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*Research Article*

# Physicochemical and Sensory Characteristics of Meatless Nuggets of Boiled Chickpea and in Combination with Oyster Mushroom

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**ABSTRACT**

This study aimed to develop meatless nuggets (MN) using different substitutions of chickpea and oyster mushrooms as key ingredients. Four different meatless nuggets which were control (100:0), MN70 (70:30), MN40 (40:60), and MN10 (10:90) with different ratios of boiled chickpea to mushroom were formulated in this study. A significantly ($p$<0.05) higher carbohydrate, protein, fat, and crude fiber contents were observed with the increasing chickpea substitution. Nuggets prepared with chickpea and mushroom proteins met the standard of protein source for the nutrient reference value as well as the source of good fiber. However, results found that a significant ($p$<0.05) lower cooking yield and higher cooking loss were recorded in the sample substituted with the maximum ratio of mushroom (MN10). Likewise, textural properties such as hardness, springiness, cohesiveness, and chewiness increase ($p$<0.05) with mushroom substitution. Substitution with higher chickpea tends to increase lightness ($L$*) and yellowness ($b$*) of control. The panelists for the sensory evaluation presented that MN40 containing an almost equal substitution of chickpea to mushroom had a better sensory mean score. However, substitution by these ingredients was the averagely scored by the panelists. Hence, nuggets with a 40:60 ratio of chickpea to mushroom were considered the ideal formulation for manufacturing meatless nuggets.

**Key words:** Chickpea, meatless nuggets, nuggets, oyster mushrooms, vegetarian nuggets

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## INTRODUCTION

Meat analogs can be defined as plant-centered food products designed to mimic the taste, texture, look, and functionality of meat products. The traditional plant-based landscape is different from modern plant-based meat products. Traditionally structured products are produced based on centuries-old recipes such as tempeh, tofu, and seitan (Ismail *et al*., 2020a). However, the acceptance in Western countries is low due to the unique taste of these products that are developed to suit the local taste and preferences of people, particularly in East Asia (Ismail & Huda, 2022). Although traditional plant-based proteins are well known, the texture and taste of these products are different from meat functionality and are not specifically created to imitate meat products. Contrarily, modern plant-based meat products are designed exactly to simulate traditional meat products' functionality and sensory attribute. This modern meatless-based protein from the plant is suitable to be referred to as a meat analog (Dekkers *et al*., 2018).

Nowadays, people have been increasingly shifting to convenience or ready-to-go foods as they save time and energy. For instance, nugget is preferred by consumers as it is a convenience food (Sharima-Abdullah *et al*., 2018). Traditional nuggets are processed meat products produced mainly from chicken meat with at least 30% fat and do not offer healthy images (Yogesh *et al*., 2013). For this reason, the increased importance of meat analogs is associated with health awareness among consumers (Ismail *et al*., 2020a). The simulation of traditional meat-based products requires the manipulation of various plant-based ingredients. Nevertheless, any meat analog developed to substitute meat and meat products must have similar nutritional benefits and functionality (Souza Filho *et al*., 2019), whether they are based on a plant (e.g., legumes & cereals), fungal (e.g., mushrooms & mycoproteins), or insects.

In the present study, chickpea and oyster mushrooms have been used as meat replacers with many economic and functional benefits. Chickpea or *Cicer arietinum L*. generally contains a good source of protein and carbohydrate and is made up of 80% of dry seed mass (Grasso *et al*., 2022). Chickpeas have important attributes such as zero cholesterol, high dietary fiber, vitamins, and minerals, which contribute to health (Wrigley *et al*., 2015). Several studies have investigated the physicochemical and nutritional characteristics of chickpea, and it was reported to replace meat in nuggets, sausages, and patties (Motamedi *et al*., 2015; Sharima-Abdullah *et al*., 2018; Husain & Huda-Faujan, 2020; Kandil *et al*., 2020). Meanwhile, the mushroom can be used as an alternative protein source (Ismail & Huda, 2022). The advantages of edible mushrooms are that they contain valuable amounts of proteins, crude fiber, essential amino acids, vitamins, and minerals. Mushroom proteins also contain all the essential amino acids, which is important to mutually supplement with chickpea proteins that lack sulfur-containing amino acids (Ismail & Huda, 2022). The umami flavor of mushrooms, tremendous benefits of nutrients, and functionality make mushrooms suitable for the development of imitation beef/chicken patties and nuggets with a healthier option, good appearance, taste, and texture (Mohamad Mazlan *et al*., 2020).

