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Development of Plant-Based Patties from the Underutilised Crop Split Gill Mushroom (*Schizophyllum commune*) using Different Cooking Methods

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ABSTRACT

Malaysia faces a dual burden of malnutrition and obesity, compounded by rising non-communicable diseases, highlighting the need for dietary diversification. Underutilised crops, such as split gill mushrooms (*Schizophyllum commune*), offer nutritional and functional benefits due to their high protein, dietary fibre, vitamins, minerals, and bioactive compounds. This study developed split gill mushroom patties as a model product to evaluate sensory attributes, consumer acceptance, and nutritional composition across three cooking methods: pan-frying (PFM), searing (SRM), and sautéing (STM). Sensory evaluation revealed moderate-to-high liking scores, with PFM achieving the highest overall acceptance (7.0/9), SRM scoring highest in texture (6.8/9), and STM receiving the highest aroma rating (6.7/9). Positive correlations were observed between colour and appearance, taste, and overall liking, while overall perception was associated with aroma, taste, and texture. Despite low consumer familiarity (74.1% reporting 'not at all familiar'), 44.4% indicated willingness to consume the patties if reasonably priced, emphasising the importance of affordability. Nutritional analysis showed that SRM had the highest ash content (4.0 g/100 g DM), STM had the highest lipid content (30.6 g/100 g DM) and energy density (536 kcal/100 g DM), and PFM provided the highest dietary fibre (3.4 g/100 g DM), demonstrating versatility for varied dietary needs. These findings indicate that split gill mushroom patties are palatable, nutritionally rich, and commercially promising. Strategic improvements in sensory quality, cost-effectiveness, and targeted marketing could facilitate mainstream adoption, offering a practical pathway to enhance dietary diversity, nutritional security, and the adoption of underutilised crops in Malaysia.

1. Introduction

Malaysia is experiencing a growing nutritional challenge, characterised by the double burden of malnutrition and obesity alongside rising non-communicable diseases. Recent surveys indicate 15.6% of adults have diabetes, 29% hypertension, and obesity rates have increased from 15.1% in 2011 to

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21.8% in 2023 [1]. Adolescents are also affected, with 16.7% overweight, 10.4% obese, and 14.7% stunted [1]. This trend is closely associated with a dietary shift toward energy-dense, nutrient-poor, and highly processed products, alongside low dietary diversity and limited consumption of plant-based foods [2].

Underutilised crops offer a promising approach to improving nutritional security due to their high protein, dietary fibre, essential minerals, and bioactive compounds. However, adoption remains limited by low consumer awareness, unfamiliarity with preparation methods, and negative perceptions regarding taste and acceptability [3-5].

Split gill mushroom (*Schizophyllum commune*), locally known as *cendawan kukur*, is an underutilised edible fungus rich in protein, beta-glucans, vitamins, minerals, and bioactive compounds [6-8]. Its firm, umami-rich texture and functional properties make it suitable for innovative food applications, including meat-substitute products, seasonings, and functional beverages [7,9-11]. Furthermore, culinary processing influences its flavour, texture, and nutrient retention, with roasting enhancing meatiness, sautéing facilitating large-scale production, and pan-frying retaining certain nutrients [12,13].

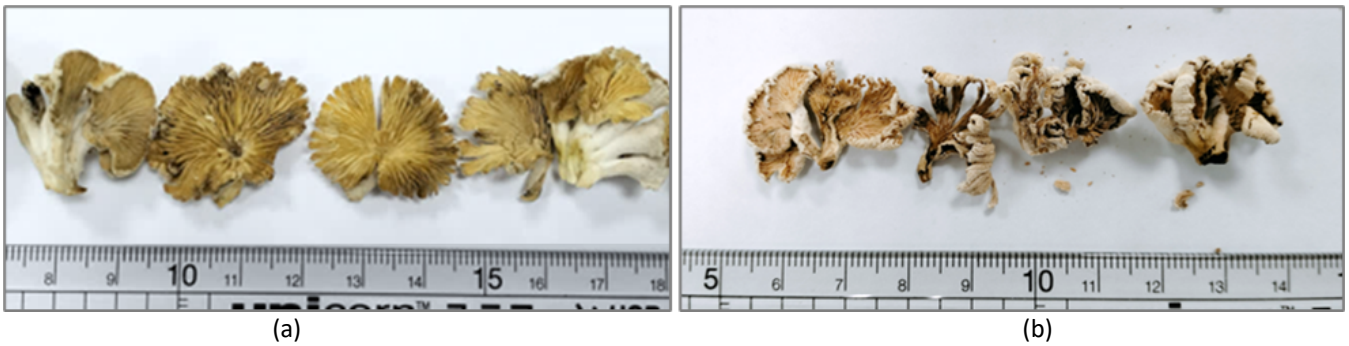
Despite its nutritional and functional potential, the use of split gill mushrooms in Malaysia remains low. This is largely due to limited awareness of their potential, including suitable processing methods, consumer preferences, and nutritional value, with their use primarily restricted to traditional dishes such as *masak lemak* or omelette prepared by villagers and rural communities.

