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Chemical characteristics of meat analog from sorghum, oyster mushroom, and red bean

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Abstract – Food security is a challenge faced by emerging countries such as Indonesia. One of the solutions is food diversification by developing meat analogs or meat substitutes, which are plant-derived food products typically processed to mimic the flavor, texture, and appearance of meat. Meat and animal-based food products are generally related to environmental threats like global greenhouse gases. Excessive red and processed meat consumption have also been identified as risk factors. Therefore, developing meat analogs from plant-based ingredients has advantages in creating a diverse, balanced, and healthy substitute. This study aims to determine the chemical characteristics of meat analogs from sorghum, oyster mushroom, and red bean. This research consisted of 4 treatments with the ratio of sorghum, oyster mushroom, and red bean (%): P1 (20:55:25), P2 (15:65:20), P3 (10:75:15), and P4 (5:85:10). Meat analog was analyzed such as water content, ash, fat, protein, carbohydrate, fiber, and Fe content. The results showed that the best treatment for physicochemical characteristics was P1 (20% sorghum:55% oyster mushroom:25% red bean), which contained fiber 3.99%, ash 0.90%, protein 7.02%, carbohydrate 42.34%, fat 1.35%, water 43.13%, and Fe 21.81%.

Keywords: chemical characteristic, meat analog, oyster mushroom, red bean, sorghum

1 Introduction

According to Indonesian law number 18 of 2012 on Food [1], food is the most important basic human need, and its fulfillment is part of human rights. It is stated in the 1945 Constitution as an essential component to realize quality human resources. The government must provide available, affordable, and adequate food that is safe, of good quality, and nutritionally balanced from individual to national level throughout Indonesia. In realizing the availability, affordability, and fulfillment of food consumption, the concept of food security emerges, namely the condition of food fulfillment by the state to individuals, which is reflected in the availability of sufficient food, both in quantity and quality, that is safe, diverse, nutritious, equitable, and affordable and does not conflict with specific interests such as religion, beliefs, and culture of a community, to be able to live healthy, active and productive lives sustainably.

Based on the *Global Food Security Index* (GFSI) data released by Economist Impact in 2022, Indonesia is ranked, in terms of food security, 63 out of 113 countries globally with a score of 60.2, below the global average score of 62.2, and ranked 10th out of 23 Asia-Pacific countries with an

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average score of 63.4 [2]. Based on Table 1, in the availability category, Indonesia is ranked at the bottom of the 23 Asia-Pacific countries recorded in GFSI with a score of 50.9, lower than the Asia-Pacific average score of 61.9. The Ministry of Agriculture has implemented a breakthrough program in strengthening food availability, which is formulated in 5 action plan steps, namely: (1) Increasing Production Capacity; (2) Local Food Diversification; (3) Strengthening Food Reserves and Logistics System; (4) Development of Modern Agriculture through Smart Farming Development by utilizing integrated agricultural modernization based on farmer corporations; and (5) Movement to Increase Three Times Exports [3]. Based on these five steps, local food diversification is one of the ways to strengthen food availability.

Table 1. Values of Indonesia's food security pillars in 2022.

Pillars of Food Security	Indonesia's average score	Asia-Pacific average value	Indonesia's ranking in the Asia-Pacific region
Affordability	81.4	73.4	9
Availability	50.9	61.9	23
Quality and safety	56.2	63.7	17
Sustainability and Adaptation	46.3	51.2	15

Food diversification, according to Indonesian Law No. 18/2012 on food [1], is an effort to increase the availability and consumption of food that is diverse, nutritionally balanced, and based on the potential of local resources. Food security supported by food diversification can contribute to reducing food availability problems. Diversification aims to fulfill diverse, nutritionally balanced, and safe food consumption patterns, develop new food businesses, and improve community welfare. One of the food diversification efforts that can be done is developing alternative food products by processing vegetable ingredients such as cereals and beans into processed vegetable meat products or meat analogs.