Textured vegetable protein or soy protein is a common ingredient used in meat analogs. The versatility of this ingredient as well as its cheap, available, and beneficial to health, has made it important in commercial meat analogs. According to extensive literature by Bakhsh *et al*. (2022) from the data set obtained from 2001 to 2022, soy protein was the main focus by many researchers (85.7%), followed by pea (17.8%), wheat (14.3%), chickpea (7.0%), and mushroom (4.0%). However, the combination of oyster mushroom and chickpea proteins in meat analog has not yet been reported. Therefore, the objective of the present study was to evaluate the effects of different ratios of chickpea and oyster mushrooms on the chemical composition, physicochemical characteristics, and sensory attributes of a meatless nugget.

## MATERIALS AND METHODS

### Materials

Chickpeas, textured vegetable protein (TVP), oyster mushrooms, vegetarian meat curry powder, potato starch, Bengal gram flour, corn starch, bread crumb, vegetable shortening, salt, sugar, and black pepper were purchased from the local market in Terengganu, Malaysia. Both chickpea and oyster mushrooms were used as key ingredients for meatless nuggets at different ratios, as shown in Table 1.

### Sample preparation and processing

The composition of chickpea and oyster mushroom nuggets was formulated based on the ratio (chickpea: mushroom) of 100:0 (labeled as control), 70:30 (labeled as MN70), 40:60 (labeled as MN40), and 10:90 (labeled as MN10), respectively. The chickpeas were hydrated in the water (ratio of chickpeas to water, 1:1.5 w/v) for six hr at room temperature (26 °C) and then cooked in boiling water (ratio of chickpeas to water, 1:2 w/v) for 15 min and the chickpea husk was removed and blended using a blender. Next, the fresh oyster mushrooms were chopped into smaller mince and mixed with the premix ingredients as shown in Table 1 using a Kitchen Aid (Classic Plus Stand Mixer, St Joseph, MI, USA). The TVP was soaked in an equal amount of water and allowed to hydrate for 1 h at 4 °C before preparing the premix ingredients. Subsequently from the whole mixture, 25 g of the mixture was shaped into nuggets using a nugget mold. For batter preparation, Bengal gram and corn flour were mixed with water and cooled at 4 °C for 1 h before coating the nugget. The molded nuggets were dipped into cold batter and coated with bread crumbs before parfrying at 180 °C for 15 s. Nuggets were allowed to cool at ambient temperature for 30 min before conducting analysis.

### Proximate composition

Moisture, protein, fat, crude fiber, and ash contents were determined based on the standard methods of AOAC (2002). Moisture content was quantified using an oven (Brad Venticall, LSIS-B2V/VC5C, München, Germany), by drying of 5 g sample at 105°C for 16 hr. Protein was measured using the Kjeldahl method (Gerhardt, 12-0057 TURBOSOG, Germany) (N × 6.25) using 1 g of sample. The fat content was determined using a 3 g sample by extraction in a Soxhlet apparatus (Gerhardt Soxtherm, sf-416, Germany) using petroleum ether as a solvent. The crude fiber determination was estimated by acid and alkali digestion method using a fiber analyzer (Gerhadt, Fibertherm FT 12, Germany) by digesting 1 g of sample. The ash was determined after the incineration of a 1 g sample in

