

Effect of black jelly mushroom (*Auricularia polytricha*) and olive oil as fat replacers on the physicochemical and microstructural properties of chicken meat emulsion

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Abstract

Black jelly mushroom (BJM) is particularly low in fat, high in fibre, and packed with many antioxidants, antimicrobials and minerals while having unique soaking characteristics and a gel-like texture, while olive oil (OO) contains high monounsaturated fatty acids where both have the potential to be used as fat replacers in meat products. This study evaluated the effect of the replacement of chicken skin (CS) at various percentages (0%, 25%, 50% and 100%) of black jelly mushroom and olive oil on the physicochemical and microstructural properties of chicken meat emulsion. Emulsions with 100% CS (Control), 50% CS + 50% OO, 50% CS + 50% BJM, 50% CS + 25% OO + 25% BJM, 100% OO and 100% BJM were developed. The pH value, cooking loss, protein content, carbohydrate content, textural properties and shear force of all fat-replaced samples were comparable to the control. The most positive results were demonstrated in the emulsion with 100% BJM, which had lower fat content ($1.31 \pm 0.84\%$) and better emulsion stability (%TEF: $7.97 \pm 4.16\%$, %EFAT: $12.97 \pm 6.53\%$), water-holding capacity ($86.67 \pm 3.06\%$), and moisture content ($76.69 \pm 2.13\%$). The colour profiles of the BJM-incorporated samples had higher redness and the OO-incorporated sample had higher lightness and yellowness. The micrographs revealed a harmonious distribution of fat droplets and mushroom particles in all samples' protein matrices. In conclusion, the black jelly mushroom is capable to be used as a fat replacer in producing low-fat meat emulsion, and its incorporation at 100% level has the highest potential.

1. Introduction

Meat emulsion is a finely chopped meat mixture which is a base for processed meat products like nuggets, sausages, meatloaf, surimi, bologna, and frankfurter (Schilling, 2019). According to Statista Search Department (2022), these types of products demonstrate a trend of steadily rising consumption, and the demand is expected to continuously grow. However, excessive consumption of meat products has become a major concern considering the high amount of fat and saturated fatty acids contained in the products that can cause adverse effects on the consumer's health. However, fat is not recommended to be fully removed in meat product formulation as it is significantly affecting the flavour, appearance, texture, shelf life and formulations of the meat products (Asyul-Izhar *et al.*, 2022). Therefore, a replacement of animal fats with plant-based ingredients

has become a popular approach to reduce fat and cholesterol content while improving the fatty acid composition and adding nutritional values to the emulsified meat products without destructively affecting the physicochemical qualities (Choi *et al.*, 2009; Jalal *et al.*, 2015).

Black jelly mushroom (BJM) or also known as *Auricularia polytricha* sp. is famous for its jelly-like character and is often used in Asian cooking. With dark greyish-brown colour, flavourless taste and gel-like texture, it can be found worldwide but is frequently consumed in Asia and tropical America. Similar to any other mushroom, BJM is packed with high dietary fibre content (9-14%) (Razak, 2013). High-fibre diets have been shown to help maintain blood sugar levels, lower cholesterol levels and promote healthy digestion (Mayo

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Clinic, 2021). A study on chicken sausages added with oyster mushrooms at either 2%, 4% or 6% significantly increased ($p < 0.05$) dietary fibres up to 6.20% and β -glucan up to 14.30% (Wan Rosli *et al.*, 2015). The BJM is also an excellent source of antioxidants and possesses antimicrobial properties (Pak *et al.*, 2021). These findings are supported by Ahmad *et al.* (2020), who documented a reduction in microbial activity and an increase in DPPH value (48.24%SA) and total phenolic content (5.70 mgCE/g) by the sausages incorporated with oyster mushrooms. Additionally, the incorporation of white jelly mushrooms, which have an almost similar texture to the BJM, showed an enhancement in cooking yield, moisture and fat-holding capacity to the control samples in a study of incorporating white jelly mushrooms in pork patties (Cha *et al.*, 2014).

Olive oil is derived from the fruit called olives which is commonly produced by the process of pressing the olive wholly and extracting the oils. It is mainly found in Mediterranean countries due to its high production and majorly used in their diets due to its high nutritional properties and acts as a source of lipids (Chrysochou *et al.*, 2022). Not only rich in antioxidants, olive oil also contains an abundance of healthy monounsaturated fatty acids such as oleic acids and eicosenoic acids which can improve the lipid profile. Pintado and Cofrades (2020) evaluated the mixture of olive and chia oils formulated in oleogel and emulsion gel as the animal fat replacer in fermented sausages and noticed an improvement in the lipid stability and the fatty acid profiles (decreasing SFA and increasing PUFA). The incorporation of olive oil in emulsified meat products, in contrast to animal fats, may have a beneficial effect on consumer health and has been documented in a few studies (Kamasani *et al.*, 2015; Nieto *et al.*, 2017; Öztürk-Kerimoğlu *et al.*, 2021).

