 [28], but the pH of grey oyster mushrooms during storage at 4 °C for 6 days (without separating cap and stems) ranged between 6.37 and 6.42 [29]. According to Beauclercq et al. [30], the normal pH range for chicken breast is between pH 5.7 and 6.1. Thus, the less acidic pH in grey oyster mushroom stem-based patties in this study as the grey oyster mushroom stems increased in the formulations could be due to the less acidic of the mushroom, especially the contribution of basic amino acid lysine in grey oyster stems mushroom compared to the fresh chicken breast fillets. The pH value is a crucial factor to be measured in meat products as it affects the colour, water-holding capacity, texture, and shelf-life of the meat products [31].

TABLE II. COOKING PROPERTIES OF CHICKEN PATTIES WITH GREY OYSTER MUSHROOM STEMS

Cooking properties (%)	Control	A	B	C	D
Cooking yield	87.45±1.09^{c}	90.68±1.53^{b}	91.53±0.81^{ab}	92.50±1.10^{ab}	93.24±0.72^{a}
Cooking loss	12.55±1.09^{a}	9.32±1.53^{b}	8.48 ±0.81^{bc}	7.51±1.10^{bc}	6.76±0.72^{c}
Moisture retention	58.59±1.11^{d}	62.04±2.16^{c}	64.85±2.12^{bc}	66.86±0.84^{ab}	69.54±0.75^{a}

Means within a row with different letters are significantly different (P<0.05).
Notes: Control = 0% grey oyster mushroom stems; A = 10% grey oyster mushroom stems; B = 20% grey oyster mushroom stems; C = 30% grey oyster mushroom stems; D = 40% grey oyster mushroom stems.

TABLE III. PHYSICOCHEMICAL PROPERTIES OF CHICKEN PATTIES WITH GREY OYSTER MUSHROOM STEMS

Physicochemical properties	Control	A	B	C	D
pH	6.26±0.06^{a}	6.11±0.00^{b}	6.13±0.00^{b}	6.17±0.01^{ab}	6.21±0.01^{ab}
Water activity	0.93±0.02^{a}	0.92±0.01^{a}	0.94±0.01^{a}	0.94±0.01^{a}	0.95±0.01^{a}
L	43.57±1.01^{c}	44.10±0.91^{bc}	45.40±0.93^{bc}	46.23±1.26^{b}	50.22±0.69^{a}
a	13.16±0.69^{a}	12.85±0.06^{a}	11.31±0.36^{b}	10.72±0.16^{b}	9.62±0.24^{c}
b	17.88±0.43^{a}	17.31±0.46^{ab}	16.71±0.30^{bc}	15.86±0.88^{c}	15.63±0.44^{c}

Means within a row with different letters are significantly different (P<0.05).
Notes: Control = 0% grey oyster mushroom stems; A = 10% grey oyster mushroom stems; B = 20% grey oyster mushroom stems; C = 30% grey oyster mushroom stems; D = 40% grey oyster mushroom stems.

Water activity (A_w) is defined as the ratio of the vapour pressure of the water in the substrate to that of pure water at the same temperature [32]. There was no significant (P>0.05) difference between all the chicken patties in the assessment of water activity. The water activity of the grey oyster mushroom stem-based patties ranged from 0.92 to 0.95. In fact, a product's stability is affected by pH and water activity in the food environment. The free water that is available to participate in the chemical or biological processes might deteriorate the products in terms of physicochemical, nutritional, and microbiological aspects [32].

Muscle food colour is a visible indicator of quality and freshness, and thus, plays an important role in influencing consumer purchasing decisions [3]. The addition of grey oyster mushroom stems to chicken patties significantly increased (P<0.05) the lightness (L*) while decreasing (P<0.05) the redness (a*) and yellowness (b*) of patties. The L* values of grey oyster mushroom stem-based patties ranged from 44.10 to 50.22, while the a* and b* values ranged from 9.62 to 12.85, and 15.63 to 17.31, respectively. This might be related to the dilution of the meat protein due to the inclusion of grey oyster mushroom stems as a percentage of the meat and the white colour of the grey oyster mushroom stems. This result is aligned with a study by Banerjee et al. [12]. In general, the impact of mushrooms on muscle foods is determined by the initial colour of the mushrooms and muscle foods, as well as the physical interactions and chemical reactions that can occur between them [3].