**Table 1.** Formulation of meatless nuggets

| Ingredients (%) | Control | MN70 | MN40 | MN10 |
|---|---|---|---|---|
| Main composition: | | | | |
| Boiled chickpea | 50.00 | 35.00 | 20.00 | 5.00 |
| Oyster mushroom | 0.00 | 15.00 | 30.00 | 45.00 |
| Premix: | | | | |
| Potato starch | 8.36 | 8.36 | 8.36 | 8.36 |
| Textured Vegetable Protein | 18.00 | 18.00 | 18.00 | 18.00 |
| Vegetable shortening | 4.00 | 4.00 | 4.00 | 4.00 |
| Onion | 1.20 | 1.20 | 1.20 | 1.20 |
| Salt | 1.00 | 1.00 | 1.00 | 1.00 |
| Baba's vegetarian meat curry powder | 2.00 | 1.00 | 1.00 | 1.00 |
| Black pepper | 0.20 | 0.20 | 0.20 | 0.20 |
| Garlic | 0.20 | 0.20 | 0.20 | 0.20 |
| Sugar | 0.04 | 0.04 | 0.04 | 0.04 |
| Battering: | | | | |
| Bengal gram flour | 5.00 | 5.00 | 5.00 | 5.00 |
| Corn starch | 5.00 | 5.00 | 5.00 | 5.00 |
| Breading: | | | | |
| Bread crumb | 5.00 | 5.00 | 5.00 | 5.00 |
| Total | 100 | 100 | 100 | 100 |

The ratio for chickpea and oyster mushroom for MN70 is 70:30, for MN40 is 40:60, and for MN10 is 10:90 compared with boiled chickpea as a control meatless nugget.

a furnace (Carbolite Gero, CWF 1100, UK) at 550 °C. The carbohydrate content was determined by subtracting the total sum percentage of moisture, protein, fat, crude fiber, and ash using the following formula (McCleary & McLoughlin, 2021):

%Carbohydrate = 100-(moisture+protein+fat+fibre+ash)

## Physicochemical properties

Cooking loss and cooking yield of cooked nuggets were determined by measuring the weight before cooking ($m_1$) and after cooking ($m_2$) nuggets (Wan Rosli *et al*., 2011; Sharima-Abdullah *et al*., 2018):

$$\text{Cooking loss (\%)} = 100 \times \frac{(m_1\text{-}m_2)}{m_1}$$

$$\text{Cooking yield (\%)} = 100\text{-cooking loss}$$

The textural properties of nuggets were analyzed using a texture analyzer double-arm (TA.XT plus, Stable Micro System Ltd., UK), compression platen (SMS P/75) with a heavy-duty platform, and the following settings: pre-test speed 1.00 mm/s, test speed 3.00 mm/s, post-test speed 10.00 mm/s, trigger force 5 g and distance of 23.0 mm. The nugget was cut into cubes (1 × 1 × 1 cm) and the cube was placed in the middle of the texture analyzer and compressed to 50% of the sample thickness through a 2-cycle sequence with a load cell of 10 kg (Bakhsh *et al*., 2021). The textural properties such as hardness, springiness, cohesiveness, and chewiness were determined for all nuggets' formulations.

The internal color of cooked nuggets was measured using a Konica Minolta Colorimeter (Chroma meter, CR-300, Japan) as a manual manufacturer procedure. The colorimeter was calibrated through a white ceramic (Y= 93.5, X= 0.3132, y= 0.3198), and color properties of lightness ($L$*), redness ($a$*), and yellowness ($b$*) values were recorded for all cooked nuggets.

## Sensory evaluation

The sensory evaluation of nuggets was randomly conducted by 35 untrained panelists from university students and staff. Small pieces of different samples (2 × 2 × 2 cm) were prepared on a round plate and coded with the three-digit random number. The cooked samples were permitted to rest for 30 min at room temperature (26 °C) and then served to panelists. The randomized order of the sample was presented once at a time to each panelist. Panelists were asked to evaluate the coded sample for attributes including color, aroma, taste, texture, and overall acceptability. The evaluation was conducted using a 7-point hedonic scale. Scores were assigned based on the degree of liking (1= dislike very much, 2= dislike moderately, 3= dislike slightly, 4= neither like nor dislike, 5= like slightly, 6= like moderately, 7= like very much) (Lukman *et al*., 2009).

### Statistical analysis

All analyses were performed in triplicate. The results of meatless nuggets were represented as the mean ± standard deviation. The proximate composition and physicochemical properties of meatless nuggets were carried out using analysis of variance (ANOVA) and SPSS version 20 (IBM Corp., Armonk, NY, USA) was used for analyzing data. The partial least squares regression (PLS-R) was used to measure the variable importance of projection (VIP) scores and correlation map between independent variables (sensory attributes), dependent variables (panelists), and active observation (samples) using XLSTAT software (Addinsoft Inc., NY). For multiple mean comparisons, Tukey's test was run at a 5% level of significance.