Although several studies have been conducted on the incorporation of mushrooms in emulsified meat products

and a brief literature review has shown some encouraging results, the incorporation of black jelly species has not yet been exclusively investigated. In addition, the incorporation of black jelly mushrooms along with olive oil as the animal fat replacement has not yet been explored. Therefore, this study aimed to evaluate the effect of the replacement of chicken skin (CS) at various percentages (0%, 25%, 50% and 100%) of black jelly mushroom and olive oil on the physicochemical and microstructural properties of chicken meat emulsion.

2. Materials and methods

2.1 Materials

Chicken breast meat and chicken skin were purchased from the local wet market in Seri Kembangan, Selangor. Black jelly mushrooms from Vita Agrotech Sdn Bhd and olive oil from Naturel brand were purchased in Lotus's Malaysia, Putrajaya. Other ingredients used for meat emulsions such as salt, sugar, garlic powder and corn starch were also bought in Lotus's Malaysia, Putrajaya. Sodium tripolyphosphate (STPP) was purchased from Mei Loon Sdn Bhd., Klang, Selangor.

2.2 Sample preparation

The processing method of meat emulsion followed the method described by Ismail *et al.* (2021a) with some modifications. The chicken breast meat and chicken skin were rinsed and minced using a 5 mm plate meat mincer (H.L TJ12- A model, China). The black jelly mushroom was rinsed and boiled for 10 mins, cut into smaller pieces, and minced using a food processor (model YM-102, China). All ingredients were first weighed using an electronic weighing balance (Mettler-Toledo model, US) according to Table 1. All the ingredients except the salt, STPP and ice water were mixed for 1 min at 1500 rpm.

Table 1. Formulations of the meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control.

Ingredients (%)	Samples					
	Control	OO50	BJM50	OO25+BJM25	OO100	BJM100
Chicken Meat	70	70	70	70	70	70
Chicken Skin	15	7.5	7.5	7.5	0	0
Olive Oil	0	7.5	0	3.75	15	0
Black jelly mushroom	0	0	7.5	3.75	0	15
Ice water (5°C)	7.5	7.5	7.5	7.5	7.5	7.5
Corn starch	4	4	4	4	4	4
Salt	1.2	1.2	1.2	1.2	1.2	1.2
Sugar	1	1	1	1	1	1
Garlic powder	1	1	1	1	1	1
STPP	0.3	0.3	0.3	0.3	0.3	0.3
Total	100	100	100	100	100	100

CS: chicken skin, OO: olive oil, BJM: black jelly mushroom. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

Then, the salt and STPP were added and mixed for 30 s at 1500 rpm followed by the addition of ice water to the mixture before being mixed for 30 s at 1500 rpm. The purpose of adding ice water is to prevent the denaturing of the meat proteins from heat generated by the mixing process. A total of 200 g of meat emulsions were divided to approximately 40 g then transferred into five tubes of 50 mL centrifuge tube and centrifuged at 2500 rpm for 1 min to eliminate air bubbles. Each sample formulation was done in triplicate and stored in a freezer at -18°C before further analysis.

2.3 Emulsion stability

Emulsion stability was determined using the method described by Zhao *et al.* (2018) with some modifications. The raw sample (15 g) was transferred into labelled centrifuge tubes and centrifuged for 15 mins at 3000 rpm at a temperature of 4°C to remove air bubbles. The samples were heated in a water bath (Mettler Waterbath WNB 14, Germany) at 75°C for 30 mins. Then, the centrifuge tubes were left upside down without the tube cap to release the expressible fluid. The total fluid released was obtained by weighing the pellet that remained in the tube. The expressible fluids were transferred in pre-weighed crucibles and dried in an oven for 16 hrs at 105°C. The dried crucibles were weighed and the total fluid released and percentage of the total fat released were calculated using the formulations stated below:

$$\text{Total fluid release} = \frac{\text{initial weight of sample}}{\text{weight of pellet}}$$

$$\text{Total fluid release (\%)} = \left(\frac{\text{Total fluid release}}{\text{Initial weight of sample}} \right) \times 100\%$$

$$\text{Total fat release (\%)} = \left(\frac{\text{Weight of dried fluid}}{\text{Total fluid release}} \right) \times 100\%$$