C. Textural Characteristics of Patties

Table IV shows the texture profile analysis of hardness, chewiness, springiness, and cohesiveness of chicken patties incorporated with grey oyster mushroom stems. The textural parameters of the chicken patties decreased slightly, but the reduction was not statistically significant (P>0.05). According to Das et al. [3], mushrooms possess a meat-like texture due to their firm texture, and when processed with muscle, their dietary fibre fractions create a dense, meaty texture. As a result, mushrooms can be added to muscle foods up to a certain level without affecting their textural qualities significantly.

In this study, the hardness of chicken patties decreased proportionally with an increased level of grey oyster mushroom stems, but the hardness is similar (P>0.05) to the control patty. The hardness of grey oyster mushroom stem-based patties ranged from 8.15 to 8.84 N, lower than the control with the value of 9.35 N. Chewiness is defined as the amount of energy needed to chew a meat product [33]. Springiness, on the other hand, describes how well a product physically springs back to its initial state during the first compression [34]. The chewiness and springiness of chicken patties also decreased proportionally with an increased level of grey oyster mushroom stems but did not statistically differ (P>0.05) among formulations and control patty. The chewiness of grey oyster mushroom stem-based patties from formulation A to D was from 2.21 to 2.92 N/cm lower (P>0.05) than the control, which recorded 3.64 N/cm. As for springiness attributes, all the grey oyster mushroom stem-based patties obtained a lower value (P>0.05) than the control (0.76 cm).

TABLE IV. TEXTURAL PROFILE ANALYSIS OF CHICKEN PATTIES WITH GREY OYSTER MUSHROOM STEMS

Patties' texture	Control	A	B	C	D
Hardness (N)	9.35±0.00^{a}	8.84±0.60^{a}	8.34±1.09^{a}	8.19±0.11^{a}	8.15 ± 0.60^{a}
Chewiness (N/cm)	3.64±0.33^{a}	2.92±0.50^{a}	2.69±0.20^{a}	2.34±0.45^{a}	2.21 ± 0.56^{a}
Springiness (cm)	0.76±0.06^{a}	0.70±0.01^{a}	0.70±0.14^{a}	0.65±0.06^{a}	0.63 ± 0.05^{a}
Cohesiveness (ratio)	0.52±0.01^{a}	0.47±0.06^{a}	0.47±0.00^{a}	0.44±0.04^{a}	0.42 ± 0.04^{a}

Means within a row with different letters are significantly different (P<0.05).
Notes: Control = 0% grey oyster mushroom stems; A = 10% grey oyster mushroom stems; B = 20% grey oyster mushroom stems; C = 30% grey oyster mushroom stems; D = 40% grey oyster mushroom stems.

The extent to which food can be deformed before it ruptures is related to cohesiveness [33]. In this study, the cohesiveness of chicken patties was also decreased proportionally (*P*>0.05) with the level of grey oyster mushroom stems added in the formulations. This finding was in line with a study by Wan Rosli et al. [16].

The incorporation of enoki mushroom stems in goat meat nuggets impacted the gelation of the meat proteins and subsequently decreased the gel strength, resulting in a softer texture of meat products [12]. In general, these findings indicate that the addition of mushrooms to muscle foods resulted in the softening of the finished products, which might be caused by a variety of physicochemical processes. Mushrooms have relatively high quantities of dietary fibres that can create a 3D biopolymer network that traps fluids, resulting in a softer texture in muscle food products. Furthermore, high amounts of mushrooms in muscle foods lower the concentration of solubilized muscle proteins, hence reducing their ability to create strong gels [3].

D. Nutritional Composition of Patties

The nutritional composition of chicken patties formulated with different levels of mushroom stems is shown in Table V. The moisture content of the grey oyster mushroom stem-based patties ranged from 68.41 to 74.58%, significantly (*P*<0.05) higher than the control (67.00%). Previously, Banerjee et al. [12] also reported that the moisture content of goat meat nuggets increased as the level of mushroom stems increased in the formulations. Moreover, Husain and Huda-Faujan [11] reported that the moisture content of imitation chicken nuggets was significantly higher (*P*<0.05) than the control due to the higher moisture content of grey oyster mushroom stems as compared to the mushroom cap. The moisture content of sausage added with mushroom ranged from 66.80 to 70.64%, which was also significantly (*P*<0.05) higher than the control (64.16%) due to the higher moisture content of the mushroom than pork lean meat [35].