## RESULTS AND DISCUSSION

### Proximate composition

Table 2 shows the results of the proximate composition of meatless nuggets. The proximate compositions of meatless nuggets differed significantly ($p$<0.05) between formulations. The meatless nuggets were higher in moisture (53.35 to 68.44%) and carbohydrate (13.96 to 22.57%) and lowered in protein (8.09 to 11.05%) and fat content (5.57 to 8.63%). Contrarily, Sharima-Abdullah *et al*. (2018) reported higher protein (10.80 to 11.78%) and carbohydrate (30.95 to 42.32%), but lower moisture (39.77 to 48.69%) and fat content (3.83 to 5.45%) in imitation chicken nuggets. The difference was due to the imitation chicken nuggets reported by Sharima-Abdullah *et al*. (2018) using chickpea flour substitution, which dehydrated form and lower moisture than in the present study used soaked and boiled chickpea, which had higher moisture. However, the protein content was almost similar, i.e., 17-21% for chickpea flour, 16-20% for raw chickpea (Grasso *et al*., 2022), 21.44-21.88% for roasted, soaked, and boiled chickpea proteins (Ouazib *et al*., 2015). The fat and carbohydrate content were different for both types of chickpeas based on the review of Grasso *et al*. (2022).

The meatless nugget's moisture contents increased significantly ($p$<0.05) based on the higher percentages of mushroom and lower percentages of boiled chickpea in the formulations; control (53.35%), MN70 (60.49%), MN40 (62.97%) and MN10 (68.44%). According to Ibrahim *et al*. (2015), oyster mushrooms have high moisture content, ranging from 85 to 88%. Moreover, boiled chickpea at the highest substitution (control) was less effective to retain moisture (Table 2). According to Grasso *et al*. (2022), the water absorption capacity of chickpea was poor against gravity interaction until it was processed and converted into chickpea protein isolates which has a greater ability to swell, dissociate and unfold.

The control contains the significantly highest ($p$<0.05) amount of carbohydrates (22.57%), while MN10 contains the significantly lowest ($p$<0.05) and was due to the control containing 100% boiled chickpeas in the formulation as compared with other meatless nuggets which contain in combination with oyster mushroom. This was likely because chickpeas contain abundant carbohydrates ranging from 70.2 to 72.9% (Ghribi *et al*., 2015) while the carbohydrates of oyster mushrooms were approximately 48.2% (Tolera and Abera, 2017).

In the current study, an increasing amount of oyster mushrooms and decreasing amount of boiled chickpeas decreased the protein of meatless nuggets significantly ($p$<0.05), as shown in Table 2. This finding was in agreement with the study reported by Husain and Huda-Faujan (2020), which obtained that decreasing the amount of chickpea flour and an increasing amount of grey oyster mushroom stems decreased the protein content in imitation chicken nuggets. According to Malaysia Food Regulation 1985 (Food-Act-281, 1994), it was stated that a food product must contain at least 10% of Nutrient Reference Value (NRV) per 100 g (for solid food) to be claimed as a source of protein. All the meatless nuggets formulated in this study qualify as a protein source based on the NRV of 25 g per serving. The addition of various plant-based ingredients (e.g., chickpeas, oyster mushrooms, potato starch, and textured vegetable protein) in the current study has met the NRV value of more than 1.25 g with control, MN70, MN40, and MN10 were recorded NRV 2.77 g, 2.41 g, 2.31 g, and 2.02 g, respectively.

**Table 2.** Proximate composition of meatless nuggets

| Percentage (%) | Formulation of nugget samples | | | |
|---|---|---|---|---|
| | Control | MN70 | MN40 | MN10 |
| Moisture | 53.35 ± 0.10[d] | 60.49 ± 0.86[c] | 62.97 ± 0.26[b] | 68.44 ± 0.50[a] |
| Carbohydrate | 22.57 ± 0.26[a] | 16.21 ± 0.32[b] | 15.80 ± 0.51[b] | 13.96 ± 0.62[c] |
| Protein | 11.05 ± 0.08[a] | 9.61 ± 0.07[b] | 9.27 ± 0.15[c] | 8.09 ± 0.08[d] |
| Fat | 8.29 ± 0.18[a] | 8.63 ± 0.50[a] | 7.73 ± 0.56[a] | 5.57 ± 0.62[b] |
| Crude fibre | 2.90 ± 0.08[a] | 2.70 ± 0.08[b] | 2.45 ± 0.05[c] | 2.31 ± 0.07[c] |
| Ash | 1.83 ± 0.04[a] | 1.70 ± 0.02[bc] | 1.77 ± 0.03[ab] | 1.64 ± 0.05[c] |