To address this gap, this study develops a plant-based patty using split gill mushrooms as a model product. The research evaluates its sensory properties, consumer acceptance, and nutritional composition, while exploring processing approaches to optimise taste, texture, and nutrient retention. By demonstrating how an underutilised crop can be transformed into a palatable, nutritionally enriched, and versatile food product, this study aims to facilitate the incorporation of split gill mushrooms into mainstream diets, thereby supporting dietary diversification and enhancing nutritional security in Malaysia.

2. Methodology

2.1 Split Gill Mushroom Preparation

Fresh split gill mushrooms were purchased from *Pasar Pagi Beranang* (Beranang morning market), Selangor and then processed at the Nutrition Research Kitchen at the University of Nottingham Malaysia. Extraneous matters and damaged parts were removed manually. Mushrooms were spread in a thin layer on an oven tray and dried in a preheated oven at 60 ± 5 °C for approximately 5 hours with fan circulation until crisp. The dried mushrooms were stored in airtight containers at 4 °C until further use. Figure 1 shows images of the fresh and dried split gill mushrooms.



(a) (b)

Fig. 1. Split gill mushrooms (a) Fresh (b) Dried

For food preparation, dried mushrooms were soaked in water at room temperature for 30 min, washed in 1% salt solution for 5 min, rinsed with tap water, drained, and gently blotted dry. The mushrooms were then divided into three portions and subjected to different heat treatments following Ložnjak and Jakobsen [13]. One portion was seared on high heat in preheated cooking oil at a ratio of 1:20 ratio (palm oil: mushroom, w/w) and stirred frequently and rapidly for 5 minutes. This portion was labelled as SRM (Seared Mushroom). The second portion was sautéed at the same oil ratio on medium heat for 10 minutes with frequent but slow stirring and labelled as STM (Sauteed Mushroom). The last portion was pan-fried (labelled as PFM) at low heat in preheated cooking oil at 1:10 ratio (palm oil: mushroom, w/w) for 20 minutes, with minimal stirring. The pan temperature could not be measured throughout the process.

2.2 Split Gill Mushroom Patty Formulation

The initial patty formulation was developed through a trial-and-error process, consisting of mushroom (45.0 g), lablab beans (15.0 g), grated potato (10.0 g), corn starch (10.0 g), onion (10.0 g), garlic (2.0 g), salt (1.5 g), and black pepper (0.5 g). Overnight-soaked lablab beans were dehulled, boiled in two changes of water until tender, then drained and cooled prior to use. Heat-treated split gill mushrooms (pan-fried, sautéed, or seared) were blended with the prepared ingredients using a mini food chopper (Tefal) until a homogeneous mixture was obtained. Approximately 25 g of the mixture was shaped into round patties (4 cm diameter), arranged on a baking sheet, covered with cling wrap, and frozen for at least 2 hours before being transferred to airtight containers and stored in the freezer until further use. Prior to consumption, patties were pan-fried in a lightly oiled pan over high heat until browned on both sides. The prepared split gill mushroom patties are shown in Figure 2.