Meat analogs, often known as meat substitutes, are plant-based food products usually processed to mimic meat's flavor, texture, and appearance [4]. Animal meat has a relatively high price, and food diversification in the form of meat analog products can help agricultural areas in Indonesia develop the potential for crop diversity. Artificial meat has several advantages, including better nutritional value, greater homogeneity, and more excellent durability in storage. It can be adjusted not to contain cholesterol and at a cheaper price [5]. Cereals like sorghum can be used as raw material for making meat analog. Currently, sorghum has only been utilized as animal feed. However, sorghum is suitable for use as an agro-industrial commodity because of its high resistance to dry environments, adaptability to high land, and low production costs [6]. It is known that sorghum has an iron content of 5.4 mg/100 g [7]. Iron is an essential nutrient for the human body. Iron acts as an oxygen carrier with functions such as enhancing the immune system and supporting the formation of hemoglobin to battle anemia. The next ingredient that can be used is the oyster mushroom plant. Oyster mushrooms have a high protein content of about 22.10% and fiber of 34.01% [8]. The digestive tract also easily digests meat analog protein from oyster mushrooms compared to casein or fermented meat [9]. Putri et al. [10] also reported that meat analog from oyster mushrooms has a chewy texture similar to meat and an aroma and texture that panelists favor. Other ingredients that can be utilized in food diversification efforts come from legumes, namely red beans. Red beans contain 24.9 g of fiber per 100 g of red beans and 7.73 g of protein per 1 cup or 110 g of red beans [11]. In addition to the primary nutrients, red beans also contain a number of vitamins such as vitamin A and B as well as other minerals. Santoso [12] explains that dietary fiber for health can control body weight or obesity, manage diabetes, prevent gastrointestinal disorders and colon cancer, and reduce blood cholesterol

levels and cardiovascular disease. Fiber sourced from meat-analog raw materials such as oyster mushrooms and red beans contributes to the texture of meat analog that resembles animal meat.

Meat analogs from sorghum, oyster mushrooms, and red beans can be an alternative to meat products that are equally nutritious and healthy at a relatively low price. Therefore, it can be accessible to people who are poor and might not be able to access animal-based meat. Food diversification in the production of meat analog is also expected to improve food availability to support food security in Indonesia. This research aims to develop meat analogs from sorghum, oyster mushrooms, and red beans and analyze characteristic meat analogs such as water content, ash, fat, protein, carbohydrate, fiber, and iron content.

2 Materials and methods

This research was conducted from May to July 2023 in Bandung, West Java. The formulation design consisted of 4 treatments with different concentrations of oyster mushroom, sorghum flour, and red bean flour. The formulation is as follows: F1 (55 g:25 g:20 g); F2 (65 g:20 g:15 g); F3 (75 g:15 g:10 g), and F4 (85 g:10 g:5 g). Additional ingredients include garlic powder, pepper powder, salt, mushroom broth, flavoring, and water. The tools used are an oven, blender, digitalscale, electronic scale accuracy 0.01 g, measuring cup size 100 mL, and measuring spoon.

Fresh oyster mushrooms were cleaned using running water for the material preparation stage. Then the leftover roots were separated and shredded to make the size smaller to facilitate mashing. The shredded mushrooms were then steamed for 30 minutes and mashed using a blender. Next is the dough-making stage, where the ground oyster mushrooms, red bean flour, sorghum flour, and all other additional ingredients were weighed and mixed by hand until a smooth dough was formed. The meat serving model was formed manually to resemble a patty with a diameter of 5.03 cm, thickness of 2.01 cm, and weight of 50 g. Preheating for 5 minutes to reach a temperature of 170-180°C and cooking time in the oven was 30 minutes. The chemical characteristics tested included moisture content [13], protein content [13], fat content [13], ash content [13], carbohydrate content (by difference), dietary fiber content [13], and iron content (Gravimetric method).