Ash is defined as an inorganic residue remaining after the complete combustion of organic matter in a food sample [36]. There was no significant difference (*P*>0.05) in the ash content of all the chicken patties in this study. The ash content of the grey oyster mushroom stem-based patties ranged from 1.81 to 1.93%. Banerjee et al. [12] reported that ash content significantly increased (*P*<0.05) as the level of mushroom stem increased, which ranged from 3.54 to 4.68%. Indeed, grey oyster mushrooms (*Pleurotus sajor-caju*) are high in calcium, magnesium, iron, and zinc [37].

The present study found that the protein content of all the chicken patties differed significantly (*P*<0.05) in all formulations. The highest protein content was recorded for control (16.88%). Meanwhile, the protein content of the grey oyster mushroom stem-based patties ranged from 8.37 to 14.80%. Increasing the amount of grey oyster mushroom stems in the formulations while decreasing the amount of chicken meat consistently decreased (*P*<0.05) the protein content of the chicken patties. This necessarily was due to the original high protein content of breast chicken. Even though mushrooms have a high protein content, chicken has a higher protein content than other fungi [38]. Previous research on chicken patties [11] and chicken frankfurters [38] supported this pattern.

Increased incorporation of grey oyster mushroom stems resulted in a quadratic pattern (*P*<0.05) in fat content. The fat content of control chicken patties was 6.96%. Chicken patties with 40% grey oyster mushroom stems recorded the highest fat content (7.58%), while chicken patties with 20% grey oyster mushroom stem contained 5.99% fat (*P*<0.05). This might be associated with the healthy fat found in the grey mushroom stems. According to Oluwafemi et al. [39], the fat content of oyster mushroom stems was 1.50%. Furthermore, the crude fat content of cultivated and wild grey oyster mushroom stems was 2.60% and 4.77%, respectively [26]. In general, mushrooms are a healthy source of essential fatty acids (52 to 87% unsaturated fatty acids), primarily in the form of linoleic acid [3]. In fact, the linoleic acid content of mushrooms (*Pleurotus sajor-caju*) was 53.80% higher than that of chicken breast, with only 25.13% [40-41]. Additionally, the fat content in the breast is considered the lowest compared to other parts of chicken meat, including wing, thigh, and ribs [42-43]. This could explain why grey oyster mushroom stem-based patties contained higher fats (*P*<0.05) than the control patty.

TABLE V. NUTRITIONAL COMPOSITION OF CHICKEN PATTIES WITH GREY OYSTER MUSHROOM STEMS

Nutritional composition (%)	Control	A	B	C	D
Moisture	67.00±1.21^{d}	68.41±1.52^{cd}	70.85±1.95^{bc}	72.28±0.68^{ab}	74.58±0.44^{a}
Ash	1.90±0.02^{a}	1.81±0.14^{a}	1.85±0.03^{a}	1.87±0.14^{a}	1.93±0.18^{a}
Protein	16.88±0.21^{a}	14.80±0.35^{b}	12.25±0.70^{c}	10.45±0.30^{d}	8.37±0.41^{e}
Fat	6.96±0.58^{ab}	7.15±0.59^{a}	5.99±0.64^{b}	6.55±0.41^{ab}	7.58±0.34^{a}
Carbohydrate	7.27±1.27^{a}	7.84±1.65^{a}	9.07±0.92^{a}	8.85±0.33^{a}	7.35±0.46^{a}
Crude Fibre	0.55±0.04^{c}	0.95±0.03^{bc}	1.14±0.19^{bc}	1.31±0.11^{ab}	1.94±0.70^{a}
Energy$^{\#}$	159±5.56^{a}	155±5.75^{a}	139±6.21^{b}	136±5.10^{b}	131±2.94^{b}

The energy content of chicken patties was expressed as kcal/g.
Means within a row with different letters are significantly different (*P*<0.05).
Notes: Control = 0% grey oyster mushroom stems; A = 10% grey oyster mushroom stems; B = 20% grey oyster mushroom stems; C = 30% grey oyster mushroom stems; D = 40% grey oyster mushroom stems.