2.4 Water-holding capacity

The analysis for water holding capacity (WHC) was adapted from Köhn *et al.* (2015) by manually mixing 5 g of raw samples with 32 mL of distilled water for 1 min in a centrifuge tube. The samples were left for 10 mins before it was centrifuged for 25 mins at 2500 g using a centrifuge machine. The supernatant formed was weighed along with the centrifuge tube before being discarded. The remaining pellet in the tube was dried 10-20°C downwards at 50°C for 20 mins. The water holding capacity was calculated using the formula given below:

$$\text{Expressible moisture} = \frac{(a+b)-(a+c)}{b} \times 100\%$$

$$\text{WHC (\%)} = 100\% - \text{expressible moisture}$$

Where a = weight of centrifuge tube, b = weight of the initial sample and c = weight of the pellet

2.5 Cooking loss

Cooking loss was evaluated by measuring the weight difference between the emulsion samples before and after cooking. A total of 40 g sample was put into a 50 mL centrifuge tube, cooked at 90°C in a water bath for 15 mins, and cooled down in cold water for 5 mins. Then, the samples were left overnight at a temperature below 5°C for fat to float on top and the liquid expressed on the next day was poured out. The difference in the weight was calculated before and after cooking and expressed as per the formula by Li *et al.* (2020).

$$\text{Cooking loss (\%)} = \left(\frac{\text{weight of raw sample} - \text{weight of cooked sample}}{\text{weight of raw sample}} \right) \times 100\%$$

2.6 pH

The determination of pH followed the procedure by Utama *et al.* (2019) with some modifications. A total of 5 g samples was homogenized with 45 mL of distilled water using a blender (MX-898M Panasonic, Malaysia) prior to analysis. The pH of the raw samples and cooked samples were determined using a calibrated pH meter (model 3505 pH Meter Jenway, UK).

2.7 Proximate analysis

The proximate composition analysis was determined according to the methods of the Association of Official Analytical Chemists (AOAC) (2012). Moisture content was determined by measuring the weight difference of the sample before and after drying, where the sample was dried overnight at 105°C. The crude protein was measured by using the micro-Kjedhal method (Method No. 978.04) and the nitrogen conversion factor used was 6.25. The crude fat was evaluated by following the Soxhlet extraction method (Method No. 930.09), where petroleum ether was used as the extraction solvent. The weight of fat recovered from the samples in the petroleum ether was measured after extraction for 8 hrs at 70°C. The ash content was measured by calculating the weight difference of the sample before and after incinerating the samples in a furnace at 550°C (Method No. 930.05). The carbohydrate content was computed afterwards by difference.

Carbohydrate (%) = 100 - [Percentage of (moisture + ash + protein + fat) in 100 g of sample].

2.8 Colour analysis

The colour of the samples was measured using a hand-held chromameter (CR- 40, Minolta Camera Co., Japan) and the colour reading includes lightness (L*), redness (a*) and yellowness (b*). The equipment was standardized using a white colour standard (Ismail *et al.*, 2021b).

2.9 Texture profile analysis

The texture profile analysis (TPA) was analysed using a texture analyser (TA-XT2i, Stable Micro System, UK) according to RamLe *et al.* (2021). Cooked samples were cut into 15 mm diameter and 20 mm length prior to analysis. The samples were studied by compressing twice with a 35 kg load at 75% height using a P75 probe using 1.0 mm/s pre-test speed, 1.5 mm/s test speed and 1.5 mm/s post-test speed. The parameters measured are hardness, springiness, cohesiveness, gumminess and chewiness.

2.10 Warner-Bratzler shear force test

The cooked samples were cut into approximately 15 mm diameter and 25 mm length and analysed using Warner-Bratzler (WB) shear blade with a triangular slow cutting edge at 1 mm thickness and cutting speed of 1.5 mm/s. The analysis was done by using a Texture Analyzer equipped with a 25 kg load cell (TA-XT2i, Stable Micro System, UK) to measure the maximum shear force (N) and work of shearing (N.sec) (Ismail *et al.*, 2021a).

2.11 Light micrographs

The samples were prepared for light microscopy according to the method outlined by Ismail *et al.* (2021a). An adequate amount of sample was thinly spread on a microscope glass and dried at 4°C. The dried slides were immersed in 1% bromophenol blue solution for 3 mins and washed with distilled water. The slides were re-immersed in diluted Sudan III solution for 3 min, washed with distilled water, and air-dried at 4°C. The samples were imaged on a light microscope at 60× magnification (Nikon Eclipse 80i Binocular, Japan).

2.12 Statistical analysis

All the analyses were performed in triplicate and the data were presented as means ± standard deviation (SD).

The probability value of $p < 0.05$ indicated a statistically significant result. One-way analysis of variance (ANOVA) and Tukey's test for pairwise comparison were measured via Minitab Statistical Software Version 19 (MiniTab Inc., USA).