3 Results and discussion

The quality of this meat analog is influenced by the composition of its constituent ingredients. Meat analog from sorghum, oyster mushroom, and red bean raw materials must have good and high nutritional value content. The results of proximate analysis of meat analog from sorghum, oyster mushrooms and red beans are in Table 2.

Table 2. Chemical analysis results of meat analog of oyster mushroom, sorghum, and red bean.

Parameters	P1 (%)	P2 (%)	P3 (%)	P4 (%)
Water Content	43.13	46.55	51.55	52.89
Fiber	3.99	3.77	3.33	3.43
Ash	0.90	0.89	0.74	0.71
Protein	7.02	6.43	6.98	6.26
Carbohydrate	42.34	39.72	35.27	34.50
Fat	1.35	1.23	1.01	0.97

3.1 Water content

Moisture content can affect the appearance, texture, flavor, freshness and shelf life of food [14]. From the results of the analysis, the best treatment with the highest water content 52.89% was found in P4,

which has the highest ratio of oyster mushroom. This may be because Oyster mushroom has a water content around 86.6% so, it may affect the water content of meat analog. The higher ratio of oyster mushroom added, the higher water content of meat analog. It shows that meat analog of oyster mushrooms, sorghum, and red beans has a lower moisture content ratio, with ranges from 40-55% of beef (65-80%). The higher moisture content increased with the addition of oyster mushroom. P1 had the lowest water content compared to the other treatments at 43.13%. This is thought to be due to the decreasing ratio of oyster mushroom usage and water loss during high temperature cooking (oven). Water loss caused by shrinkage during cooking will be greater because the use of high temperatures will cause protein denaturation and reduce the value of water binding capacity [5].

3.2 Fiber content

The results of the analysis showed that the highest fiber content of meat analog 3.99% was found in P1, which is the highest proportion of sorghum and red bean. Sorghum and red bean contain high dietary fiber, which is 6.3 g [15] and 4 g [16] in 100 g serving. It can be concluded that the higher the proportion of sorghum and red bean flour added to the meat analog dough, the higher the fiber content. Oyster mushrooms also contain high dietary fiber, which is 33.44% in 100 g serving [9]. Dietary fiber consists of complex carbohydrates that are mostly found in plant cell walls that cannot be digested by digestive enzymes and cannot be absorbed by the human digestive system. Although it cannot be digested and absorbed by humans, food fiber has a function for health as a prevention of various degenerative diseases [5].

3.3 Ash content

The results of the analysis showed that the highest ash content of meat analog 0.90% was found in P1, which is the highest proportion of red bean. This occurred due to the addition of the proportion of red beans which has a high mineral content of 4.26% [17] compared to other cereal so that the higher the ratio of the addition of red beans, the higher the ash content in the meat analog. From the results of the analysis also showed that the meat analog from oyster mushroom, sorghum, and red bean had a lower ash content ratio, which ranged from 0.7- 0.9% of beef (1.5-3.0%) [18]. The amount of ash or minerals in foodstuffs shows the amount of minerals that do not burn into substances that can evaporate from a processing process. The determination of ash content can be used for various purposes, including to determine whether or not a processing is good, to determine the type of material used, and as a parameter for the nutritional value of food [19].

3.4 Protein content

The results of the analysis showed that the highest protein content of meat analog 7.02% was found in P1. This may be due to each addition of oyster mushroom ratio, the amount of red bean ratio is reduced. Where red beans contain protein around 23.1% [20] which is almost equivalent to meat and contributes a large protein value to meat analog products. In 100 g of red beans, there is lysine 13.23 g, aspartate acid 10.4 g, leucine 6.93 g, glutamate acid 5.95 g, arginine 5.37 g, serine 4.72 g, phenylalanine 4.69 g, valine 4.54 g, isoleucine 3.83 g, proline 3.68 g, threonine 3.65 g, alanine 3.64 g, glycine 3.39 g, methionine 1.05 g and cysteine 0.84 g. The limiting amino acids in red bean protein are methionine and cysteine with a relatively low content [21]. In addition, oyster mushrooms contain 19-35% protein higher than protein in rice (7.38%) and wheat (13.2%), as well as 9 essential and specializedamino acids [22]. Meanwhile, sorghum protein content is 10-11%, higher than milled rice protein (6-7%) and only slightly below wheat (12%).

