Effects of Canning Temperature and Period on the Proximate Composition of Oyster Mushrooms (*Pleurotus ostreatus*) and the Functional Properties of its Brine

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Canning is a method for preserving perishable items, including edible mushrooms. However, the high temperatures applied during canning result in nutritional degradation and leaching into the brine. This study measured the proximate composition of oyster mushrooms after canning at three different temperatures (116, 121, and 126 °C) and periods (25, 30, and 35 minutes). Foaming capacity, foaming stability, and emulsion capacity tests were performed to establish the brine's functional qualities, while the SDS-PAGE technique was used to identify the molecular weight of the proteins. The results demonstrated that the canning temperature and period significantly reduced the protein and fat levels of oyster mushrooms ($p < 0.05$) by approximately 20.20 % and 50.30 %, respectively. This outcome suggests nutrient denaturation and leaching during the canning process of oyster mushrooms. In contrast, the ash and fibre levels of the mushroom samples increased with canning temperature and period ($p < 0.05$). The brine of canned mushrooms subjected to > 30 minutes of the canning process exhibited improved foam formation (60 - 83 %) and the greatest stability ($p < 0.05$). Gel electrophoresis revealed that the proteins in the brine solution had a molecular weight of less than 120 kDa. Thus, the nutritional composition of oyster mushrooms was significantly influenced by the temperature and period of the canning process. The formation of stable aerated bubbles also demonstrated the efficacy of the brine in preserving the mushrooms despite some nutrient loss.

Keywords: Mushroom; canning; proximate; foaming properties; emulsion; gel-electrophoresis

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Mushrooms are macroscopic fruiting bodies of fungi that can be classified as edible, medicinal, or wild [1]. Edible mushrooms have high market demand due to their nutritional value and unique qualities such as distinct aroma, flavour, and texture. Its distinct texture and taste have led to its utilisation as meat replacers in patty formulations [2-3], sausages [4–5], nuggets [6 – 8], and salt replacers [9 – 10]. Mushrooms are also considered a healthy food as they are low in fat but rich in proteins, fibre and carbohydrates [11]. Food and Agriculture Organisation Statistics (FAOSTAT) [12] reported that the high mushroom demand resulted in a 387.92 % increase in global production over the last 20 years, starting from 2000. In Malaysia, mushroom production has increased by 20 % from 2019 to 2024 (10,997 t) [13].

Despite the high demand, fresh mushrooms are highly perishable due to their high moisture content (± 90 %) and respiration rate, and degrade rapidly in quality after approximately three days of storage at ambient temperature. The quality changes include nutrient and flavour loss, discolouration, and texture changes [14]. As a result of the growing mushroom supply and the rapid loss of quality, effective processing is essential to extend their shelf life, marketability, and quality preservation. Mushroom preservation approaches align with one of the 17 Sustainable Development Goals (SDG), particularly SDG 2 Zero Hunger. The SDG 2 aims to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture. The canning of fresh mushrooms is in line with this goal to achieve a sustainable food supply,

as the produce is not seasonal, nutritious, and ready to eat.

Numerous efforts have been undertaken to manage the oversupply of top-cultivated mushroom species for commercial purposes, including the canning of button mushrooms and drying or vacuum packaging of shiitake. The oyster mushroom, *Pleurotus ostreatus*, one of the top three cultivated mushroom species, is usually sold fresh and is the least preserved compared to button and shiitake mushrooms. Nevertheless, stakeholders have studied several methods of oyster mushroom preservation, such as drying [15–18], freezing [19], and canning [20]. Retort processing or canning is one of the most common food preservation methods, where perishable items are hermetically sealed in an airtight container. The canning process consists of several steps, namely washing, blanching, filling, brining, exhausting, sterilising, cooling, and storing. Canned foods are exposed to high temperatures (115–130 °C) during sterilisation for a fixed period to extend their shelf life, primarily by eliminating harmful microorganisms and inactivating enzymes [20]. The sterilisation period varies depending on the type of food and its effects on food quality. Canned mushrooms are one of the most common canned food varieties found on store shelves. Mushrooms are sterilised at high temperatures for 12 to 30 minutes [21–22].

