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# Physical and Sensory Characteristics of Soybean and Glucomannan Based Meat Analogue for Obesity Intervention

## *Karakteristik Fisik dan Sensoris Daging Tiruan Berbasis Kedelai dan Glukomanan untuk Intervensi Obesitas*

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**ABSTRACT**

**Background:** Foods low in calories, low in fat, high in protein and fiber can be an option for treating obesity. Soy protein is high quality and low fat, while glucomannan is a fiber with low energy density. In this research, artificial meat based on soybeans and glucomannan was developed with low calories and fat but high protein and fiber for obesity intervention.

**Objectives:** This research aims to develop soybean and glucomannan-based meat analogue for obesity interventions and determine the physical and sensory characteristics of soy and glucomannan-based meat analogue.

**Methods:** This study was an experimental study with a completely randomized design, four treatment proportions (%) of soybean protein isolate-glucomannan (30:0, 29:1, 27:3, and 25:5) and three treatment replications. The data collected included physical test data (water holding capacity and cooking loss), and sensory test data (appearance, texture, aftertaste, and preferences). According to the data category, physical test data were analyzed using Variance Analysis or Kruskal Wallis. Sensory test data were analyzed using analysis of variance followed by the post hoc Duncan Multiple Range Test**.**

**Results:** The proportion of soy protein isolate-glucomannan did not affect the water binding capacity and cooking loss. The water binding capacity ranges from 12.44 to 34.61%, and the cooking loss ranges from 2.17 to 4.44%. The sensory score for the appearance, taste, and texture was neither resembling (score 2) nor somewhat resembling (score 3) chicken meat. The proportion of soy protein isolate-glucomannan influences the appearance and texture but does not influence the taste, aftertaste, and level of liking. The aftertaste scores are strong and moderate. The liking score was between dislike and somewhat like.

**Conclusions:** Meat analogue for obesity intervention can be developed using soybeans and glucomannan. The cooking loss and water-holding capacity of artificial meat are proper, while the sensory characteristics of meat analogue do not yet resemble real meat.

## INTRODUCTION

Obesity is one of the triple burden malnutrition conditions faced by Indonesia. Based on Riskesdas 2018, the prevalence of obesity aged 18 years and over is 21.8%[1]. The obesity rate target in 2024 remains the same at 21.8%. Achieving this target requires efforts from various sectors, one of which is through nutritional intervention efforts, namely changing diet patterns and consuming healthier food. Consumption of foods high in fat, such as junk food, tends to increase obesity, especially central obesity[2]. Diet intervention to treat obesity and overweight with a combination of calorie restriction, namely reducing 15-40% calories per day combined with aerobic exercise. Restricting calories in obesity diets is generally done by reducing fat and carbohydrates while keeping protein high. To make it easier to maintain a low-calorie intake, food/drinks are needed that provide a sensation of fullness for longer[3].

Treating obesity through food engineering is carried out to produce food with a nutritional composition suitable for weight loss, namely low calories and low fat, but still filling. The protein content must be high because protein is essential for health. Soy protein quality is high, close to animal protein, such as meat and milk. The essential amino acid content is balanced except for those containing sulphur, such as methionine. Soy protein has a texture that allows it to develop into various soy-based food products[3]. Dried soybeans contain 35-40% protein, 20% lipids, 9% dietary fiber, and 8.5% water. Soy protein is isolated from soybeans through



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treatments, including hulling, flaking, and fat removal. Soybeans can be processed into three high-protein commercial products: soy flour, concentrate, and isolate. Soy protein isolate (SPI) is the purest form, with a protein content of >90% and high digestibility[4].

Vegetable protein has been used in various processed meat products for many purposes. Several sources state that vegetable protein is applied in meat processing mainly to reduce costs, improve nutritional quality, and quality attributes such as cooking results and water/oil retention, optimizing meat texture, binding between cuts of meat, and stabilizing the water and fat components in the emulsion during preparation and cooking[5], improving texture and nutritional composition6, as well as sensory quality. Vegetable protein is applied as the main component and even replaces all animal ingredients in the meat analogue products manufactured [7–11].