(a) (b) (c)

Fig. 2. Split gill mushroom patty (a) Pan-fried mushroom (b) Seared mushroom (c) Sauteed mushroom

2.1 Sensory Analysis

The sensory questionnaire included three sensory evaluation questions. The first question assessed the appearance, taste, colour, texture, and aroma using a 9-point hedonic scale. The second question was a 5-point scale to rate each attribute's influence on consumption. The last question was an open-ended feedback section. Eight additional items measured familiarity with underutilised crops, likelihood of consumption, habitual intake, expected price, willingness to pay, and demographics (gender, age, household income), providing insight into consumption behaviour while minimising participant fatigue. Participants were recruited from staff and students at the University of Nottingham Malaysia, aged ≥18 years, with no food allergies or relevant medical conditions. Upon

arrival, they were provided with an informed consent form and study briefings. The patties were prepared 15 minutes prior to serving, maintained at serving temperature, and served on paper plates labelled with randomised three-digit codes. Drinking water was provided for palate cleansing in between sample.

2.2 Ethical Considerations

Ethical permission involving human subjects was obtained from the Science and Engineering Research Ethics Committee (SEREC) of Nottingham University Malaysia with the SEREC reference AJ020322.

2.3 Nutritional Analysis

Thirty cooked patties were randomly selected and analysed at the Analytical Laboratory, University of Nottingham Malaysia. Patties were diced into 1 cm pieces, oven-dried at 105°C for 24 h or until constant mass, then ground to pass through a 1 mm sieve, stored in airtight containers, and preserved at 4°C until analysis.

Proximate composition was determined following the Protocol for Sampling and Methods for Malaysian Food Composition Data [14]. Crude protein was measured using the Kjeldahl method (Buchi KjelDigestor K-446; KjelFlex K-380) with manual titration. Crude fat was extracted with petroleum ether via Soxhlet apparatus (Gerhardt EV6, Germany). Crude ash was determined by incineration in a muffle furnace (Carbolite, UK) and weighed gravimetrically. Crude fibre was assessed by sequential acid and alkaline digestions using a manual FibreBag system (Gerhardt GmbH, Germany), with ashed residue weight loss calculated. Carbohydrate and energy contents were estimated by difference.

2.4 Data Analysis

Hedonic sensory data and nutritional values were expressed as means ± standard deviation (SD) or standard error of the mean (SEM). Parametric comparisons were performed using one-way ANOVA, followed by Tukey's honestly significant difference (HSD) test for multiple comparisons where applicable. Correlations were assessed using Spearman's Rho, with statistical significance defined at $p < 0.05$. Demographic and consumer perception were analysed using frequency analysis. All statistical analyses were conducted with IBM SPSS Statistics version 28.0.

3. Results

3.1 Sensory Acceptance

The results of consumer group sensory evaluation indicate similar levels of liking across all attributes for the three split gill mushroom patty samples (Figure 3). Overall, the samples were generally well-liked, with scores ranging from 5.8 (for the colour of SRM and STM) to the highest score of 7.0 (for the taste of PFM). The PFM sample also received the highest overall liking score (7.0). In terms of aroma, STM was rated slightly higher (6.7) compared to the other samples, while SRM scored the highest for texture (6.8) and appearance (6.0). Since there were no significant differences among the three samples, they were equally preferred. These findings suggest that any of the samples have potential for further development in terms of consumer sensory acceptance.