Despite canning being a viable option to preserve mushroom quality, the high temperatures applied during canning may cause nutrient deterioration. In canned foods, deterioration can occur when the nutrient is denatured or leaches into the brine [23–24]. The leaching of nutrients such as proteins may cause the brine to have functional qualities similar to aquafaba [25–26]. Understanding the functional properties of the brine can help determine its application in the food industry. Thus, studies have been conducted to identify the application of such ingredients over the years, e.g., mushroom brine for *bahulu*, chocolate mousse [27], cake [28], and meringue [29]. Elucidating the functional properties of brine can aid in developing new functional ingredients while reducing mushroom waste. Furthermore, there is a lack of research on the effects of different canning parameters on canned oyster mushrooms. Thus, this study examined the proximate composition of canned oyster mushrooms processed at various temperatures and periods. In addition, the brine from each experiment was evaluated for its functional properties, including foaming capacity, foaming stability, and emulsifying capacity. Finally, the brine was subjected to sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) to determine the molecular weight of the proteins contributing to its functional qualities.

EXPERIMENTAL

Materials and Preliminary Treatment

Fresh oyster mushrooms (7 kg) were purchased from a local supplier in Kota Kinabalu, Sabah. Firstly, the unwanted parts were trimmed, and the remaining biomass was cleaned thoroughly using cold running water to remove any debris. The mushrooms were then blanched in boiling water for one minute.

Canning

The blanched mushrooms (150 g) were drained and placed in cans. A 2 % salt solution was prepared as the brine which was filled into each can (200 mL) containing mushrooms [1]. The canned mushrooms were then sterilised by removing the air and sealing immediately. The canning process was carried out at different temperatures (116, 121 and 126 °C) and periods (25, 30 and 35 minutes). Subsequently, the canned mushrooms were stored at room temperature for a month prior to analysis to ensure equilibration of their contents and preservation [1].

Proximate Composition

The proximate composition (moisture, ash, protein, fibre, fat, and carbohydrate) of the fresh and canned mushrooms was determined according to AOAC guidelines [30]. Protein content was determined using the Kjeltec instrument (FOSS Kjeltec 2300, Denmark), with a protein conversion factor of 4.38 [31]. The total carbohydrate content was calculated according to Equation 1:

$$\text{Total carbohydrate (\%)} = 100 - \text{Moisture (\%)} - \text{Ash (\%)} - \text{Protein (\%)} - \text{Fibre (\%)} - \text{Fat (\%)} \quad (1)$$

Brine Solution Analysis

The brine from the canned oyster mushrooms was subjected to protein analysis using the Kjeldahl nitrogen method (FOSS Kjeltec 2300, Denmark).

Foaming Capacity and Stability

Foaming capacity and stability were determined according to García-Vaquero *et al.* [32] with modifications. Foam was prepared by homogenising 30 mL of brine solution using ULTRA TURRAX® T25 basic homogeniser (IKA, Saufen, Germany) at 13 000 rpm for two minutes. Foam volumes generated at two time points (at production and 10 minutes) were recorded using a 250 mL measuring cylinder. The experiment was performed in triplicate. Foam capacity and stability were calculated using Equations 2 and 3:

$$\text{Foam capacity (\%)} = [(V_F - V_O)/V_F] \times 100 \quad (2)$$

where V_O is the volume of brine before homogenisation (30 mL), and V_F is the volume of foam generated after homogenisation.

$$\text{Foam stability (\%)} = [V_{10}/V_F] \times 100 \quad (3)$$

where V_{10} is the volume of the remaining foam after 10 minutes, and V_F is the volume of foam generated after homogenisation.

Emulsifying Capacity

Emulsifying capacity was determined according to García-Vaquero *et al.* [32] with modifications. Emulsions were generated using palm oil as the oil phase and brine as the aqueous phase at a ratio of 3:2 (v/v). Subsequently, the emulsions were homogenised using the ULTRA TURRAX® T25 basic homogeniser (IKA, Saufen, Germany) at 13 000 rpm for two minutes. The samples were then centrifuged (5430 R, Eppendorf, Hamburg, Germany) at 4000 rpm for 10 minutes, and the emulsion capacity was calculated using Equation 4:

$$\text{Emulsion capacity (\%)} = [V_E/V_T] \times 100 \quad (4)$$

where V_E is the volume of the emulsion layer after centrifugation and V_T is the total emulsion volume inside the tube.