3. Results and discussion

3.1 Emulsion stability, water-holding capacity, cooking loss and pH value

Emulsion stability measures the ability of an emulsion to resist changes in its characteristic over time (Öztürk *et al.*, 2016) and is expressed as the total expressible fluid (%TEF) and total expressible fat (%EFAT). One of the key quality criteria for emulsified meat products is a stable entrapment of water and fat in the matrix of meat products after cooking (Shin *et al.*, 2022), which is indicated by lower %TEF and %EFAT (Serदारoğlu *et al.*, 2016). According to Table 2, BJM100 was the only sample that exhibited a lower ($P < 0.05$) % TEF compared to Control, while no significant differences ($P > 0.05$) were portrayed for %EFAT. As reported by Bandara *et al.* (2019), the mushrooms from *Auricularia* species mostly comprise protein and polysaccharides (carbohydrates) except for moisture. According to Jung *et al.* (2022), polysaccharides and proteins are responsible for enhancing the emulsion stability of emulsion-type sausage by a few mechanisms. Polysaccharides are categorized as both water-soluble and insoluble, and both can serve as stabilizers in a meat emulsion system. Umaña *et al.* (2021) reported that the water-soluble polysaccharides in mushroom concentrate can improve water viscosity, while the insoluble polysaccharides generate steric repulsion by adhering to the protein-formed interface in fat globules, both of which can promote emulsion stability. Meanwhile, proteins have surface activity due to their amphiphilic characteristics, which improves their emulsion abilities by adhering to the interface between aqueous and lipid phases (Kurt and Gençcelep, 2018). From this

Table 2. The emulsion stability, water holding capacity (WHC), cooking loss and pH values of the meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control.

Samples	Emulsion stability		WHC (%)	Cooking loss (%)	pH value	
	%TEF	%EFAT			Raw	Cooked
Control	13.77±0.40 ^a	6.43±2.66 ^a	70.00±2.00 ^b	1.54±2.09 ^a	5.72±0.18 ^b	5.93±0.07 ^a
OO50	12.23±1.36 ^{ab}	7.20±2.48 ^a	72.00±6.00 ^b	0.84±0.89 ^a	5.88±0.03 ^{ab}	5.83±0.21 ^a
BJM50	9.10±2.31 ^{ab}	12.03±2.16 ^a	78.00±8.72 ^{ab}	0.84±0.88 ^a	5.89±0.07 ^{ab}	5.98±0.07 ^a
OO25+BJM25	11.80±1.01 ^{ab}	7.57±3.10 ^a	78.00±5.29 ^{ab}	0.43±0.24 ^a	5.88±0.05 ^{ab}	5.98±0.09 ^a
OO100	8.20±1.01 ^{ab}	10.57±3.26 ^a	88.00±4.00 ^a	0.07±0.12 ^a	5.99±0.03 ^a	6.09±0.10 ^a
BJM100	7.97±4.16 ^b	12.97±6.53 ^a	86.67±3.06 ^a	0.08±0.13 ^a	5.89±0.09 ^{ab}	6.05±0.06 ^a

Values are presented as mean±SE of triplicates. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$). CS: chicken skin, OO: olive oil, BJM: black jelly mushroom. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

perspective, it can be concluded that polysaccharides and proteins contained in BJM can enhance the emulsion stability of the emulsion systems.

The cooking loss and water-holding capacity (WHC) are crucial characteristics that affect the appearance of emulsified meat products, which directly impacts consumers' acceptance and willingness to pay for them (Cheng and Sun, 2008; Liu *et al.*, 2019). Generally, cooking yield/loss in the meat emulsion system is influenced by its ability to retain fluid and fat during the cooking process (Suman and Sharma, 2003). Thus, cooking yield/loss is considered a reliable measure to study the influence of WHC on emulsified meat products. In this study, a total fat replacement with BJM and OO (BJM100 and OO100) has significantly increased ($p < 0.05$) the WHC of the emulsion samples without affecting their cooking loss ($p > 0.05$). The high content of polysaccharides and protein in BJM fruiting body once again shows a beneficial value in enhancing the WHC of the emulsion system, by creating a three-dimensional matrix that is responsible to trap water to compensate for the fat component in the emulsion system (RamLe *et al.*, 2021). This result agreed with Jung *et al.* (2022), who reported an increase in the WHC in emulsion-type sausages with the incorporation of oyster mushroom powder. Although the mechanism of WHC enhancement by direct replacement of olive oil in the meat emulsion system is still unclear, however, a few literature data have reported an enhancement in the WHC when incorporating olive oil with other vegetable oils or pre-emulsion olive oil with other ingredients. For example, an increase of the WHC in sausages incorporated with canola-olive oil (Alvares *et al.*, 2011) and good water binding properties was demonstrated by replacing pork backfat with emulsified olive oil with few types of protein system (soy protein isolate, sodium caseinate, microbial transglutaminase and meat protein) in frankfurters (Jiménez-Colmenero *et al.*, 2010).