[a-d] Different letters in the same row indicate significant differences ($p$<0.05). The ratio for chickpea and oyster mushroom for MN70 is 70:30, for MN40 is 40:60, and for MN10 is 10:90 compared with boiled chickpea as a control meatless nugget.

Consequently, meatless nuggets with different boiled chickpea and oyster mushrooms exhibited no major difference ($p$>0.05) in fat content and were lower than commercial chicken nuggets (18.1 to 20.8% of fat) (Lukman *et al*., 2009). It has been reported that the fat content of meat alternatives is rationally different from traditional processed meat products (Bakhsh *et al*., 2021). The fat content of the present study (5.57 to 8.63%) was less or within the range reported by Bohrer (2019) (5.63 to 15.93%). Generally, plant-based meat products are considered low in fat and protein contents than traditional meat Ahirwar *et al*. (2015).

The fiber contents for meatless nuggets (2.45 to 2.90%) were recorded as higher than traditional nuggets (0.00%) Bohrer (2019), due to the chickpea and mushroom incorporated in the nugget formulations (Table 2). The fiber content of the control was significantly ($p$<0.05) higher than other meatless nugget formulations. A similar finding was also found by Husain and Huda-Faujan (2020) in their imitation chicken nuggets. Although mushrooms contributed less fiber (7.5 to 8.1%) (Oluwafemi *et al*., 2016) than chickpeas (18.7 to 21.9%) (Ghribi *et al*., 2015), both ingredients were believed to enrich the fiber in the meatless nuggets. The added value of fiber in plant-based meat can provide a health benefit to prevent ischaemic heart disease, large bowel disease, and diabetes mellitus than traditional meat products (Bakhsh *et al*., 2021).

Irrespective of the application of different ratios of chickpea and oyster mushrooms, ash content showed a significant difference ($p$<0.05). The difference in ash content was very marginal between formulations. However, the ash content in the present study (1.64 to 1.83%) was lower than that reported by Sharima-Abdullah *et al*. (2018) in imitation chicken nuggets (3.11 to 3.36%) but almost similar to commercial chicken nuggets (1.20 to 1.58%) reported by Lukman *et al*. (2009).

## Physicochemical properties

Table 3 shows the results of cooking loss, cooking yield, textural, and color properties of different formulations of meatless nuggets. It was found that the cooking loss of MN10 was the highest ($p$<0.05) (7.11%), while the cooking loss of control was the lowest (3.03%). An increment of oyster mushroom level in meatless nuggets by up to 90% increased the cooking loss and decreased the cooking yield. These findings contrasted with the result reported by Husain and Huda-Faujan (2020) who found the substitution of higher chickpea flour and lower grey oyster mushroom contributed to a higher cooking yield (negative cooking loss). Nevertheless, the current study was similar to Sharima-Abdullah *et al*. (2018) in the imitation chicken nugget with the lower incorporation of chickpea flour represents a higher cooking loss. The reason could be associated with the biopolymer network of chickpeas (protein and polysaccharides) that is good at retaining water (Jukanti *et al*., 2012; Wood *et al*., 2011). Meanwhile, the biopolymer network of mushrooms is unstable and interfered with by temperature. It loses its integrity of binding water after subjecting to a temperature above 40 °C (Paudel, 2015). Although the moisture content of MN10 (90% oyster mushroom) was the highest before cooking (Table 2), it tends to lose of water through evaporation upon heating and results in a lower yield (Table 3).

