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Sensory Evaluation, Protein Digestibility, and Soluble Protein Content of Beef Meatballs Substituted with Oyster Mushrooms (*Pleurotus ostreatus*)

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ABSTRACT
Oyster mushrooms (*Pleurotus ostreatus*) are one of the preferred sources of plant protein. This is a nutritious food alternative with a combination of cheaper prices than beef as meatballs. The study aimed to sensory evaluate, protein digestibility, and soluble proteins of beef meatball substituted by oyster mushrooms. Samples with four treatments were beef and mushroom ratios of 100:0 (control), 75:25 (F1), 25:75 (F2), 0:100 (F3). The data obtained were analyzed using One Way Anova and followed by the Duncan Multiple Range Test (DMRT). The results of the sensory evaluation data showed that the p-value was significantly different ($p<0.05$) between 1.8-3.6 from the aspect of taste, aroma, and texture that had no significant difference, on the contrary from the aspect of color. Meanwhile, protein digestibility had a significant difference with the best F2 formula with a value of 41. In contrast, soluble proteins delivered the best formula was sample k with a value of 2.0. The best formula for sensory evaluation was meatballs with beef dominant. While the digestibility of protein increases and lowers dissolved protein with the addition of oyster mushrooms.

INTRODUCTION

Meatballs are a long-established food product that remains popular. They are commonly prepared primarily from meat and served as a side dish (Astuti, 2019). Meatballs are made by mixing minced meat with flour or starch, shaping the mixture into balls, and boiling them (Muliady et al., 2016). Meat can be relatively expensive, and household purchasing power declined during the COVID-19 pandemic (Prayogo and Sukim, 2020). A potential way to reduce production costs is to replace some or all of the meat with plant-based ingredients, such as oyster mushrooms.

Plant-based meatball products, particularly those made with oyster mushrooms (Pleurotus ostreatus), are a potential alternative to conventional meatballs. Oyster mushrooms have been reported to offer nutritional benefits and may provide an alternative to meat (Lamadjido et al., 2019). Oyster-mushroom meatballs can retain a firm, tender texture similar to that of meatballs. Their texture is influenced by the water content and the addition of starch or flour. Oyster mushrooms have been reported to contain approximately 10.5%–30.4% protein per 100 g (Hajriatun et al., 2017), while beef contains approximately 16% protein per 100 g (Cahyono, 2013).

Protein quality can be assessed by measuring protein digestibility, including through in vitro methods (Mugendi et al., 2010). Soluble protein content is also used to characterize protein-related properties. Combining animal- and plant-based protein sources may be useful in developing food products with different nutritional characteristics. However, plant proteins may differ from animal proteins in their amino acid composition and structural properties.

The development of halal food products in Indonesia may also be considered in the context of maqāṣid al-sharīʿah, which informs innovation and the production of halal food. This framework emphasizes the values reflected in the Qur'an and Sunnah, including the consumption of food that is halal and wholesome (Sulistiani, 2018). Developing products from locally available ingredients may therefore be relevant to both food innovation and the production of halal and wholesome foods.

The Qur'an states, "Then let mankind look at his food" (Qur'an 80:24). In this context, developing safe, nutritious, affordable, and accessible foods using plant-based ingredients may be valuable. This study

examined soluble protein content and in vitro protein digestibility in beef meatballs substituted with oyster mushrooms. The objectives were to evaluate the sensory acceptability of the formulations and to analyze protein digestibility and soluble protein content in beef meatballs containing different proportions of oyster mushrooms.

MATERIALS AND METHODS

This experimental study used a completely randomized design with three replicates. The study was conducted at the Food Technology Laboratory, Faculty of Health Sciences, University of Darussalam Gontor, from November 2021 to March 2022. Four formulations were prepared: the control contained 100% beef and 0% oyster mushrooms; F1 contained 75% beef and 25% oyster mushrooms; F2 contained 25% beef and 75% oyster mushrooms; and F3 contained 0% beef and 100% oyster mushrooms.

The meatball formulations consisted of minced beef and oyster mushrooms as the main ingredients, with salt, pepper, garlic, tapioca starch, wheat flour, and egg white, based on a modified formulation described by Syaharuddin (2014). Laboratory analyses used 0.1 N HCl, 0.5 N NaOH, 0.2 M phosphate buffer (pH 8), pepsin, pancreatin, and Lowry reagents. Equipment included a digital scale (IdeaLife IL210) and a meat grinder/blender (Philips 2115). In vitro protein digestibility was assessed using laboratory glassware, a water bath, and a Kjeldahl apparatus. Soluble protein was measured spectrophotometrically (Naufalina et al., 2020).

The outcomes assessed were sensory acceptability, in vitro protein digestibility, and soluble protein content using the Lowry method. Data were analyzed using one-way analysis of variance (ANOVA), followed by Duncan's multiple range test for post hoc comparisons. The study received ethical approval under decision number 407/KEPK/EC/2021.

Table 1. Ingredients used in the meatball formulations

Formula	Kontrol	F1(g)	F2(g)	F3(g)
Beef	250 g	187,5	62,5	0
Oyster mushrooms	0 g	62,5	187,5	250
Table salt (1%)	5 g	5	5	5
Pepper (1%)	5 g	5	5	5
Garlic (10%)	12 g	12	12	12
Starch (40%)	40 g	40	40	40
Flour (15%)	15 g	15	15	15
Egg whites (2%)	10 g	10	10	10

Source: Modified from Syaharuddin (2014).