The analysis for pH values was done for both raw

and cooked samples. As shown in Table 2, no notable difference ($p > 0.05$) was recorded among all raw and cooked samples except for raw OO100. However, the difference in the pH value for raw OO100 with the other raw samples is still considered small and almost negligible. It is challenging to ascertain whether the statistically significant ($p < 0.05$) change in pH values between raw OO100 and the other raw samples was caused by olive oil because it is an insoluble material in water. Thus, analysing the oil using an electrode pH meter without proper method preparation, i.e., diluting the oil with a suitable solvent, might produce inaccurate readings. However, considering the oil is only present in a small amount in the emulsion (15%), the olive oil itself might not be the contributing factor to the higher pH value of OO100. Meanwhile, the result of the pH value for BJM incorporated samples can be supported by the similar insignificant trend observed by Olonto (2012) that adding oyster mushrooms to beef patties had no discernible influence ($p > 0.05$) on pH readings.

3.2 Proximate composition and colour properties

Table 3 shows the proximate composition of the emulsion samples. The proximate composition of the BJM from the same supplier (Vita Agrotech Sdn Bhd) has been reported by Razak (2013) as follows: 90.35% moisture, 0% fat, 7.6% protein, 14% fibre, 3.2% ash and 83.5% carbohydrate. All samples incorporated with the BJM exhibited significantly higher ($p < 0.05$) moisture content compared to the control. The moisture content of OO25+BJM25, BJM50 and BJM100, increased by 2.03%, 5.62% and 9.65%, respectively, in comparison to the control due to high moisture content in fresh BJM (90.35%) incorporated in these samples. An increase in moisture content in fat-replaced meatballs with a few different types of mushrooms (brown beech, shiitake, white oyster, brown and king oyster) was also documented by RamLe *et al.* (2021). Meanwhile, a total fat replacement with the OO, which was represented by OO100 showed a significantly lower moisture content

Table 3. The proximate composition of the meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control.

Samples	Proximate composition (%)				
	Moisture	Protein	Fat	Carbohydrate	Ash
Control	69.94±1.47 ^{bc}	14.06±2.44 ^a	3.69±2.77 ^a	10.23±3.39 ^a	2.08±0.07 ^b
OO50	66.16±1.90 ^{cd}	14.33±0.62 ^a	8.71±7.30 ^a	7.72±4.78 ^a	3.08±0.52 ^a
BJM50	73.87±2.04 ^{ab}	13.83±0.82 ^a	4.09±2.54 ^a	6.18±3.89 ^a	2.03±0.06 ^b
OO25+BJM25	71.36±2.02 ^{abc}	13.26±1.64 ^a	6.18±2.95 ^a	7.73±3.06 ^a	1.48±0.56 ^b
OO100	63.84±2.43 ^d	12.01±1.11 ^a	8.82±4.43 ^a	13.34±3.02 ^a	1.99±0.06 ^b
BJM100	76.69±2.13 ^a	12.49±1.33 ^a	1.31±0.84 ^a	7.48±2.10 ^a	2.03±0.04 ^b

Values are presented as mean±SE of triplicates. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$). CS: chicken skin, OO: olive oil, BJM: black jelly mushroom. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

($p < 0.05$) compared to the Control. This observation was in line with the data stated by Serdaroğlu *et al.* (2017), who observed a significantly lower moisture content ($p < 0.05$) of cooked chicken patties with a 100% fat replacement with gel-emulsified olive oil compared to replacement at other concentrations (0%, 25% and 50%).

There were no significant differences ($p > 0.05$) in protein, carbohydrate, and fat content observed in samples incorporated with BJM and OO compared to the control. Although BJM has higher protein (7.6%) and carbohydrate (83.5%) than OO (0%), the incorporation of BJM even at a 100% fat replacement (BJM100) still did not notably rise ($p > 0.05$) the total protein and carbohydrate content in emulsion samples. This might be due to the small amount of BJM incorporated in the sample, which is only 15% of the total emulsion formulations. Interestingly, notwithstanding the insignificant statistical differences ($p > 0.05$) remarked between the BJM and OO-incorporated samples with the control, it is clearly shown in Table 3 that the samples incorporated with BJM (OO25+BJM25, BJM50 and OO100) had lower fat content than OO50 and OO100. The BJM100 possessed the lowest amount of fat since BJM itself has 0% fat, thus the fat present in this sample was fully contributed by the fat associated with chicken meat only. A higher fat content in OO50 and OO100 was anticipated because olive oil is a 100% lipid substance, thus incorporating this oil would increase the fat content of the emulsion samples. This finding was consistent with those from Domínguez *et al.* (2016) who reported insignificant differences, but a higher amount of fat in the fat-replaced pate with 50% and 100% olive oil compared to pate with 0% olive oil.