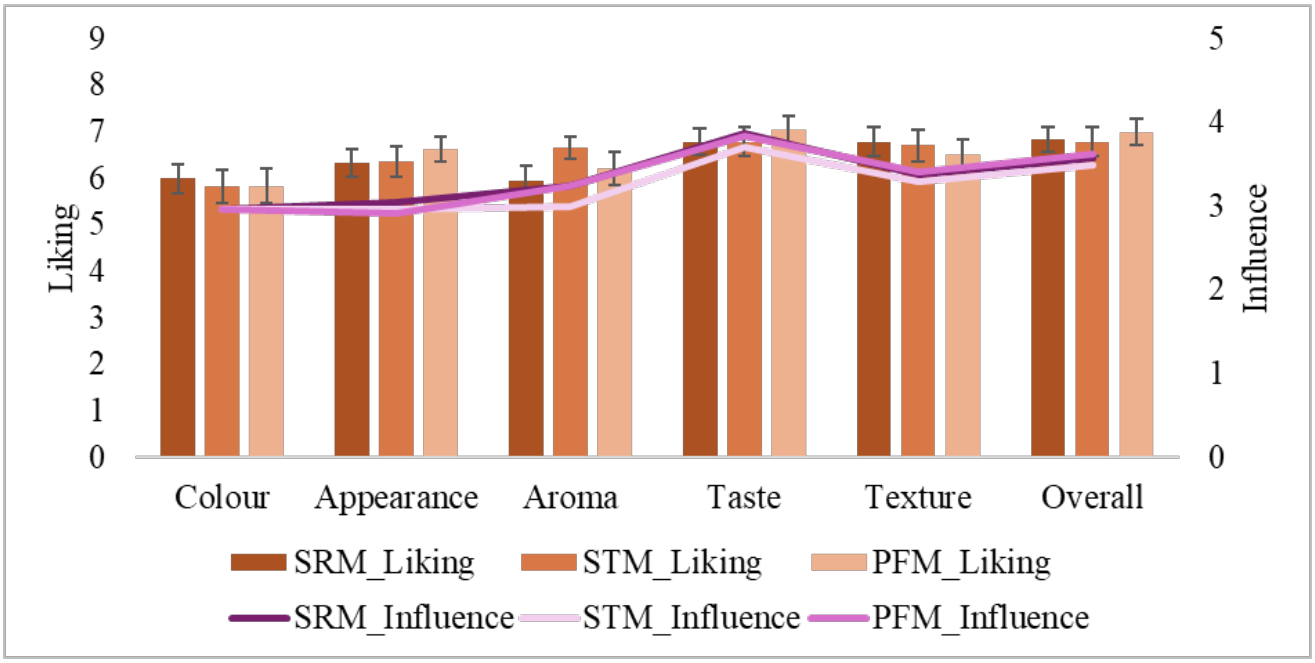


Fig. 3. Sensory evaluation of split gill mushroom patty (*n* = 27)

Note. Bars represent mean ± standard error mean (primary y-axis). The solid line represents mean influence scores (secondary y-axis). Liking was analysed using a 9-point Hedonic scale (ranging from 1 = dislike extremely to 9 = like extremely). Influence was analysed using a 5-point scale (ranging from 1 = not affected at all to 5 = majorly affected). SRM = Seared mushroom, STM = Sauteed mushroom, and PFM = Pan-fried mushroom.

Existing literature demonstrated that different cooking methods significantly influence the sensory profile of mushrooms [12,15,16]. Myrdal-Miller *et al.,* [12] reported that varying cooking techniques can either enhance or diminish key flavour and aroma characteristics in plant-based ingredients. For example, searing generates pronounced toasted/roasted characteristics with burnt/charred and smoky notes, while roasting enhances sweet, salty, and umami flavours along with caramelised, nutty, and buttery undertones [12]. In contrast, steamed mushrooms retain more moisture but develop predominantly cardboard/paper-like flavours with stronger raw mushroom notes. Sautéed preparations show intermediate characteristics, maintaining higher moisture content than roasted variants but exhibiting less flavour intensity than either seared or roasted mushrooms [12].

Sun *et al.,* [16] also highlighted that cooking, such as stewing, autoclaving, microwaving, and sous vide, increased total free amino acid (FAA) content compared to fresh mushrooms. However, the type and level of FAA are not the same for all thermal treatments. For example, umami-associated amino acids (glutamic acid [Glu], aspartic acid [Asp]) and sweet-tasting amino acids (threonine [Thr], serine [Ser], proline [Pro], glycine [Gly], alanine [Ala]) were most concentrated in autoclaved soup and sous vide–cooked samples [16].

The analysis of the attributes influence on consumption revealed that colour had only a minor effect on consumer decisions across all three samples. Similarly, appearance demonstrated a minor influence for both PFM and STM, with mean scores falling below the neutral threshold of 3.0. In contrast, taste shows a near-moderate effect on consumption desire with scores between 3.7 to 3.9.