The textural properties are crucial in meatless nuggets because the products must mimic the appearance and texture of chicken nuggets. Table 3 shows the textural properties, including hardness, springiness, cohesiveness, and chewiness. All of the textural attributes of MN10 were significantly ($p$<0.05) the highest compared to all meatless nuggets. The higher hardness in MN10 was expected, this was due to the higher loss of water. Also, this was evidenced by Sharima-Abdullah *et al*. (2018) in their imitation chicken nugget. However, the incorporation of a higher proportion of oyster mushrooms in the recipe was not the main factor for the nugget's hardness because Wan Rosli *et al*. (2011) found chicken patty hardness decreased proportionally with the level of mushroom. An increment in chickpea concentration decreased

**Table 3.** Cooking loss, cooking yield, textural, and color properties of meatless nuggets

| | Formulation | | | |
|---|---|---|---|---|
| | Control | MN70 | MN40 | MN10 |
| Cooking loss (%) | 3.03 ± 0.15$^{c}$ | 4.20 ± 0.21$^{b}$ | 4.39 ± 0.30$^{b}$ | 7.11 ± 0.27$^{a}$ |
| Cooking yield (%) | 96.97 ± 0.15$^{a}$ | 95.80 ± 0.21$^{b}$ | 95.61 ± 0.30$^{b}$ | 92.89 ± 0.27$^{c}$ |
| Hardness (N) | 100.75 ± 1.65$^{d}$ | 143.50 ± 0.34$^{c}$ | 150.82 ± 0.64$^{b}$ | 218.05 ± 0.53$^{a}$ |
| Springiness (cm) | 0.47 ± 0.01$^{c}$ | 0.65 ± 0.01$^{b}$ | 0.73 ± 0.02$^{b}$ | 0.78 ± 0.03$^{a}$ |
| Cohesiveness (N/cm) | 0.35 ± 0.01$^{b}$ | 0.51 ± 0.01$^{b}$ | 0.57 ± 0.02$^{a}$ | 0.59 ± 0.01$^{a}$ |
| Chewiness (N/cm) | 15.79 ± 0.61$^{d}$ | 47.06 ± 0.25$^{c}$ | 55.07 ± 0.61$^{b}$ | 101.20 ± 1.24$^{a}$ |
| Lightness (L*) | 45.06 ± 0.51$^{a}$ | 40.66 ± 0.50$^{b}$ | 38.08 ± 0.24$^{c}$ | 35.86 ± 0.50$^{d}$ |
| Redness (a*) | 7.36 ± 0.23$^{ab}$ | 7.34 ± 0.04$^{ab}$ | 7.87 ± 0.15$^{a}$ | 7.11 ± 0.34$^{b}$ |
| Yellowness (b*) | 44.93 ± 0.64$^{a}$ | 41.28 ± 0.44$^{b}$ | 37.53 ± 0.49$^{c}$ | 31.52 ± 0.44$^{d}$ |

$^{a-d}$ Different letters in the same row indicate significant differences ($p$<0.05). The ratio for chickpea and oyster mushroom for MN70 is 70:30, for MN40 is 40:60, and for MN10 is 10:90 compared with boiled chickpea as a control meatless nugget.

the hardness of meatless nuggets markedly, as shown in the control. The lower hardness values were due to the extensive hydration of chickpea with water at the early stage of the processing phase. Dry chickpea hardness drops significantly ($p$<0.05) after soaking and blanching from 346 N to 38 N (Gowen *et al*. 2007).

The range of springiness and chewiness of all the nugget samples was between 0.47 to 0.78 cm and 15.79 to 101.20 N/cm, respectively. The apparent changes in these textural properties were due to the cooking process of the nugget that contains a higher concentration of oyster mushrooms. After heat treatment, the cell wall structure of the mushroom breaks down and results in protein denaturation, solubilization of pectin, and other complex reactions, thereby exhibiting chewier attributes (Nketia *et al*., 2020). Meanwhile, Wan Rosli *et al*. (2011) reported that the springiness of cooked patties increased when mushrooms were added at high concentrations. Our results in Table 3 evidence this, the springiness of MN70, MN40, and MN10 were significantly ($p$<0.05) increased with oyster mushroom concentration (30, 60, and 90%, respectively) compared to control (without mushroom). Also, we empirically observed that the textural properties of the control are mushy and deform easily only at first compression. This can be associated with lower cohesiveness ($p$<0.05), as shown in Table 3. According to Sharima-Abdullah *et al*. (2018), the lower cohesiveness in imitation chicken nuggets was due to the weaker intermolecular attraction of chickpea flour where it cannot adhere or bind other ingredients together.