Sodium Dodecyl Sulphate-Polyacrylamide Gel Electrophoresis (SDS-PAGE)

Freeze-Drying of Samples

The brine from the canned oyster mushrooms was freeze-dried according to Stantiall *et al.* [29] with modifications. The solution was frozen at -80°C for 30 minutes in an ultra-low temperature freezer (New Brunswick™ Innova® U535 ultra-low temperature freezer, Edison, USA). The samples were transferred immediately into a freeze-drying chamber for five days using the FreeZone 4.5 L console freeze-dry system (Labconco Corp., USA).

Gel Electrophoresis

The freeze-dried brine was subjected to SDS-PAGE according to the method described by Roslan *et al.* [33] with modifications. The gel was prepared using 10 % resolving gel and 4 % stacking gel. Sample aliquots (15 µL) were added to 4x Laemmli SDS loading buffer (1610747, Bio-rad Lab., Inc., CA, USA) at a ratio of 1:1 (v/v) and heated at 90 °C for five minutes. Subsequently, 15 µL of the sample mixture was loaded into each well. Gel electrophoresis was conducted using a Mini-PROTEAN® Tetra vertical electrophoresis cell (Bio-Rad, USA) at 120 V. Subsequently, the gel was stained with a solution comprising 15 % methanol, 5 % acetic acid, and 0.05 % Coomassie brilliant blue R-250 for one hour, followed by destaining with 30 % methanol and 10 % acetic acid for 30 minutes. The gel was placed in distilled water until the background was clear and ready for imaging using a densitometer (BIO-RAD GS-800™ calibrated imaging densitometer, USA). The molecular weight of the protein bands was estimated using the Thermoscientific PageRuler Plus prestained protein ladder (10–250 kDa).

Statistical Analysis

The experimental data was analysed using the Statistical Package for Social Sciences (SPSS) software, version 28.0 (IBM, USA). The data was subjected to a one-way analysis of variance (ANOVA), and the results were expressed as the mean and standard deviation. The confidence level of $p < 0.05$ was considered statistically significant. Subsequently, Duncan's test was performed to determine significant differences between groups.

RESULTS AND DISCUSSION

Proximate Composition of Fresh and Canned Mushrooms

Table 1 presents the proximate composition of canned oyster mushrooms processed at various temperatures and periods. Fresh oyster mushrooms contained high moisture and protein levels, comparable to the results obtained by Shbeeb *et al.* (moisture: 90.40 %, protein: 20.00 %) [34]. Thus, the oyster mushroom is categorised as a highly perishable food due to its high moisture content. The current findings also indicate that the ash, protein, fibre, and carbohydrate contents of oyster mushrooms were significantly affected ($p < 0.05$) by the canning process.

Fresh and canned mushrooms had comparable moisture levels in general, except for those canned at 126 °C, which demonstrated a significant difference ($p < 0.05$). According to Nketia *et al.* [1], the isotonic condition produces little to no moisture migration from mushroom into brine and vice versa, which explains the insignificant moisture results at 25 and 30 minutes. Significant changes were observed at 35 minutes of canning, which induced cell wall damage and led to moisture release from the mushroom cells and tissues into the brine [35]. Furthermore, the canning process resulted in a two-fold increase ($p < 0.05$) in ash content compared to fresh samples. The presence of salt in the brine solution significantly contributed to the increased ash level, hence increasing the mineral content of mushrooms [36]. The ash levels in this study were higher than the levels recorded by Shbeeb *et al.* (6.20 % dry weight) [34].

Table 1. Proximate composition (%) of fresh and canned oyster mushrooms processed under various conditions.