Foods for obesity nutritional intervention must provide a high sensation of fullness. Food high in protein and fiber are very effective in producing a feeling of fullness[12]. Dietary fiber has been proven to increase the satiety index[13]. Glucomannan is a dietary fiber applied in beverage formulations and capsule preparations to treat obesity[3,14,15]. Glucomannan's bulking properties and low energy content can support weight reduction by reducing energy content and increasing satiety. Glucomannan absorbs water and expands in the stomach, increasing viscosity that delays gastrointestinal transit time[3]. One potential source of glucomannan is *porang* (*Amorphophallus konjac*), hence known as konjac glucomannan (KGM). KGM has anti-obesity and antihyperglycemic properties because it increases satiety, delays gastric emptying, slows intestinal transit time, and reduces the rate of sugar absorption, thereby reducing postprandial glucose increases[16]. KGM has also been applied as a functional ingredient for manufacturing healthier processed meat[17]. The development of meat analogue products based on soybeans and glucomannan could be one way to solve the obesity problem, namely by providing food products that are low in calories, low in fat, but high in quality protein and fiber and suitable for obesity nutritional interventions. So that meat analogue consumers are convinced of its benefits, meat analogue must have textural, sensory, and nutritional properties similar to real meat.

The research aims to develop meat analogues with various proportions of soy protein isolate and glucomannan. Another aim is to test the meat analogue's physical properties comprising cooking loss and water-holding capacity, and sensory properties comprised of appearance, texture, taste, aftertaste, and preference. The meat analogue then could be applied to obesity intervention.

## METHODS

### Design, Time, and Place

Experimental research was carried out using a Completely Randomized Design (CRD) with four treatments in the form of proportion ratios (%) of soy protein isolate and glucomannan in the meat analogue formula (30:0, 29:1, 27:3, and 25:5) with three treatment replications. The research was carried out from June to August 2023. Meat analogue processing, water binding capacity, cooking losses, and sensory testing were conducted at the Food Technology Laboratory, STIKes Panti Rapih Yogyakarta.

### Materials

The primary materials are soy protein isolate (*Para Agro*) and Konjac glucomannan (*d3lynfood*). Additional ingredients include distilled water, oyster mushrooms, wheat gluten (*Ric and Bris Fine Food Products*), and stock powder (*Maggi Block*), used in identical amounts in all treatments.

### Meat Analogue Processing

The meat analogue formulation refers to Dinani's research with a water content of ± 60% and solids of 40%[18]. The treatment applied was the proportion (%) of soy protein isolate and glucomannan in the meat analogue formula, namely 30:0 (MA_0), 29:1 (MA_1), 27:3 (MA_2), and 25:5 (MA_3). The experiment was repeated three times. The primary equipment used is a food processor, an electric pasta machine (Wiratech Noodle Maker NOD-888), and cooking equipment.

**Table 1.** Meat analogue formulation with different soybean protein isolate-konjac glucomannan proportions

| Material | Treatment | | | |
|---|---|---|---|---|
| | MA_0 | MA_1 | MA_2 | MA_3 |
| Soy Protein Isolate (g) | 120 | 116 | 108 | 100 |
| Glucomanan (g) | 0 | 4 | 12 | 20 |
| Wheat Gluten (g) | 40 | 40 | 40 | 40 |
| Fresh Oyster Mushroom (g) | 100 | 100 | 100 | 100 |
| Water (g) | 150 | 150 | 150 | 150 |
| Stock Powder (g) | 4 | 4 | 4 | 4 |

MA_0: Meat analogue formula 0; MA_1: Meat analogue formula 2; MA_2: Meat analogue formula 2; MA_3: Meat analogue formula 3; g: gram

The meat analogue processing procedure includes preparation, mixing, cooking, kneading, extrusion in a pasta machine, molding, and steaming. Apart from soy protein isolate and glucomannan, other ingredients are added in equal amounts to all treatments. The complete procedure for making meat analogue is shown in Figure 1.