The color properties of meatless nuggets are shown in Table 3. Nuggets tended to decrease in lightness ($L$*) and yellowness ($b$*) with a decrement in boiled chickpeas concentration. Our result is in tandem with the imitation chicken nuggets investigated by Sharima-Abdullah *et al*. (2018). However, the $L$* values of the present study were lower (35.9 to 45.1) than the $L$* values of commercial chicken nuggets (64.4 to 68.4) reported by Lukman *et al*. (2009). The variation of $L$* values in the present study compared to commercial chicken nuggets could be due to the full substitution of plant-based proteins (100% substitution) and the addition of mushrooms in the formulation. These ingredients also affected the $b$* values of meatless nuggets apparently (31.5 to 44.9) more than commercial chicken nuggets' $b$* values (16.4 to 19.4) (Lukman *et al*., 2009). The lighter color of meat-based nuggets was probably due to the meat globules impregnated with water and fat which can reflect more light to cause higher lightness (Bakhsh *et al*., 2021). Meanwhile, the higher $b$* values of meatless nuggets in this study are directly linked with the yellow pigment of chickpeas (Husain & Huda-Faujan, 2020).

In general, the different concentrations of chickpeas and mushrooms formulated in meatless nuggets affected the $L$* values because chickpeas and mushrooms characterized the color as lighter (Sharima-Abdullah *et al*., 2018) and darker (Wan Rosli *et al*., 2011), respectively. Similarly, the $L$* values of meatless nuggets were associated directly with the substitution ratio of chickpea and oyster mushrooms. As shown in Table 3, control represents a higher lightness with chickpea and is substantially reduced with the increasing mushroom concentration. Similar effects were observed in the $b$* values of meatless nuggets incorporated with different ratios of chickpea to mushroom. However, chickpea and mushroom concentration at different percentages only plays a minor role in the $a$* values of cooked meatless nuggets. The $a$* values recorded in this study were 7.11 to 7.87, slightly different between formulations. These redness properties were higher than those reported by Lukman *et al*. (2009) and Sharima-Abdullah *et al*. (2018) in commercial chicken nuggets (0.51 to 3.51) and imitation chicken nuggets (2.76 to 6.21), respectively.

## Sensory evaluation

The sensory score of meatless nuggets is shown in Table 4. It was difficult to determine the sensory features of meatless nuggets because some treatments did have not a statistical difference ($p$>0.05). Partial least square regression (PLS-R) was used to identify the correlation between samples and sensory attributes. Figure 1a is a correlation map between sensory attributes (X-components; independent variables), panelists (Y-components; dependent variables), and samples (active observations).

**Table 4.** Sensory evaluation of meatless nuggets

| | Formulation | | | |
|---|---|---|---|---|
| | Control | MN70 | MN40 | MN10 |
| Colour | 4.63 ± 1.65[a] | 4.74 ± 1.29[a] | 4.60 ± 1.14[a] | 4.29 ± 1.18[a] |
| Aroma | 4.83 ± 1.54[a] | 4.80 ± 1.55[a] | 4.86 ± 1.24[a] | 4.26 ± 1.46[a] |
| Taste | 3.54 ± 1.34[b] | 3.97 ± 1.45[ab] | 4.71 ± 1.36[a] | 4.63 ± 1.50[a] |
| Texture | 3.14 ± 1.26[c] | 3.91 ± 1.42[bc] | 4.77 ± 0.91[a] | 4.40 ± 1.56[ab] |
| Overall acceptability | 3.89 ± 1.39[b] | 4.03 ± 1.34[b] | 5.00 ± 1.14[a] | 4.57 ± 1.40[ab] |

[a-c] Different letters in the same row indicate significant differences ($p$<0.05). The ratio for chickpea and oyster mushroom for MN70 is 70:30, for MN40 is 40:60, and for MN10 is 10:90 compared with boiled chickpea as a control meatless nugget.