3.5 Carbohydrate content

The results of the analysis showed that the carbohydrate content of meat analog from sorghum, oyster mushrooms, and red beans was between 34.50% - 42.34%. P1 has the highest carbohydrate content of 42.34%. The high carbohydrate content in the P1 meat analog sample probably came from red beans and sorghum. The carbohydrate content of red beans per 100 g is 56.20 grams [21]. The carbohydrate content of sorghum flour ranged from 75.4-79.8%. Sorghum contains high carbohydrates in the form of starch. Starch contained in sorghum ranges from 50-73%. 20-30% of which is stored in the form of amylose, while 70-80% is in the form of amylopectin [23]. Thus, the higher the ratio of red beans and sorghum, the higher the carbohydrate contentof meat analog.

3.6 Fat content

The results of the analysis showed that the highest protein content of meat analog 1.35% was found in P1. From the analysis, it also shows that oyster mushroom, sorghum, and red bean meat analog has a lower fat content ratio, which ranges from 0.9-1.4% of beef (1.5-13%) [18]. This happens because oyster mushrooms, sorghum, and red beans used as the basic ingredients of meat analog have low fat content. The higher ratio of oyster mushroom addition caused the lower fat content. The higher the addition of oyster mushrooms, the lower the fat content, this is because the higher water content in the oyster mushrooms will cause the fat content to decrease. High water content in the material causes fat to be difficult to extract with non-polar solvents (ether) because solvents are difficult to enter wet tissues and cause solvents to become saturated with water so that they are less efficient for extraction [14].

3.7 Iron (Fe) content

Table 3. Results of Fe content analysis of meat analog of oyster mushroom, sorghum,and red bean.

Oyster mushroom (%) : Sorghum (%) : Red Bean (%)	Fe
P1(55 : 25 : 20)	21.81^{c}
P2 (65 : 20 : 15)	19.47^{b}
P3 (75 : 15 : 10)	18.65^{b}
P4 (85 : 10 : 5)	15.58^{a}

Description: Data are presented as mean ± standard deviation. Values with different superscripts in the same row indicate significant differences ($P<0.05$).

The results of the analysis showed that the formulation of oyster mushroom, sorghum, and red bean meat analog had a very significant effect on the Fe content of meat analog. The treatment with the highest Fe content was P1 with a value of 21.81 ppm. This may be because sorghum is one of the cereals that have a high iron content. The iron content of sorghum is 5.4 mg/100 g, higher than iron in cracked rice (1.8 mg/100 g) and wheat (3.5 mg/100 g) [7]. Therefore, the substitution of sorghum flour caused the iron content in meat analog to increase along with the ratio of sorghum added. Based on the Nutrition Adequacy Rate set by The Health Ministry of Indonesia, the iron requirement in adults is 18 mg/day [24]. From the test results of iron content in 100 gr of meat analog, the highest iron content (P1) was able to fulfill about 12.2% of the iron needs needed by the body.

4 Conclusion

From the results of the study, the best chemical characteristics treatment is P1 with a ratio of 55% oyster mushroom, 25% sorghum, and 20% red bean with fiber content of 3.99%, ash content of 0.90%, protein 7.02%, carbohydrate 42.34%, fat 1.35%, and water 43.13%. In addition, the

formulation of oyster mushroom, sorghum, andred bean meat analog had a significant effect on iron (Fe) content, where the highest iron content of 2.18 mg was found in P1, which is the highest proportion of sorghum flour (25%). It can be concluded that the higher the proportion of sorghum flour added to the meat analog dough, the higher the iron (Fe) content.

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