There was no significant (P>0.05) difference in the carbohydrate content of all the chicken patties. This result was in line with Yahya and Ting [44] on the inclusion of fresh oyster mushroom powder in chicken sausages. Meanwhile, Wan Rosli et al. [38] found that carbohydrate contents of chicken frankfurters were increased in line with the amounts of oyster mushrooms used in the formulations. In general, mushrooms' stems contain a high amount of carbohydrate as compared to their caps with values of 61.80% and 52.90%, respectively [39].

The crude fibre content of the grey oyster mushroom stem-based patties ranged from 0.95 to 1.94%, higher than the control (0.55%). Increasing the amount of grey oyster mushroom stems in the formulations consistently increased (P<0.05) the crude fibre content of the chicken patties and was in line with Banerjee et al. [12]. Mushroom-based frankfurters [38] and mushroom-based chicken sausages [44] also exhibited higher crude fibres compared to the control. The crude fibre content of fresh *Pleurotus sajor-caju* was reported to be higher (17.27%) than that of broiler chicken breast (0.18%) [44]. Indeed, the addition of plant-based materials into processed meat products increases the level of dietary fibre, thus, improving the nutritional value of the food [38]. Owing to their high dietary fibre content, mushrooms are ideally preferred in the development of low-calorie functional foods [3].

The energy content of the mushroom stem-based patties ranged from 155 to 131 kcal/g, lower than the control (159 kcal/g). It was found that increasing the amount of grey oyster mushroom stems generally decreased the energy content of chicken patties. The results obtained in this study are in line with the findings of Husain and Huda-Faujan [11]. The energy content of the control was significantly higher (P<0.05) than all imitation chicken nuggets due to the high protein and fat content in the control formulation, which greatly contributed to energy content. Similarly, increasing amounts of mushrooms lowered the energy value of sausages, which ranged from 207 to 186 kcal/g, lower than the control, which had a value of 217 kcal/g [26].

V. CONCLUSIONS

The addition of grey oyster mushroom stems in chicken patty formulation positively affects the cooking properties (P<0.05). Meanwhile, patties with 40% grey oyster mushroom stems significantly improved (P<0.05) the moisture and crude fibre contents as compared to the control patty. These findings concluded that mushroom stem-based patties are comparable with chicken patty and provide patty-rich fibre. Thus, it could be a promising ingredient to be used in attaining value-added meat products to support the human population as well as contribute to the circular economy and environmental protection.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES

[1] Paul, V., "Mushroom Products." In Mushrooms of India, edited by S. Sharma, M. Singh, S. Prasad, and H. Rathore, vol. 1, 254-262. India: I, IIT Delhi, 2016.

[2] Valverde, M. E., Hernández-Pérez, T., and Paredes-López, O, "Mushrooms: Improving Human Health and Promoting Quality Life," International Journal of Microbiology 2015, Article ID 376387, 14 pages, 2015, https://doi.org/10.1155/2015/376387.

[3] Das, A. K., P. K. Nanda, P. Dandapat, S. Bandyopadhyay, P. Gullón, G. K. Sivaraman, D. J. McClements, B. Gullón, and J. M. Lorenzo, "Edible Mushrooms as Functional Ingredients for Development of Healthier and More Sustainable Muscle Foods: A Flexitarian Approach," Molecules 26, no. 9 (April 2021): 2463, https://doi.org/10.3390/molecules26092463.

[4] Assemie, A., and G. Abaya, "The Effect of Edible Mushroom on Health and Their Biochemistry," International Journal of Microbiology, 2022, Article ID 8744788, 7 pages, 2022. https://doi.org/10.1155/2022/8744788.

[5] FocusM, "Supply Chain Disruption: When Mushrooms Are Not Mushrooming Anymore." Focus Malaysia, 11 August 2021, Retrieved on 9th April 2022 from https://focusmalaysia.my/supply-chain-disruption-when-mushrooms-are-not-mushrooming-anymore/.

[6] MarketWatch, "Latest Survey on "Edible Mushrooms Market" Trend 2023-2028, Updated Report with 99 Pages," Market Watch, 25 February 2023, Retrieved on 9th May 2023 from https://www.marketwatch.com. https://www.marketwatch.com/press-release/latest-survey-on-edible-mushrooms-market-trend-2023-2028-updated-report-with-99-pages-2023-02-25.