The ash content for the emulsion samples is still regarded as low (1.48%-3.08%) despite small statistical disparities ($p < 0.05$) identified between the control and the fat-replaced samples, which were only noted in OO50. While the proportion of the BJM added to the

emulsion samples was capable of providing minerals such as calcium, sodium, phosphorus, magnesium, and potassium (Razak, 2013), it was unable to considerably raise ($p > 0.05$) the ash levels in samples incorporated with the BJM. However, this outcome contradicted the results presented by Banerjee *et al.* (2021) who recorded an increase of ash content in goat meat nuggets when incorporated with enoki (*Flammulina velutipes*) mushroom at 2%, 4% and 6%. Besides, the incorporation of button mushrooms (*Agaricus bisporus*) either at 10 or 15% also caused an increase in the ash content of beef patties (Patinho *et al.*, 2021). Thus, it may be inferred from the data of previous work and the result of the current study that the BJM does not enhance the ash content in meat emulsion to the same extent as other mushroom species.

Colour are customers' initial impression, which mainly affected their acceptance and decision to buy any emulsified meat product. Table 4 compares the colour properties (lightness, L^* ; redness, a^* ; yellowness, b^*) of the emulsion samples before and after cooking between the Control and the samples incorporated with BJM and OO at various percentages. The raw samples incorporated with the BJM recorded a lower L^* value (lightness) ($p < 0.05$, except for OO25+BJM25) and were darker in colour in the order of decreasing intensity as follows: BJM100 > BJM50 > OO25+BJM25 ($p > 0.05$). This observation can be explained by the naturally black-brown colour of the fresh BJM incorporated in these samples. Raw OO100 recorded the highest L^* value ($p < 0.05$) among all raw samples, while raw OO50 lightness was higher but comparable ($p > 0.05$) to the control. The L^* of cooked samples showed that BJM100 was the only BJM-incorporated sample that shows significantly ($P < 0.05$) lower than cooked OO50 and OO100. Nieto *et al.* (2017) suggested that the lighter shade observed in olive oil sausage was caused by the increase of fat particle surfaces, which dispersed within the actomyosin matrix that occur during the chopping

Table 4. The colour profiles of the raw and cooked meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control.

Samples	Raw			Cooked		
	L^*	a^*	b^*	L^*	a^*	b^*
Control	63.12±1.40 ^{bc}	3.41±1.21 ^{bcd}	16.05±1.55 ^a	63.97±0.79 ^{ab}	3.36±0.06 ^a	12.91±1.05 ^a
OO50	67.83±1.56 ^{ab}	2.83±0.30 ^{cd}	15.99±1.13 ^a	65.56±2.31 ^a	2.61±0.17 ^b	13.34±0.99 ^a
BJM50	55.66±1.38 ^d	4.60±0.44 ^{ab}	13.35±0.25 ^{ab}	60.21±2.63 ^{ab}	2.56±0.17 ^b	8.41±0.30 ^{bc}
OO25+BJM25	62.35±2.54 ^c	3.67±0.22 ^{bc}	14.45±0.84 ^a	61.62±4.74 ^{ab}	2.48±0.02 ^b	11.25±2.20 ^{ab}
OO100	71.89±2.08 ^a	1.88±0.20 ^d	15.67±1.76 ^a	67.10±2.07 ^a	1.89±0.23 ^c	12.76±0.89 ^a
BJM100	46.81±0.97 ^e	5.67±0.31 ^a	10.65±0.23 ^b	57.06±1.09 ^b	3.15±0.10 ^a	7.10±0.62 ^c

Values are presented as mean±SE of triplicates. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$). CS: chicken skin, OO: olive oil, BJM: black jelly mushroom. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

process.

In terms of a^* value of the raw samples, only BJM100 and OO100 recorded some statistical differences ($p < 0.05$) compared to the control, where BJM100 was the highest and OO100 was the lowest. From this result, it can be seen that a 100% replacement of the BJM would intensify the redness value of the raw emulsion samples. Surprisingly, after cooking, BJM100 documented an insignificant redness to the control ($p > 0.05$), while the other samples were remarkably lower ($p < 0.05$) than the control. This finding might be interpreted that the intensified redness caused by the BJM in emulsion samples has become mild after cooking thus resulting in a comparable redness value to the control. In the aspect of yellowness, BJM100 was the only BJM-incorporated sample that showed a significantly lower ($p < 0.05$) b^* value compared to the control for both raw and cooked samples. Although no significant difference ($p > 0.05$) was detected between the OO-incorporated samples and the control, however, 0050 and 00100 showed higher L^* value. This may be due to the presence of yellow pigments in olive oil particles, such as lutein and β -carotene (Braniša et al., 2014), which causes an increase in the b^* value in these samples. Overall, the OO25+BJM25 was the most comparable sample in terms of colour profiles to the control.