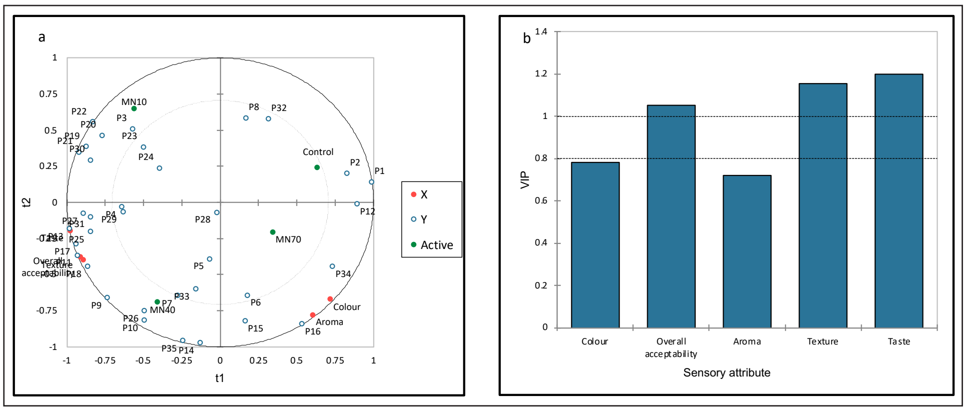


**Fig. 1.** (a) Partial least square regression (PLS-R) correlation loadings for X-t1 and Y-t2, where X-variables are independent variables and Y-variables are dependent variables. The observed samples are Control, MN70, MN40, and MN10. (b) Ranking of the variable importance in the projection (VIP) scores. The ratio for chickpea and oyster mushroom for MN70 is 70:30, for MN40 is 40:60, and for MN10 is 10:90 compared with boiled chickpea as a control meatless nugget.

Active observations/ samples are well separated throughout each biplot and there was a clear difference in the sample relative position that characterise different formulations. Results found that both control and MN70 were placed in the right part of the first component (t1), while MN40 and MN10 were placed on the left. Interestingly, only MN70 and MN40 were positioned on the lower part of the second component (t2) together with sensory attributes. From Figure 1a and 1b, it was observed that some panelists displayed at the center of the correlation map, meaning that correlations were low towards sensory attributes. Regarding the active observation, MN40 was located away from the center circle and explained a better correlation to texture, taste, and overall acceptability at the lower left quadrant. However, MN70 was explained with little preference for color and aroma as it is located towards the center line and in the central circle. This can be evidenced by Figure 1b, where the variable importance in the projection (VIP) explained that the color and aroma were less significant in the current study as the VIP scores were lesser than 1. According to Ismail *et al*. (2020b), a VIP score higher than one was regarded as an influential variable in a given model.

The effect between ingredients represented well on the graph with a high concentration of boiled chickpea influenced the color and aroma. In contrast, a high concentration of mushrooms influenced the judgment towards taste, texture, and overall acceptability (Figure 1a). Empirically, the meatless nuggets with the higher substitution of boiled chickpea and mushroom (in control and MN10) tended to have a lower preference by the panelists on the sensory mean scores. Although MN40 was the most preferred by panelists, the substitution of plant-based ingredients in meatless nuggets was only an average score. The results in the present study were in line with the study reported by Husain and Huda-Faujan (2020), which found that substitution with 55% oyster mushroom and 15% chickpea recorded a better score in appearance, texture, juiciness, taste, and overall acceptability in imitation chicken nugget.

## CONCLUSION

Different substitution ratios of boiled chickpea and oyster mushrooms significantly affected the quality characteristics of meatless nuggets. A higher concentration of boiled chickpeas showed promising results, especially on carbohydrate, protein, fiber content, cooking yield, and color properties (lightness & yellowness). Meatless nuggets with higher substitution of oyster mushrooms exhibited better textural properties and sensory mean scores. However, samples with a maximum substitution of chickpea or mushroom (i.e., control & MN10) were not the best option for producing meatless nuggets. They failed to satisfy the sensory panelists as the added ingredient affect the texture and taste. It can be concluded that a meatless nugget with a 40:60 ratio of boiled chickpea to oyster mushroom (MN40) was recommended to prepare as an acceptable plant-based nugget with good physicochemical properties and sensory acceptability.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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