RESULTS AND DISCUSSION

Table 2. Sensory acceptability scores

	K	F1	F2	F3	Reference Standards
Taste	$3,5^{c}$	$2,4^{b}$	$2,1^{ab}$	$1,8^{a}$	Normal, characteristic of meatballs
Aroma	$3,5^{c}$	$2,4^{b}$	$2,1^{ab}$	$1,8^{a}$	Normal, characteristic of beef
Texture	$2,3^{a}$	$2,7^{ab}$	$2,8^{bc}$	$3,1^{c}$	Firm/elastic
Color	$3,6^{d}$	$3,0^{c}$	$2,2^{b}$	$1,0^{a}$	Normal

Notes:
Different superscript letters indicate statistically significant differences ($p < 0.05$).
Formulations:
K: 100% beef and 0% oyster mushrooms
F1: 75% beef and 25% oyster mushrooms
F2: 25% beef and 75% oyster mushrooms
F3: 0% beef and 100% oyster mushrooms
Source: Indonesian National Standard (SNI) 3818:2014.

Sensory evaluation showed that oyster-mushroom substitution significantly affected taste scores. One-way ANOVA indicated a difference among the four formulations ($p < 0.001$), followed by Duncan's multiple range test. Taste scores ranged from 1.8 to 3.5. The control formulation (K; 100% beef) received the highest score, whereas F3 (100% oyster mushrooms) received the lowest score.

The panelists' lower preference for the oyster-mushroom meatballs may be related to their relatively bland taste (Astuti and Naufalin, 2011). Hajriatun et al. (2017) suggested that the addition of tapioca starch may influence the taste of oyster-mushroom meatballs and reduce their characteristic savory flavor. Oyster-mushroom substitution also significantly affected aroma scores (one-way ANOVA, $p < 0.001$). Scores ranged from 1.8 to 3.5. The control formulation received the highest score, while F3 received the lowest score, indicating that the panelists preferred the aroma of the beef-based formulation.

The panelists appeared to prefer a less intense mushroom aroma. Muliady et al. (2016) reported that oyster mushrooms stored for too long may develop a strong, unpleasant aroma, potentially because of lipid

deterioration and oxidation. Oyster-mushroom substitution significantly affected texture scores (one-way ANOVA, $p < 0.001$). Scores ranged from 2.3 to 3.1. F3 (100% oyster mushrooms) received the highest texture score, while the control received the lowest. This finding suggests that panelists preferred the texture of the oyster-mushroom meatballs, which may be perceived as firm and similar to meat (Falahudin, 2013).

Oyster-mushroom substitution significantly affected color scores (one-way ANOVA, $p < 0.001$). Scores ranged from 1.0 to 3.6. The control formulation received the highest score, while F3 received the lowest. This result is consistent with the possibility that the paler color of oyster-mushroom meatballs affects consumer acceptance, as discussed by Hajriatun et al. (2017).

Table 3. Soluble protein content and protein digestibility

	K	F1	F2	F3
Soluble protein content	$2,0^{d}$	$1,4^{c}$	$1,2^{b}$	$1,0^{a}$
Protein digestibility	$35,2^{b}$	$31,8^{a}$	41^{c}	$37,2^{b}$

Notes:
Different superscript letters indicate statistically significant differences ($p < 0.05$).
K: 100% beef and 0% oyster mushrooms
F1: 75% beef and 25% oyster mushrooms
F2: 25% beef and 75% oyster mushrooms
F3: 0% beef and 100% oyster mushrooms

Oyster-mushroom substitution significantly affected protein digestibility (one-way ANOVA, $p < 0.001$). Values ranged from 31.8 to 41.0. The highest value was observed in F2 (25% beef and 75% oyster mushrooms), while the lowest was observed in F1 (75% beef and 25% oyster mushrooms). Wardani and Widjanarko (2013) suggested that plant-protein digestibility may be influenced by changes in protein structure and breakdown into smaller molecules. Protein digestibility involves enzymatic hydrolysis of complex proteins into simpler compounds (Setyawan, 2015). Asrullah and Mathar (2012) also described how heat-induced denaturation during cooking can alter protein structure and make proteins more susceptible to enzymatic action. Combining animal and plant protein sources may affect protein digestion and absorption (Sari, 2017).

Oyster-mushroom substitution significantly affected soluble protein content (one-way ANOVA, $p < 0.001$). Values ranged from 1.0 to 2.0. The control formulation had the highest value (2.0), while F3 had the lowest (1.0), indicating that soluble protein content decreased as the proportion of oyster mushrooms increased. The soluble protein content was higher in the beef-based formulation than in the oyster-mushroom formulation. Gropper et al. (2021) discuss differences between animal and plant proteins in amino acid composition and structural characteristics that may affect protein breakdown. Setyawan (2015) also reported that processing can influence soluble protein content. These possible explanations should be interpreted cautiously because the present study measured soluble protein content rather than directly characterizing protein structure.

CONCLUSIONS

Among the four formulations, the control (100% beef) received the highest sensory scores for taste, aroma, and color, while F3 (100% oyster mushrooms) received the highest texture score. Protein digestibility was highest in F2 (25% beef and 75% oyster mushrooms), at 41.0. Soluble protein content was highest in the control formulation (2.0) and lowest in F3 (1.0). These findings suggest that oyster-mushroom substitution influenced sensory characteristics, protein digestibility, and soluble protein content. The most suitable formulation will depend on whether sensory acceptance, texture, or protein-related outcomes are prioritized

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