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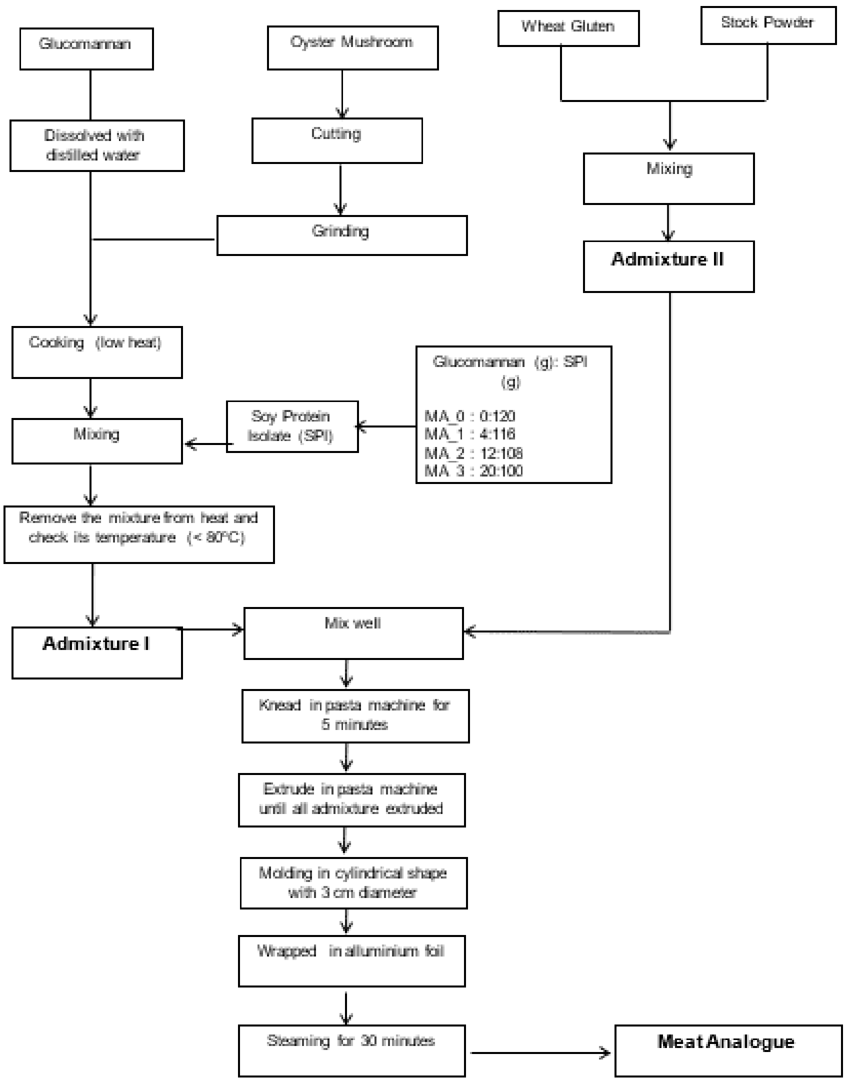


**Figure 1.** Flow diagram of Meat analogue processing

***Ethical Clearance***

Ethical clearance is a written statement by the Research Ethics Commission for research involving living creatures and stating that research is suitable to be carried out after fulfilling requirements. This research involves humans as respondents in the sensory testing stage. This research has been declared ethically appropriate. The ethical clearance of the research was obtained through letter 0152.3/FIKES/PL/VII/2023 published by the Health Research Ethics Commission of Respati University, Yogyakarta.

**Physical Properties Testing**

The cooking loss test was measured using the Houton method, namely preparing a sample of 10 g for each treatment (X) and then cooking at a temperature of 75°C for 45 minutes[19,20]. The meat sample liquid is separated, and the meat sample is dried using impregnating paper so that the adhering water is absorbed, then the sample is weighed (Y). The initial and final weight difference is called cooking loss and is stated as a percentage[15]. The calculation of cooking losses is as follows:

$$\text{Cooking Loss (\%)} = \frac{(X - Y)\ x\ 100}{X}$$

Water holding capacity (WHC) testing uses a method developed by Dinani[18]. A circle measuring 1 cm in diameter (±1.5 g) was cut from each sample to obtain the same surface area for all samples. Circles were cut for each sample at approximately the same place to avoid unnecessary data variations. The circle was weighed and then hydrated with 15 ml of demineralized water in a beaker. The beaker with the sample was rested for 16–17 h in a 50°C water bath. Next, the water on the surface of the sample was gently dried. After draining, the sample was weighed and the WHC of the sample was measured according to the formula:

$$\text{WHC} = \frac{Wah - Wbh}{Wbh} \times 100\%$$

Wbh = Weight before hydration
Wah = Weight after hydration

**Sensory Testing**

Sensory testing involved 31 panelists from the Bachelor of Nutrition Study Program at STIKes Panti Rapih Yogyakarta. The panelists must meet the inclusion criterion, being willing to be respondents, not allergic to ingredients in the meat analogue formula, healthy, and not experiencing health problems with the function of the five senses. Sensory testing uses the differentiation and preference test by giving a value/score to the sample (Scoring difference and preference test). Panelists were asked to provide an assessment of the appearance, taste, and texture by comparing it with the R (Reference, comparison) sample, with a score of 1 (very unlike R) to 5 (very much like R) as well as providing an assessment of the aftertaste (foreign taste that remains after sample swallowed) with a score of 1 (very intense) to 5 (very faint), and overall liking with a score of 1 (dislike very much) to 5 (like very much). The sensory test questionnaire uses a multiple comparison test questionnaire[20]. Sample R was prepared from fresh skinless chicken breast, added with wheat gluten and stock powder in the same percentage as in the treatment, and then ground, moulded, and steamed.

**Data Processing and Analysis**

Data processing is done using Microsoft Excel, while data analysis is carried out using statistical software. Acoording to the data category, physical test data is analyzed using Variance Analysis or Kruskal Wallis. Sensory test data were analyzed using Variance Analysis and post hoc Duncan Multiple Range Test testing.

## RESULTS AND DISCUSSION

**Physical Characteristics**

Cooking Loss is a weight loss in food products caused by temperature and processing. Factors that influence meat cooking loss include pH, length of muscle fiber sarcomeres, and the amount of water lost during cooking[21]. Meat with low cooking losses has good quality because there are few degraded meat component[22]. Normal/reasonable cooking losses range from 1.5-54.5%23. Water holding capacity (WHC) is the maximum amount of water absorbed by a certain amount of material[18]. WHC is an important quality attribute in meat products because it correlates with its freshness and the ability of the proteins in the product to retain water and form a protein gel network[18]. The results of measuring cooking loss and water binding capacity of artificial meat with different proportions of soy protein isolate-glucomannan are shown in Table 2.

**Table 2.** Cooking loss and water holding capacity of meat analogue with different soybean protein isolate-konjac glucomannan proportions

| Treatment | Average test value for the physical properties of meat analogue*) | |
|---|---|---|
| | Cooking Loss (%) | Water Holding Capacity (%) |
| MA_0 | 2.17 ± 0.70a | 12.44 ± 1.65a |
| MA_1 | 3.41 ± 1.77a | 17.55 ± 4.40a |
| MA_2 | 3.06 ± 1.90a | 25.14 ± 7.49a |
| MA_3 | 4.44 ± 1.08a | 34.61 ± 15.64a |
| P-value | 0.071 | 0.23 |

MA_0: Meat analogue formula 0; MA_1: Meat analogue formula 2; MA_2: Meat analogue formula 2; MA_3: Meat analogue formula 3; *) Average value from three treatments and two analysis replications

The results showed that the proportion of soy protein isolate-glucomannan did not affect the cooking loss of meat analogue despite a tendency to increase cooking loss and the proportion of glucomannan in the meat analogue formula. The cooking loss of imitation meat 2.17-4.44% is still in the reasonable category[23]. Cooking loss indicates the nutritional value of meat related to the liquid content of the meat/meat juice, namely the amount of water bound in and between muscle fibers. The lower the cooking loss of meat, the better quality because there will be less nutrient loss during cooking. The greater the cooking loss of meat, the lower the quality because many components were degraded.