Samples		Moisture (% wet basis)	Ash	Protein	Fibre (% dry basis)	Fat	Carbohydrates
Fresh oyster mushrooms		92.81 ± 0.13^{bc}	6.35 ± 0.02^{a}	18.66 ± 0.34^{e}	12.14 ± 0.26^{a}	1.53 ± 0.99^{b}	54.15 ± 0.57^{e}
116 °C	25 mins	93.23 ± 0.15^{cd}	16.08 ± 0.18^{cd}	14.44 ± 1.86^{ab}	22.68 ± 0.90^{e}	0.98 ± 0.23^{ab}	38.68 ± 2.32^{a}
	30 mins	93.21 ± 0.22^{cd}	16.24 ± 0.34^{bcd}	13.91 ± 0.21^{ab}	21.66 ± 0.15^{de}	0.49 ± 0.08^{a}	40.91 ± 0.26^{bc}
	35 mins	93.33 ± 0.40^{d}	15.94 ± 0.10^{d}	15.06 ± 0.10^{bc}	18.92 ± 0.26^{b}	0.95 ± 0.25^{ab}	42.00 ± 0.52^{cd}
121 °C	25 mins	93.34 ± 0.13^{d}	15.80 ± 0.34^{bcd}	14.91 ± 0.89^{bc}	22.67 ± 1.08^{e}	0.86 ± 0.07^{ab}	39.09 ± 0.52^{ab}
	30 mins	93.51 ± 0.34^{d}	15.42 ± 0.20^{b}	16.72 ± 0.59^{d}	21.23 ± 0.31^{cd}	0.66 ± 0.26^{a}	39.74 ± 0.74^{ab}
	35 mins	92.51 ± 0.27^{ab}	15.69 ± 0.57^{bcd}	13.09 ± 1.26^{a}	19.86 ± 0.85^{bc}	0.69 ± 0.25^{a}	43.31 ± 1.73^{d}
126 °C	25 mins	93.42 ± 0.18^{d}	15.90 ± 0.38^{bcd}	14.48 ± 0.46^{ab}	22.07 ± 0.94^{de}	0.93 ± 0.42^{ab}	39.72 ± 0.89^{ab}
	30 mins	93.40 ± 0.13^{d}	16.09 ± 0.22^{cd}	16.49 ± 1.25^{cd}	21.84 ± 0.66^{de}	0.58 ± 0.08^{a}	38.41 ± 1.07^{a}
	35 mins	92.13 ± 0.32^{a}	15.54 ± 0.20^{bc}	14.99 ± 0.13^{bc}	19.92 ± 0.17^{c}	0.69 ± 0.04^{a}	41.02 ± 0.34^{bc}

*Data is expressed as mean ± standard deviation, where n = 3.
Means within the same column with different superscripts differ significantly ($p < 0.05$).

The protein composition of canned oyster mushrooms decreased significantly ($p < 0.05$) (average of 20.20 %) under all conditions compared to fresh mushrooms. Protein is sensitive to heat and salt. Therefore, the high temperature during the canning process could have caused protein denaturation and leaching of water-soluble proteins [21]. Heat-induced vibrations within the molecule produce enough energy to disrupt the protein structure, leading to denaturation [37]. Earlier studies also reported similar changes in protein levels of canned oyster mushrooms [34, 38].

There was a significant increase in the fibre content ($p < 0.05$) of all oyster mushrooms processed under different conditions compared to the fresh samples. This finding may be the result of nutrient concentration from the reduced moisture in the biomass [39]. According to Baeva *et al.* [40], oyster mushrooms contain several polysaccharides, particularly β-glucan. High temperatures during canning disrupt the glycosidic linkages in polysaccharides, resulting in the release of oligosaccharides, and increasing the fibre content [41]. Oyster mushrooms that were canned for 35 minutes recorded a significant decrease in fibre levels ($p < 0.05$) compared to those processed for 25 and 30 minutes.

Fat levels in oyster mushrooms also decreased significantly ($p < 0.05$) by an average of 50.30 % under all canning conditions. The diluting effects of the brine and fat hydrolysation caused by high heat resulted in fat reduction in canned oyster mushrooms compared to the fresh samples. Salt in the brine creates a hypotonic environment that promotes the migration of compounds from the hypertonic mushroom tissue to the hypotonic brine, resulting in reduced fat content [22, 42].

The carbohydrate composition of canned oyster mushrooms also reduced significantly ($p < 0.05$) under all processing conditions compared to fresh mushrooms. Despite the decrease, the carbohydrate levels recorded in this study were still high. This finding suggests the retention of carbohydrates in oyster mushrooms after canning. Complex carbohydrates, namely polysaccharides such as β-glucans and chitins in mushrooms, are bioactive compounds with various health benefits [43]. These compounds help maintain a good gut microbiota [45], and serve as anti-diabetic [44] and anti-cancer agents [46]. In addition, high heating temperatures, particularly at 25 minutes, demonstrated better carbohydrate retention than other conditions, potentially due to the increase of total dietary fibre after processing [47]. Nonetheless, these increments were insignificant, and carbohydrate degradation continues to occur during a prolonged canning process.