3.3 Texture profile analysis and Warner-Bratzler shear force test

Texture profile analysis is an important measure for choosing the best quality meat products in the food industry as it plays a significant role in the acceptability of consumers to the products. Serdaroğlu et al. (2016) mentioned that the texture properties of an emulsion can be changed by using different types of ingredients from non-meat sources. Table 5 shows the results of the texture profile analysis that measures the intensity of the parameter of hardness, springiness, cohesiveness,

gumminess and chewiness along with the Warner-Bratzler shear force (WBSF) value. The WBSF test measures the physical force needed to cut through the cooked emulsion samples. Theoretically, the WBSF value is directly proportional to the hardness value of the emulsion sample. Since no noteworthy ($p > 0.05$) difference was observed between the hardness value and the WBSF value, this theory is considered justifiable. Overall, as shown in Table 5, none of the analysed textural parameters revealed a significant difference ($p > 0.05$) between all BJM and OO-incorporated samples and the control. The results regarding the textural qualities of the BJM-incorporated samples were inconsistent with those reported by Wan Rosli et al. (2011) who found that the incorporation of oyster mushrooms in chicken patties increased ($p < 0.05$) in all textural parameters except for springiness. These disparities might be due to textural differences between the BJM and the oyster mushroom, where the BJM appears to have a springy-soft texture (ASEAN Standard, 2017), while oyster mushrooms happen to be denser and springy (Ahmed et al., 2016). Besides, the concentration of mushrooms incorporated in the chicken patties of the mentioned study was also higher than the current study, at levels 25% and 50%, whereas the BJM concentration incorporated in the emulsion of the current study was at 15%.

Meanwhile, the insignificant difference ($p > 0.05$) noted between OO-incorporated samples with the control was also in disagreement with the observation documented by (Muguerza et al., 2001), where lower hardness ($p > 0.05$) of the fat-replaced fermented sausages with pre-emulsified olive with soy protein isolate was observed. This might be due to the different application methods of olive oil in the sample's formulation between the current study and the previous study. In the current study, the oil is directly incorporated into the samples, while the olive oil in the previous study was pre-emulsified with soy protein isolate before being

Table 5. The textural properties and Warner-Bratzler shear force (WBSF) value of the meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control.

Samples	Textural properties			WBSF value			
	Hardness (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)	Max Shear Force (N)	Work of Shear (Ns)
Control	6223±2111 ^a	0.55±0.11 ^a	0.28±0.10 ^a	1869±1074 ^a	1102±712 ^a	0.97±0.04 ^a	13.53±1.76 ^a
OO50	7725±835 ^a	0.65±0.05 ^a	0.33±0.02 ^a	2579±321 ^a	1690±298 ^a	1.07±0.24 ^a	14.42±2.45 ^a
BJM50	5025±1448 ^a	0.59±0.09 ^a	0.29±0.05 ^a	1507±674 ^a	921±548 ^a	0.79±0.13 ^a	10.53±1.67 ^a
OO25+BJM25	6143±561 ^a	0.62±0.05 ^a	0.29±0.02 ^a	1788±163 ^a	1117±151 ^a	0.92±0.12 ^a	12.78±1.97 ^a
OO100	6962±917 ^a	0.70±0.04 ^a	0.32±0.01 ^a	2194±227 ^a	1535±107 ^a	1.12±0.06 ^a	14.01±0.37 ^a
BJM100	5558±890 ^a	0.60±0.01 ^a	0.31±0.03 ^a	1731±127 ^a	1035±56 ^a	0.77±0.09 ^a	10.33±1.03 ^a

Values are presented as mean±SE of triplicates. Values with different superscripts within the same column are statistically significantly different ($p < 0.05$). CS: chicken skin, OO: olive oil, BJM: black jelly mushroom. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

incorporated into the samples. Moreover, the direct incorporation of liquid oil as a fat replacer in meat emulsion products is less technologically suitable due to the different technological characteristics of real fat (Nieto and Lorenzo, 2021). Overall, the incorporation and replacement of fat with BJM and OO minimally influenced the textural properties and shear force of the emulsion samples.