The research results also showed the proportion of soy protein isolate did not affect the water-binding capacity of meat analogue despite a tendency to increase WHC along with increasing glucomannan in the meat analogue formula. The WHC of meat analogue samples ranged from 12.44 to 34.61%. In Dinani's research[24], which applied various hydrocolloids at various concentrations in a gluten-based meat analogue formula and pea protein isolate, WHC was 3.34-167.4%. In Kaleda's research[7], which developed meat analogue from an oat and pea protein mixture, WHC values were between 1.63 and 2.51%. The meat analogue developed by Jia[9] using the functional ingredients wheat gluten, soy protein concentrate, and rapeseed protein concentrate has a WHC of 1.6-6.3%. WHC is closely related to the most important attribute of plant-based meat analogue, namely juiciness[24]. Protein is the main constituent of meat analogue such will determine the meat analogue properties, including WHC. Meat analogue protein mainly comes from soy protein isolate and wheat gluten. Water binds to the hydrophilic groups of the protein side chains through hydrogen bonds[7]. In theory, the water binding capacity will also increase with the addition of hydrocolloids[23]. Hydrocolloids are water-soluble or water-dispersible polysaccharides that can improve textural properties by acting as cross-linkers and binder protein filaments together[18]. Glucomannan is a hydrocolloid compound that can retain water and form soft gels. Hydrocolloids will increase the meat analogue's viscosity and plasticity[24].

**Sensory Characteristics**

Consumer studies show that to stimulate the transition from meat consumption to plant-based meat alternatives artificial meat must be improved to have characteristics similar to real meat. The most important characteristics are its textural and sensory characteristics which are often directly linked to a fibrous texture[7]. Sensory characteristics related to the quality of meat analogue are appearance, texture, and taste, including off-flavour and aftertaste[7]. Table 3 shows the results of meat analogue sensory testing with different proportions of soy protein isolate-glucomannan.

**Table 3.** Sensory characteristics of meat analogue with different soybean protein isolate-konjac glucomannan proportions

| ***Perlakuan*** | ***Kenampakan*** | ***Cita rasa*** | ***Tekstur*** | **Aftertaste** | ***Kesukaan*** |
|---|---|---|---|---|---|
| MA_0 | 2.1 ± 1.16a | 2.13 ± 1.02a | 2.26 ± 1.06a | 2.58 ± 1.2a | 2.45 ± 0.92a |
| MA_1 | 2.94 ± 0.85b | 2.23 ± 0.88a | 2.32 ± 0.70a | 2.90 ± 1.3a | 2.35 ± 0.98a |
| MA_2 | 2.47 ± 0.94ab | 2.81 ± 1.05a | 2.97 ± 1.05b | 2.94 ± 1.26a | 2.74 ± 0.93a |
| MA_3 | 2.68 ± 1.19b | 2.45 ± 1.26a | 2.65 ± 1.05ab | 2.29 ± 1.21a | 2.35 ± 0.91a |
| P-value | **0,017** | 0.064 | **0.019** | 0.144 | 0.32 |

MA_0: Meat analogue formula 0; MA_1: Meat analogue formula 2; MA_2: Meat analogue formula 2; MA_3: Meat analogue formula 3; R: Reference sample, processed chicken meat; Numbers in the same column followed by the same letter notation indicate there is no significant difference (p > 0.05)

The proportion of soy protein isolate-glucomannan in the meat analogue formula affected appearance ($p<0.05$), with an appearance score between not resembling and somewhat resembling R. The highest appearance score was 2.94 (somewhat resembling R) in sample MA_1 with a glucomannan proportion of 1 %. Colour is one of the important appearance attributes of artificial meat that seeks to be similar, and better control of colour can help design plant-based meat analogue that is more attractive and acceptable to consumers[24]. Figure 2 shows that the colour of meat analogue tends to be browner compared to R. The formation of brown colour in imitation meat is generally related to the occurrence of the Maillard reaction during processing involves a heating process[24,25]. The Maillard reaction occurs between the free carbonyl group of the reducing sugar and amino acids and forms a covalent bond to produce melanoidin that is brown in color[24]. The intensity of the brown colour tends to increase as the proportion of glucomannan increases. Glucomannan is a polysaccharide of the hemicellulose type composed of galactose, glucose, and mannose monomers. The source of the carbonyl group as a substrate for the Maillard reaction is found in the monomers that make up glucomannan.