Correlation analysis (Table 1) identified several significant relationships. Colour ($\rho = 0.24$, $p < 0.05$) and overall perception ($\rho = 0.43$, $p < 0.01$) showed direct positive associations with their respective attribute likings. Furthermore, colour exhibited significant positive correlations with appearance ($\rho = 0.53$, $p < 0.01$), taste ($\rho = 0.32$, $p < 0.01$), and overall ($\rho = 0.28$, $p < 0.05$) product liking. Whereas, overall perception was positively associated with aroma ($\rho = 0.33$, $p < 0.01$), taste ($\rho = 0.41$, $p < 0.01$),

and texture (ρ = 0.34, p < 0.01) preferences. An additional positive relationship was observed between texture and aroma liking (ρ = 0.29, p < 0.05).

Table 1
Correlations of perceived attributes influencing split gill mushroom patty liking

Influence	Liking					
	Colour	**Appearance**	**Aroma**	**Taste**	**Texture**	**Overall**
Colour	0.24*	0.53**	0.18	0.32**	0.19	0.28*
Appearance	0.05	0.11	0.13	-0.13	-0.19	-0.16
Aroma	0.07	0.08	0.15	0.15	0.13	0.16
Taste	-0.12	-0.11	0.11	0.19	0.14	0.21
Texture	-0.03	-0.23	0.29*	-0.09	-0.12	-0.10
Overall	0.03	0.14	0.33**	0.41**	0.34**	0.43**

Note. Correlation matrix showing Spearman Rho ρ coefficients. ** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

For this product, colour and overall perception are key drivers in increasing the desire to consume it. This is supported by literature indicating that visual cues, including food colour, influence perceived healthiness and tastiness [17]. In addition, multiple attributes, both internal (e.g., visual appeal, taste, and aroma) and external (e.g., functionality, convenience), shape consumer decision-making on food consumption [18].

3.2 Consumer Perception

The demographics of consumers participating in the sensory analysis and their perceptions of alternative crops and crop-derived products are presented in Table 2. Most participants were aged 18–39, indicating strong representation of younger consumers, while those aged ≥60 were minimally represented (3.7%). Females accounted for 70.4% of respondents. Income levels varied, with the largest group earning ≤ RM2,000 (40.7%), followed by 22.2% in the highest bracket (> RM8,000).

Table 2
Participant demographic profiles and consumer perceptions of split gill mushroom and patty

Category	Frequency (%)
Age	
18-39	23 (85.2)
40-59	3 (11.1)
≥ 60	1 (3.7)
Gender	
Female	19 (70.4)
Male	8 (29.6)
Income	
≤ RM2,000	11 (40.7)
RM2,001-4,000	2 (7.4)
RM4,001-6,000	3 (11.1)
RM6,001-8,000	4 (14.8)
≥ RM8,001	6 (22.2)
Frequency of consuming similar products	
Less than 3 times a week	8 (29.6)
Less than 3 times a month	13 (48.1)

Less than 3 times a year	5 (18.5)
Never consume	1 (3.7)
Familiarity with the underutilised crops used	
Not at all familiar	20 (74.1)
Slightly familiar	1 (3.7)
Somewhat familiar	3 (11.1)
Moderately familiar	1 (3.7)
Extremely familiar	2 (7.4)
Likelihood to consume the product if widely available	
Unlikely	5 (18.5)
Neutral	5 (18.5)
Likely	12 (44.4)
Extremely likely	5 (18.5)
Likelihood to consume the product if reasonably priced	
Unlikely	2 (7.4)
Neutral	7 (25.9)
Likely	12 (44.4)
Extremely likely	6 (22.2)
Expected cost of underutilised crop products compared to similar products	
Much less (≤ 50%)	1 (3.7)
Slightly less (≤ 25%)	7 (25.)
Not more, not less	6 (22.2)
Slightly more (≥ 25%)	5 (18.5)
Much more (≥ 50%)	1 (3.7)
Willingness to pay for underutilised crop products compared to similar products	
Much less (≤ 50%)	1 (3.7)
Slightly less (≤ 25%)	7 (25.90
Not more, not less	10 (37.0)
Slightly more (≥ 25%)	7 (25.9)
Much more (≥ 50%)	2 (7.4)

Consumer perceptions of the split gill mushrooms and the patty provide further insight into the market readiness of the developed products. The consumption frequency of similar products already available in the market shows that patties were usually consumed less than three times a month (48.1%), indicating moderate habitual demand. While patties are not common in Malaysian dishes, they are sometimes sought as snacks or fast-food meals. This positions patties as a product with potential to be integrated into existing diets.