[7] Kumar, H., K. Bhardwaj, R. Sharma, E. Nepovimova, N. Cruz-Martins, D. S. Dhanjal, R. Singh, C. Chopra, R. Verma, K. A. Abd-Elsalam, A. Tapwal, K. Musilek, D. Kumar, and K. Kuča, "Potential Usage of Edible Mushrooms and Their Residues to Retrieve Valuable Supplies for Industrial Applications," Journal of Fungi 7, no. 6 (May 2021): 427 (17 pages), https://doi.org/10.3390/jof706042.

[8] Ayser, M., "Fractionation of Mushroom Stems to Various Bioactive Molecules and Processing Chitin to Hydrogel for Wound Healing Application," Undergraduate Research Day Student Projects, 2023, Retrieved from https://uh-ir.tdl.org/items/5c4370d7-3f5a-4356-bdf3-9d0de017628a on 22nd September 2023.

[9] Li, S., A. Wang, L. Liu, G. Tian, S. Wei, and F. Xu, "Evaluation of Nutritional Values of Shiitake Mushroom (*Lentinus edodes*) Stipes," Journal of Food Measurement and Characterization, 12 (Sept 2018): 2012-2019.

[10] Sivakumar, D., and G, Bozzo. "Mushroom Biomass Waste Is a Source of the Antioxidants Ergothioneine and Glutathione." Sustainability 15, no. 15 (August 2023): 11961 (13 pages). https://doi.org/10.3390/su151511961.

[11] Husain, H., and N. Huda-Faujan, "Quality Evaluation of Imitation Chicken Nuggets from Grey Oyster Mushroom Stems and Chickpea

Flour," Malaysian Applied Biology 49, no. 3 (October 2020): 61-69, https://doi.org/10.55230/mabjournal.v49i3.1542.

[12] Banerjee, D. K., A. K. Das, R. Banerjee, M. Pateiro, P. K. Nanda, Y. P. Gadekar, S. Biswas, D. J. McClements, and J. M. Lorenzo, "Application of Enoki Mushroom (Flammulina Velutipes) Stem Wastes as Functional Ingredients in Goat Meat Nuggets," Foods 9, no. 4 (April 2020): 432, https://doi.org/10.3390/foods9040432.

[13] Mahfuz, S., H. Song, Y. Miao, and Z. Liu, "Dietary Inclusion of Mushroom (Flammulina velutipes) Stem Waste on Growth Performance and Immune Responses in Growing Layer Hens," Journal of the Science of Food and Agriculture 99, no. 2 (January 2019): 703-710, https://doi.org/10.1002/jsfa.9236.

[14] Hamid, M. A., F. L. Tsia, A. A. Okit, C. W. Xin, H. Cien, L. Harn, P. Patrick, S. Samirin, W. A. Azizi, A. Irfanian, and C. F. Yee, C. F. "The Application of Jackfruit By-Product on The Development of Healthy Meat Aanalogue, " IOP Conference Series: Earth and Environmental Science, Vol. 575, no. 1 (2020): 012001, https://doi.org/10.1088/1755-1315/575/1/012001.

[15] Van Ba, H., H. W. Seo, S. H. Cho, Y. S. Kim, J. H. Kim, J. S. Ham, B. Y. Park, and S. P. Nam, "Antioxidant and Anti-Foodborne Bacteria Activities of Shiitake By-Product Extract in Fermented Sausages," Food Control 70 (December 2016): 201-209, https://doi.org/10.1016/j.foodcont.2016.05.053.

[16] Wan Rosli, W. I., M. A. Solihah, M. Aishah, N. A. Nik Fakurudin, and S. S. J. Mohsin, "Colour, Textural Properties, Cooking Characteristics and Fiber Content of Chicken Patty Added with Oyster Mushroom (Pleurotus sajor-caju)," International Food Research Journal 18, no. 2 (April 2011): 621-627.

[17] Huda-Faujan, N., A. Najeeba, and Arifin, N, "Proximate Composition and Sensory Preference of Beef Sausages with Unripe Jackfruit," Malaysian Journal of Science Health & Technology 8, no. 2 (May 2022): 9-13, https://doi.org/10.33102/2022249.

[18] Murphy, E. W., P. E. Criner, and B. C. Gray. "Comparisons of Methods for Calculating Retention of Nutrients in Cooked Foods," Journal of Agricultural and Food Chemistry 23, no. 6 (November 1975): 1153-1157, https://doi.org/10.1021/jf60202a021.