Protein Analysis of Brine

Table 2 details the protein content of the brine after the oyster mushroom canning process, which ranged from 0.06 to 0.31 % ($p > 0.05$). The solutions were generally low in protein, but indicated potential protein leaching from mushrooms subjected to the canning process. This finding also supported the reduction of protein levels in canned oyster mushrooms. Nketia *et al.* [20] found that solids leached from canned oyster mushrooms. High temperatures led to cellular damage in mushrooms, resulting in protein release into the brine [48]. The protein loss in mushrooms and protein leaching into the brine resulted from the denaturation or hydrolysis of proteins into peptides and amino acids during canning, explaining the small amount of leached protein detected in the brine [49].

Table 2. Protein content in the brine of canned oyster mushrooms.

Brine of canned oyster mushrooms		
Temperature	Time	Protein (%)
116 °C	25 mins	0.31 ± 0.07^{b}
	30 mins	0.26 ± 0.05^{ab}
	35 mins	0.18 ± 0.02^{ab}
121 °C	25 mins	0.12 ± 0.15^{ab}
	30 mins	0.14 ± 0.12^{ab}
	35 mins	0.06 ± 0.09^{a}
126 °C	25 mins	0.10 ± 0.13^{ab}
	30 mins	0.12 ± 0.17^{ab}
	35 mins	0.11 ± 0.09^{ab}

*Data is expressed as mean ± standard deviation, where n = 3.
Means with different superscripts differ significantly ($p < 0.05$).

Foaming Properties of Canned Oyster Mushroom Brine

Table 3 demonstrates the foaming capacity and stability of the brine solution of canned oyster mushrooms at different canning temperatures and periods. Foam is a product of a colloidal system where gas is dispersed in a continuous aqueous phase. It has various applications in the food industry, including influencing the appearance and texture of aerated foods such as whipping cream, meringue, beer, and bread. Egg white is the most common source of food foams due to its excellent functional properties. Nevertheless, recent findings have led to brine solutions such as aquafaba and other non-animal-derived foams gaining attention as an alternative to egg whites [50]. Proteins and saccharides in aquafaba play pivotal roles in the foamability and stability of food foams. These compounds are also found in oyster mushrooms [51–52]. Previous studies focused on aquafaba as it displays good foaming properties, but there is a lack of research on the potential of mushroom brine. Thus, this study explored the foaming potential of canned oyster mushroom brine.

Table 3. Foaming capacity and stability of canned oyster mushroom brine.

Brine of canned oyster mushrooms			
Temperature	Time	Foaming capacity (%)	Foaming stability (%)
116 °C	25 mins	0.00 ± 0.00^{a}	00.00 ± 0.00^{a}
	30 mins	29.50 ± 11.84^{b}	00.00 ± 0.00^{a}
	35 mins	79.28 ± 2.78^{e}	75.02 ± 11.81^{d}
121 °C	25 mins	19.59 ± 2.53^{b}	5.26 ± 9.12^{a}
	30 mins	60.25 ± 6.31^{d}	20.73 ± 1.88^{bc}
	35 mins	79.81 ± 2.50^{e}	79.90 ± 2.25^{d}
126 °C	25 mins	47.63 ± 14.24^{c}	13.48 ± 12.28^{ab}
	30 mins	73.70 ± 2.36^{e}	31.35 ± 10.39^{c}
	35 mins	83.43 ± 1.86^{e}	81.86 ± 3.22^{d}

*Data is expressed as mean ± standard deviation, where n = 3.
Means within the same column with different superscripts differ significantly ($p < 0.05$).

A significant difference ($p < 0.05$) was observed between the foaming capacity at 116 °C and other canning temperatures. The lowest canning temperature exhibited the lowest foaming capacity, while the highest foaming capacity was obtained at 126 °C for 35 minutes. This result exceeded the foaming capacity of the aquafaba of haricot beans (39.00 %) and garbanzo beans (58.00 %), but was inferior to that of split yellow beans (93.00 %) [29]. A study by Stantiall *et al.* [29] showed that the aquafaba of split yellow beans produced good quality meringues with a foaming capacity of 93 %. As the foaming capacity of mushroom brine (83.43 %) in this study was approximately 10 % less than the split yellow bean aquafaba, the current brine solution has the potential to become a functional ingredient.