Overall familiarity with the split gill mushroom is very low, with 74.1% of respondents indicating that they are 'not at all familiar' on the familiarity scale. These findings suggest that targeted awareness campaigns may be required to improve consumer recognition of this crop. Despite this low familiarity, a substantial proportion of respondents (44.4%) indicated that they would be 'likely' to consume the product if it were widely available and reasonably priced. Similarly, Bayudan *et al.,* [19] reported that despite low familiarity, there is a strong curiosity from consumers, particularly among health-conscious, environmentally beneficial, environmentally aware and urbanites.

In addition, affordability appears to be a significant factor influencing consumer willingness to try these products, highlighting the importance of pricing strategies. Consumer expectations regarding cost further emphasise pricing sensitivities: most respondents (52%) believe the products should not cost more than existing alternatives, while only 33% are willing to accept higher prices.

3.3 Nutritional Composition

The proximate composition of the three patty samples is presented in Figure 3. All three samples showed similar and consistent nutritional profiles, apart from variations in the levels of crude ash and fibre content. SRM showed significantly higher ($p < 0.016$) ash content (4.0 g/100 g DM) than PFM (3.7 g/100 g DM), while PFM and STM (3.8 g/100 g DM) differed only marginally. Searing and sautéing at high heat may lead to a loss of moisture content, resulting in a higher ash concentration. Myrdal-Miller *et al.,* [12] reported that searing and sautéing can cause water loss of up to 38% in white mushrooms (*Agaricus bisporus*). In contrast, PFM exhibited the highest fibre content (3.4 g/100 g DM), significantly higher ($p < 0.024$) than that of SRM and STM (2.8 g/100 g DM and 2.7 g/100 g DM, respectively). The impact of dry-heat cooking methods (pan-frying, searing, sautéing) on fibre retention remains understudied in the current literature. Future research should prioritise this area to address the critical knowledge gap in food science research.