[19] Bouton, P. E., P. V. Harris, W. R. Shorthose, and R. W. Ellis, "Comparison of Some Properties of Meat from Normal Steers and Steers Heterozygous for Muscular Hypertrophy," Meat Science 2, no. 3 (July 1978): 161-167, https://doi.org/10.1016/0309-1740(78)90001-3.

[20] Osman, K., and K. Sukru, "The Effects of Cereal and Legume Flour on The Quality Characteristics of Beef Patties," Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 18, no. 5 (2012): 725-730.

[21] AOAC (Association of Official Analytical Chemists), "Official Methods of Analysis (18th Edition)," Washington: Washington D. C., 2005.

[22] Atwater, W. O., and C. D. Woods, "The Chemical Composition of American Food Materials. US Official Experiment Stations," Experiment Station Bulletin No. 28. Washington, D. C., Washington, 1896.

[23] Cha, M. H., J. Y. Heo, C. Lee, Y. M. Lo, and B. Moon, "Quality and Sensory Characterization of White Jelly Mushroom (Tremella fuciformis) as A Meat Substitute in Pork Patty Formulation," Journal of Food Processing and Preservation 38, no. 4 (October 2013): 2014-2019, http://dx.doi.org/10.1111%2Fjfpp.12178.

[24] Arifin, N., N. F. Mohd Hanifah, and H. N. Yahya, "Physicochemical Properties, Nutritional Composition and Sensory Acceptance of Chicken Meat Sausages with Chia Seed Powder Substitution," Malaysian Journal of Science Health & Technology 7, no. 1 (March 2021): 34-42, https://doi.org/10.33102/mjosht.v7i1.137.

[25] Straková, E., P. Suchý, F. Vitula, and V. Večerek, "Differences in The Amino Acid Composition of Muscles from Pheasant and Broiler Chickens," Archives Animal Breeding 49, no. 5 (2006): 508-514, https://doi.10.5194/aab-49-508-2006.

[26] Oyetayo, F. L., A. A. Akindahunsi, and V. O. Oyetayo, "Chemical Profile and Amino Acids Composition of Edible Mushrooms Pleurotus sajor-caju," Nutrition and Health 18, no. 4 (January 2007): 383-389. https://doi.org/10.1177/026010600701800407.

[27] Dospatliev, L., V. Lozanov, M. Ivanova, P. Papazov, P. Sugareva, Z. Petkova, and D. Bojilov. "Comparison of Free Amino Acid Compositions of Stem and Cap in Wild Edible Mushrooms, Bulgaria," Oxidation Communications 41, no. 4 (2018): 542-549.

[28] Jia, B., S. C. Yoon, H. Zhuang, W. Wang, and C. Li, "Prediction of pH of Fresh Chicken Breast Fillets by VNIR Hyperspectral Imaging," Journal of Food Engineering 208, (September 2017): 57-65, https://doi.org/10.1016/j.jfoodeng.2017.03.023.

[29] Suhaili, M., M. A. R. Nor-Khaizura, Z. Hanani, M. R. Ismail-Fitry, N. I. P. Samsudin, and N. N. Jambari, "Assessment of Microbiological Safety and Physicochemical Changes of Grey Oyster Mushroom (Pleurotus sajor-caju) During Storage at 4 °C and 25 °C," Sains Malaysiana 50, no. 10 (October 2021): 2993-3002, http://doi.org/10.17576/jsm-2021-5010-13.

[30] Beauclercq, S., S. Mignon-Grasteau, A. Petit, Q. Berger, A. Lefèvre, S. Metayer-Coustard, S. Tesseraud, P. Emond, C. Berri, and E. Le Bihan-Duval, "A Divergent Selection on Breast Meat Ultimate pH, A Key Factor for Chicken Meat Quality, is Associated with Different Circulating Lipid Profiles," Frontiers in Physiology 13, (June 2022): 935868. https://doi.org/10.3389/fphys.2022.935868.

[31] Darwish, S. M. I., M. A. H. El-Geddawy, R. M. B. Khalifa, and R. A. A. Mohamed, "Physico-chemical Changes of Frozen Chicken Burger Formulated with Some Spices and Herbs", Frontiers in Science 2, no. 6 (2012): 192-199, https://doi.org/10.5923/j.fs.20120206.10.