The best foaming capacity of the brine solution was observed at 35 minutes, without significant differences between all temperatures. In contrast, mushroom brine subjected to the shortest canning period recorded the lowest foaming capacity. The low foaming capacity at lower canning temperatures could be associated with protein denaturation, which may influence the protein's ability to unfold sufficiently for the best foam formation. Nevertheless, the brine solution maintained its foaming ability despite a little protein leaching from the oyster mushrooms into the solution (Table 2). The presence of lipids also interferes with protein adsorption at the air-water interface due to the hydrophobic nature of the molecule, and these may be adsorbed faster than protein [53].

The presence of protein influences a sample's foaming capabilities as the protein molecule is a surface-active agent and provides kinetic stability to foams [52]. Longer heating periods and temperature increases (116–126 °C) cause protein denaturation, resulting in lower molecular weight compounds that enhance foaming capabilities [54]. Protein denaturation increases surface hydrophobicity [55], thus improving the adsorption rate of the air/water interface by lowering the energy barrier for adsorption. Consequently, the foaming capacity of a sample is enhanced [56]. Furthermore, protein denaturation reduces the particle size of protein aggregates. The smaller protein particles improve the adsorption rate at the liquid interface, hence enhancing foaming capacity via foam expansion [57]. However, no foaming was observed at lower canning temperatures and shorter times in this study, which could be attributed to a lack of starches in the brine solution [24].

The foaming stability of the brine also increased gradually with time and temperature, consistent with foaming capacity (Table 3). The results showed a steady increase at 116, 121, and 126 °C, with the greatest stability at 35 minutes ($p < 0.05$). There was no significant difference in foaming stability between all temperatures at 35 minutes of canning. Nonetheless, there was a substantial difference in foaming stability at 35 minutes of canning compared to 25 and 30 minutes. The foaming stability of mushroom brine observed after 35 minutes was comparable to a study using aquafaba, where the foaming stability ranged from 74.21 to 91.61 % [58]. The formation of a stable foam also suggests the presence of saponins in the brine. Saponins are a major contributor to foam formation, and earlier studies have reported the presence of these compounds in oyster mushrooms [59]. The high foaming capacity and stability values obtained in this study imply that the brine of canned oyster mushrooms has the potential to become a plant-based egg replacer to produce meringue, cakes or other food products.

Emulsifying Capacity of Canned Oyster Mushroom Brine

Table 4 illustrates the emulsifying capacity of the brine of canned oyster mushrooms at different canning temperatures and periods. The emulsifying properties of a solution reflect the functional characteristics crucial for developing plant protein-based food products. In the present study, the brine solution exhibited its highest emulsifying capacity ($p < 0.05$) at the highest canning temperature (126 °C) and period (35 minutes).

Higher temperatures and longer canning periods promote protein denaturation and further structural unfolding of protein molecules. These conditions increase the protein's molecular flexibility and expose more hydrophobic groups hidden in the protein structure. Consequently, the bubble coalescence is retarded, and the surface tension is reduced, thus facilitating molecular rearrangement at the oil-water interface. As a result, an elastic layer forms around the fat droplets and facilitates protein adsorption at the oil-water interface [60], hence increasing the solution's emulsifying properties. At 116 °C, a higher emulsifying capacity ($p>0.05$) was obtained with a lower canning duration. Heating also breaks down mushroom cell walls, causing other emulsifying compounds, such as polysaccharides and saponins, to leach into the brine [61]. Interactions between the leached compounds and their structural changes also contribute to the difference between the emulsifying capacity of brine at shorter and longer canning periods.

Table 4. Emulsifying capacity of canned oyster mushroom brine.

Brine of canned oyster mushrooms		
Temperature	Time	Emulsifying capacity (%)
116 °C	25 mins	21.33 ± 11.55[a]
	30 mins	14.67 ± 12.22[a]
	35 mins	4.00 ± 0.00[a]
121 °C	25 mins	5.33 ± 2.31[a]
	30 mins	10.67 ± 11.55[a]
	35 mins	4.00 ± 0.00[a]
126 °C	25 mins	4.00 ± 0.00[a]
	30 mins	4.00 ± 0.00[a]
	35 mins	50.67 ± 18.48[b]

*Data is expressed as mean ± standard deviation, where n = 3.
Means with different superscripts differ significantly ($p < 0.05$).