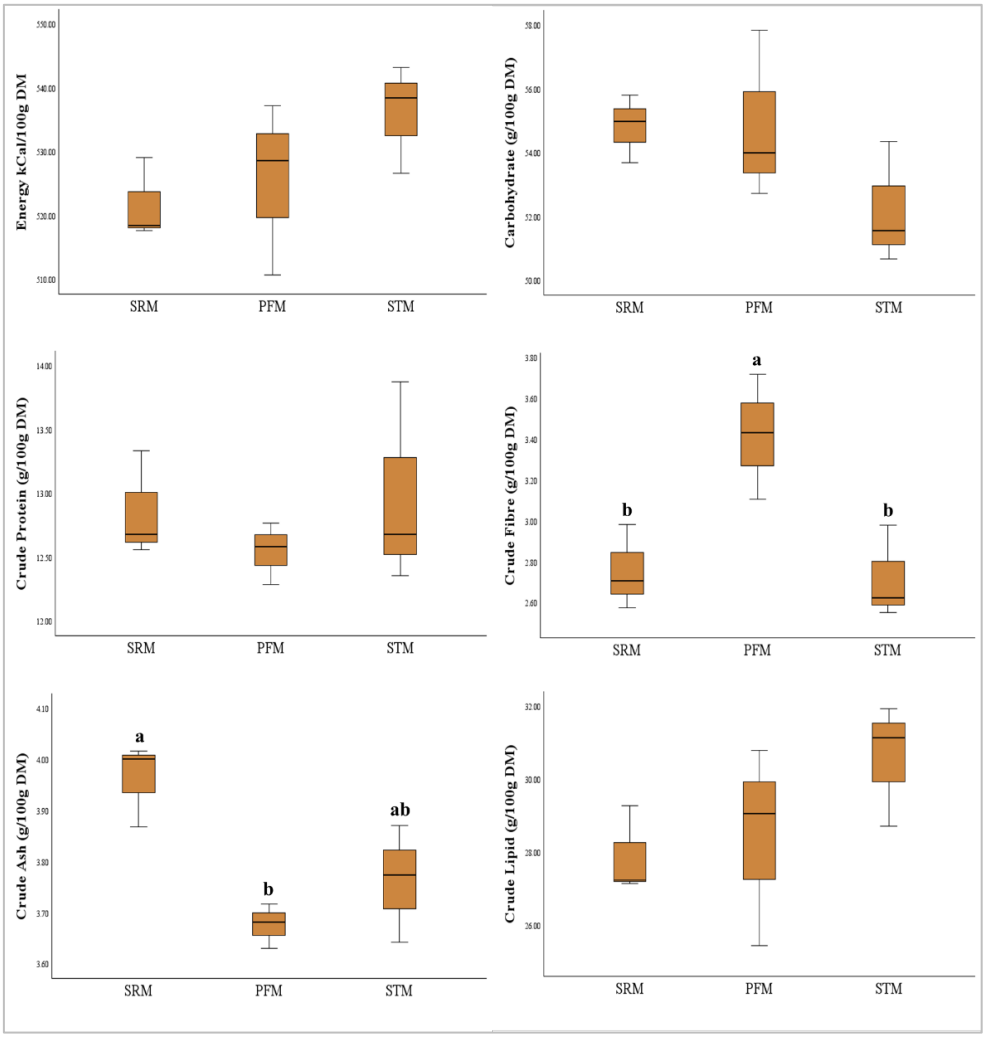


Fig. 3. Nutritional composition of split gill mushroom patty

Note. All analyses were performed in triplicate. Different letters above the boxes within each group indicate significant differences ($p < 0.05$, ANOVA with Tukey's HSD test). SRM = Seared split gill mushroom patty, STM = Sauteed split gill mushroom patty, and PFM = Pan-fried split gill mushroom patty.

While most nutrient components did not show significant differences among the three samples, distinct patterns emerged for each sample's profile. SRM exhibited the highest carbohydrate content (54.8 g/100 g DM) but the lowest caloric value (521.7 kcal/100 g DM), demonstrating an inverse relationship between these parameters. Conversely, STM displayed the opposite trend, with the highest energy density (536.0 kcal/100 g DM) coinciding with its lowest carbohydrate level (52.2 g/100 g DM) and highest lipid content (30.6 g/100 g DM), suggesting that its elevated caloric value was primarily driven by its increased fat concentration. PFM maintained an intermediate nutritional profile, with moderate levels of energy (525.5 kcal/100g), carbohydrates (54.9 g/100 g DM), and lipids (28.4 g/100 g DM) that positioned it between the two extremes represented by SRM and STM. These distinct nutritional patterns suggest that processing methods or pre-treatments influenced the macronutrient distribution. Research has shown that cooking methods significantly impact vitamin D retention in mushrooms, with boiling leading to a 38% loss, while pan-frying at low heat preserves up to 88% of the nutrient [13].

The findings suggest that STM's nutritional profile, characterised by enhanced lipid content and energy density, could make it particularly suitable for high-energy feed formulations. In contrast, SRM, with higher mineral and carbohydrate content but lower lipid levels and caloric value, may be more appropriate for weight management or individuals with low physical activity. Meanwhile, PFM offers a moderate nutritional profile with higher fibre content, making it beneficial for improving fibre intake.

4. Conclusions

Split gill mushroom-based patties demonstrate strong potential as nutrient-rich plant-based food products, even in the context of low consumer familiarity. Consumer acceptance was driven primarily by sensory quality, texture, and affordability, while price sensitivity remains a key barrier. The nutritional composition varied across the heat treatments, offering options for energy-dense diets, lower-calorie consumption, or increased dietary fibre, highlighting their versatility for different dietary needs.

Strategic improvements in flavour, texture, and cost-effectiveness, combined with targeted marketing and recipe development for both consumers and small-scale entrepreneurs, could facilitate broader adoption. By promoting underutilised crops through accessible, trend-aligned products, these patties not only enhance consumer health but also support sustainable food systems. Overall, the findings demonstrate a practical pathway to transform split gill mushrooms into palatable, nutritionally enriched, and commercially viable products, supporting the incorporation of this underutilised crop into mainstream diets to promote dietary diversification and enhance nutritional security in Malaysia.

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