**Figure 2.** Appearance of meat analoguq (MA) compared to chicken meat (R)

The proportion of soy protein isolate-glucomannan in the meat analogue formula did not affect taste ($p>0.05$), with a taste score between not resembling and somewhat resembling R. Most panelists stated that the soy taste in the fake meat was still strong/prominent. Even though broth powder has been added to the formula, it does not yet provide a meat-like taste sensation. It has been identified that the taste/flavor of chicken meat is determined by various volatile compounds such as 2-methyl-3-furanthiol, 2-furfurylthiol, methionol, 2,4,5-trimethyl-thiazole, nonanol, 2-trans-nonenal, and several compounds. The compound 2-methyl-3-furanthiol is considered the most important chemical compound in determining the taste of chicken26. In the artificial meat formula, apart from soy protein isolate which has a distinctive soy taste, the other ingredients, wheat gluten, and glucomannan, tend to taste bland.

The proportion of soy protein isolate-glucomannan in the meat analogue formula affects texture ($p<0.05$), with a texture score between not resembling and somewhat resembling R. The highest texture score was 2.97 (somewhat resembling R) in the MA-2 sample with the proportion glucomannan 3%. Most of the panelists stated that the texture of R was dense and fibrous, while the texture of the meat analogue sample was smooth (not fibrous) and slightly soft. Fibrous texture is a desired quality parameter in meat analogue[7]. The fibrous texture is related to high protein content, making cross-link reactions and disulfide bond formation during the extrusion process at high temperatures. In an extruder machine, the heating and extrusion processes coincide. In this research, meat analogue was made using a pasta machine where the heating and extrusion processes could not be carried out simultaneously. Oyster mushrooms were added to the meat analogue formula to help form a fibrous texture, but this did not provide optimal results.

The proportion of soy protein isolate-glucomannan in the meat analogue formula did not affect the aftertaste (p>0.05), with an aftertaste score between strong and somewhat intense. An aftertaste is a foreign taste that remains in the mouth after food/drink is swallowed. Almost all panelists said that after swallowing the meat analogue sample, they left behind a bitter taste or a typical soybean flavour. One of the obstacles to the acceptance of soy protein in the food industry is the typical soybean taste due to the oxidation of unsaturated fatty acids catalysed by the lipoxygenase enzyme, which leads to an unpleasant taste and colour degradation. The dominant compounds that cause unpleasant sensations that result from fatty acid oxidation are hexanol, hexanal, and pentanol[27].

The proportion of soy protein isolate-glucomannan in the meat analogue formula did not affect overall liking (p>0.05), with a liking score between not liking and somewhat liking. The appearance, taste, and texture characteristics of imitation meat are not close to the characteristics of chicken meat, and the strong soybean aftertaste is quite strong, causing the panelists' preference for meat analogue to be not high. Although health is important, consumers are generally unwilling to compromise on food taste. Low sensory quality is an important barrier to consumer acceptance of plant-based and meat-analogue hybrid products. A strong meat taste, meat-like colour, and moist texture have been proven to increase the acceptance of meat-vegetable and artificial meat hybrid products[28].

This research has the advantage of using materials that are cheap enough and easy to obtain. The research equipment used is simple. This research's weakness was not extruder equipment generally used in research on developing meat analogue as a reference. In general, the meat analogue produced in this study has reasonable physical properties of cooking loss and water binding capacity, its sensory properties do not resemble real meat, and improvements are required for texture and taste.

## CONCLUSIONS

Meat analogue could be manufactured from soy protein isolate and glucomannan with additional ingredients of wheat gluten, stock powder, and oyster mushrooms. The cooking loss value of 2.17-4.44% of imitation meat is proper, while the water binding capacity ranges from 12.44 to 34.61%. The meat analogue's appearance, taste, and texture cannot yet resemble real meat. The meat analogue aftertaste was intense and moderate, with a distinctive soy flavour, while the favourability score was between dislike and somewhat like it.

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