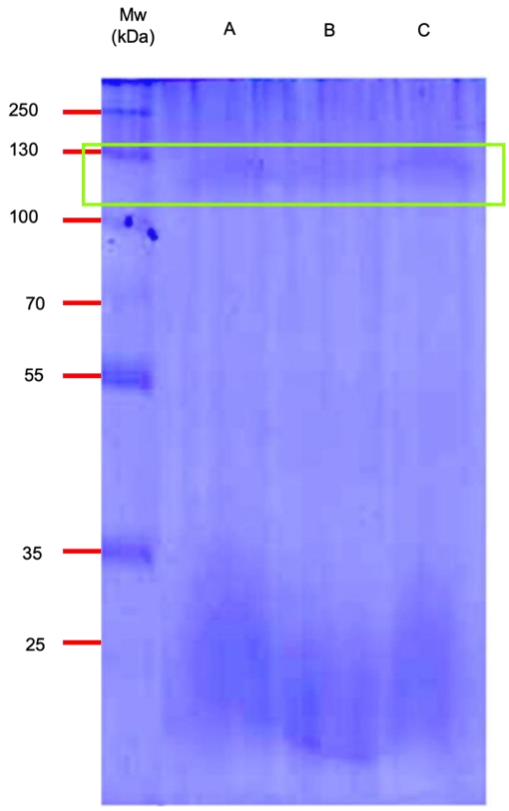

Figure 1. SDS-PAGE pattern of canned oyster mushroom brine samples. A: 116 °C, B: 121 °C, C: 126° C; M_w standard marker (BioBasic).

The unstable emulsifying capacities at lower canning temperatures and periods may be attributed to bubble coalescence. Other factors that contribute to the inconsistencies may include leached compounds in the brine solution, such as hydrophobins. Hydrophobins are good surfactants for foam stabilisation, but these compounds are not good emulsifiers as they do not provide sufficient steric hindrance to prevent droplet coalescence [62]. The emulsifying capacity of the brine observed in this study demonstrates its ability as an emulsifier. Nonetheless, more investigation is needed to uncover its full potential in the food industry.

Gel Electrophoresis

Mushrooms have a high protein content, which is released into the heating medium or brine solution during treatment along with other soluble nutrients. SDS-PAGE was performed on the brine solution with the highest foaming properties at temperatures of 116, 121, and 126 °C to determine the molecular weight of the leached proteins. Figure 1 illustrates the SDS-PAGE protein profile of canned oyster mushroom brine. Despite the temperature difference, the protein bands of the brine were at 130 kDa at 35 minutes of canning. The appearance of bands on the gel can be attributed to protein aggregation caused by protein cross-linking [63]. This finding indicated that the sizes of protein molecules present in the brine were 130 kDa and less than 35 kDa, causing the gel to smear. Smeared bands below 25 kDa indicated that lower molecular weight proteins had leached from the mushroom into the brine during the canning process. The proteins detected may be lectins (12 – 190 kDa) and hydrophobins (10–20 kDa) [64 – 66]. Hydrophobins are good surfactants that can promote foaming capacity and emulsifying stability [64]. Moreover, these findings suggest that the proteins in brine stimulate foam production and emulsion, particularly proteins of low molecular weight.

CONCLUSION

The canning process significantly altered the nutritional content of canned oyster mushrooms, notably increasing its ash and fibre levels while slightly reducing protein levels. A longer canning period led to greater nutrient changes, characterised by increased fat degradation. Despite the significant changes in nutrient content, most nutrients in canned oyster mushrooms were retained. Additionally, canning resulted in protein leaching into the brine. Nevertheless, the increase in protein levels in the brine enhanced its foaming and emulsifying properties, suggesting its potential as an egg-white substitute and emulsifier in new functional foods, and as a halal ingredient. In summary, the study findings demonstrated nutrient retention in oyster mushrooms post-canning, thus making it a sustainable food supply. Furthermore, food waste may be reduced if the brine is utilised as a food emulsifier. Further studies are recommended to investigate the mechanism of protein leaching to understand its patterns and kinetics. In addition, protein identification is strongly recommended to identify all the proteins present in the brine. The brine may also be explored and assessed for other compounds with the potential to become functional foods.

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