[32] Sandulachi, E. "Water Activity Concept and Its Role in Food Preservation," Meridian Ingineresc 1, no. 4 (2012): 40-48, Retrieved on 9th April 2023 from https://ibn.idsi.md/vizualizare_articol/26419.

[33] Chiang, J. H., S. M. Loveday, A. K. Hardacre, and M. E. Parker, "Effects of Soy Protein to Wheat Gluten Ratio on The Physicochemical Properties of Extruded Meat Analogues," Food Structure 19, (January 2019): 100102 (8 pages), 2019. https://doi.org/10.1016/j.foostr.2018.11.002.

[34] Martinez, O., J. Salmeron, M. D. Guillen, and C. Casas, "Texture Profile Analysis of Meat Products Treated with Commercial Liquid Smoke Flavourings," Food Control 15, no. 6 (September 2004): 457-461, https://doi.org/10.1016/S0956-7135(03)00130-0.

[35] Wang, L., H. Guo, X. Liu, G. Jiang, C. Li, X. Li, and Y. Li, "Roles of Lentinula edodes as The Pork Lean Meat Replacer in Production of The Sausage," Meat Science 156, (October 2019): 44-51, https://doi.org/10.1016/j.meatsci.2019.05.016.

[36] Harris, G. K., and M. R. Marshall, "Ash Analysis." In Food Analysis edited by Nielsen, S. S. Springer International Publishing: Food Science Text Series. pp. 287-297, 2017, https://doi.org/10.1007/978-3-319-45776-5_16.

[37] Ahmed, M., A. Noorlidah, and M. M. Nuruddin, "Yield and Nutritional Composition of Oyster Mushrooms: An Alternative Nutritional Source for Rural People," Sains Malaysiana 45, no. 11 (November 2016): 1609-1615.

[38] Wan Rosli, W. I., M. S. Nor Maihiza, and M. Raushan, "The Ability of Oyster Mushroom in Improving Nutritional Composition, β-Glucan and Textural Properties of Chicken Frankfurter," International Food Research Journal 22, no. 1 (February 2015): 311-317.

[39] Oluwafemi, G. I., K. T. Seidu, and T. N. Fagbemi, T.N, "Chemical Composition, Functional Properties and Protein Fractionation of Edible Oyster Mushroom (Pleurotus ostreatus)," Annals Food Science and Technology 17, no. 1 (2016): 218-223.

[40] Kavishree, S., J. Hemavathy, B. R. Lokesh, M. N. Shashirekha, and S. Rajarathnam, "Fat and Fatty Acids of Indian Edible Mushrooms," Food Chemistry 106, no. 2 (January 2008): 597–602, https://doi.org/10.1016/j.foodchem.2007.06.018.

[41] De Marchi, M., R. Riovanto, M. Penasa, and M. Cassandro, "At-Line Prediction of Fatty Acid Profile in Chicken Breast Using Near Infrared Reflectance Spectroscopy," Meat Science 90, no. 3 (March 2012): 653-657. https://doi.org/10.1016/j.meatsci.2011.10.009.

[42] Mohammed, H. A., "Moisture, Fat and Protein Content in Various Types of Animal Marketing Meats." (2020): 19-22, Retrieved on 22nd September 2023 from https://www.researchgate.net/profile/Hassan-Mohammed-7/publication/341313739_Moisture_fat_and_protein_content_in_various_types_of_animal_marketing_meats/links/5eba745c92851cd50dab69ba/Moisture-fat-and-protein-content-in-various-types-of-animal-marketing-meats.pdf. on 22nd September 2023.

[43] Shedeed, N. A., S. A. S. Hallabo, F. A. EI-Wakeil, and E. D. Shames, "Characteristics of Chicken Meat as Affected by Different Cooking Methods," Journal of Agricultural Science Mansoura University 31, no. 12 (2006): 7821-7832, Retrieved on 24th September 2023 from https://journals.ekb.eg/article_236907_4ae785a0ee9399e4a3320213981b5699.pdf. on 24th September 2023.

[44] Yahya, F., and H. T. Ting, "Effect of Different Ratios of Chicken Meat to Fresh Oyster Mushroom (*Pleurotus sajor-caju*) on The Physicochemical Properties and Sensory Acceptability of Sausages," International Journal on Food, Agriculture, and Natural Resource 1, no. 1 (April 2020): 7-14, https://doi.org/10.46676/ij-fanres.v1i1.2.