3.4 Microstructure properties

Figure 1 shows the micrographs of the raw emulsion samples incorporated with different percentages of black jelly mushroom and olive oil. The fat droplets (labelled as FD in the micrographs) were mostly oval but irregular in shape and distributed evenly in the protein matrix of emulsion samples. It is further observed that the fat droplets in the control seem to be more flocculated compared to other samples. The fat droplets in BJM100 were almost invisible and presented in very small amounts. Given that no additional fat was added in the formulation of BJM100, the source of the fat droplets in

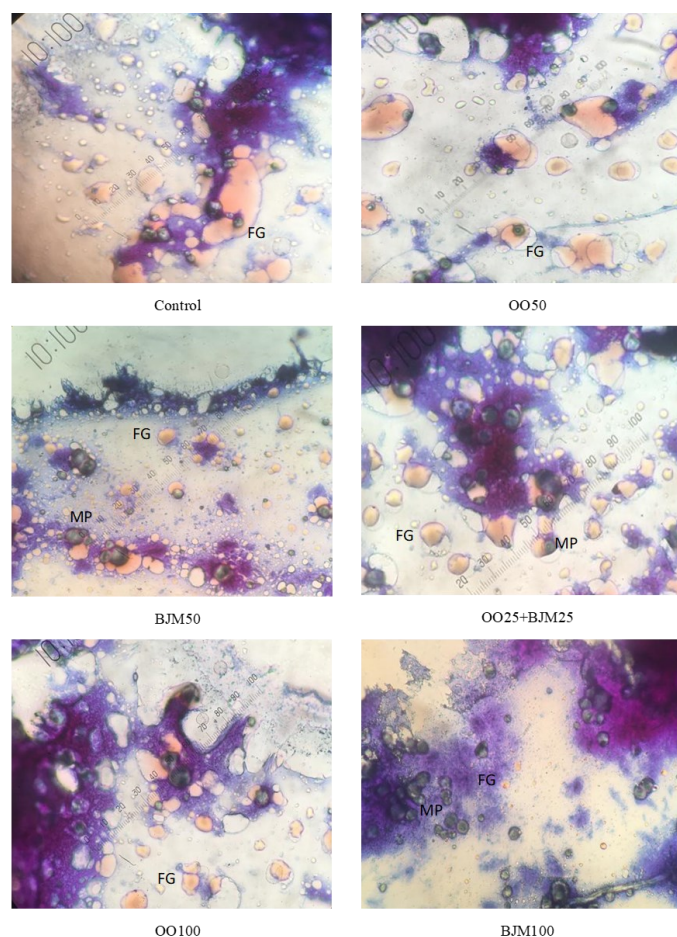


Figure 1. Light micrographs at 60 \times magnification of the meat emulsion incorporated with different levels of black jelly mushroom and olive oil compared to the control. CS: chicken skin, OO: olive oil, BJM: black jelly mushroom, FG: fat globules, MP: mushroom particles. 100% CS (Control); 50% CS + 50% OO (OO50); 50% CS + 50% BJM (BJM50); 50% CS + 25% OO + 25% BJM (OO25+BJM25); 100% OO (OO100); and 100% BJM (BJM100).

this sample must have been from the chicken meat itself. On top of that, the mushroom particles (labelled as MP in the micrographs) were able to comparably simulate the dispersion of fat droplets in the protein matrix as the other fat droplets of chicken skin and olive oil in the control and OO-incorporated samples. The micrographs of the samples that were partially incorporated with either BJM, OO or both (OO50, BJM50 and OO25+BJM25) exhibited harmonious distribution of both fat droplets and mushroom particles, which represents well incorporation of both substances in the protein matrix of the emulsion samples. Overall, the light micrographs revealed that the distribution of fat droplets and mushroom particles in the protein matrix of BJM and OO incorporated samples were comparable to that of the control.

4. Conclusion

In conclusion, the study documented positive attributes of incorporating black jelly mushrooms and olive oil in the chicken meat emulsion. The black-brown colour pigment has intensified redness in the black jelly mushroom incorporated samples, while olive oil incorporated samples appeared to have higher lightness and yellowness. The pH value, cooking loss, protein content, carbohydrate content, textural properties and shear force of the black jelly mushroom and olive oil incorporated samples were statistically insignificant to the control sample. The light micrographs exhibited a comparable distribution of fat droplets and mushroom particles in the protein matrix of black jelly mushroom and olive oil incorporated samples compared to the control sample. However, the sample with a total fat replacement with black jelly mushroom (BJM100) portrayed better emulsion stability (%TEF: $7.97 \pm 4.16\%$, %EFAT: $12.97 \pm 6.53\%$), water holding capacity ($86.67 \pm 3.06\%$), moisture content ($76.69 \pm 2.13\%$) and lower fat content ($1.31 \pm 0.84\%$), indicating that it is a superior fat replacer to olive oil, and a total replacement (100%) is the most optimum level of fat-replacement. Nevertheless, a combination of 25% BJM and 25% OO can be accepted as the second-best fat replacement formulation considering the health benefits contributed by olive oil in meat emulsion.

Conflict of interest

The authors declare no conflicts of interest.

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