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Physicochemical and Organoleptic Characteristics of Black Noodles with Substitution of Black Soybean Flour and Addition of *Glycerol Monostearate*

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A B S T R A C T

Black noodle is an innovative food product that incorporates natural pigment-rich ingredients to enhance visual appeal and nutritional value, setting it apart from conventional noodles. This study aimed to evaluate the effects of black soybean flour substitution and glycerol monostearate (GMS) addition on black noodles' physicochemical and organoleptic properties, and to determine the optimal formulation. A Completely Randomized Design (CRD) with a factorial pattern was employed, consisting of two factors: black soybean flour substitution (10%, 20%, and 30%) and GMS concentration (1%, 2%, and 3%), with three replications. Data were analyzed using Analysis of Variance (ANOVA), and significant differences were further examined using Duncan's Multiple Range Test (DMRT) at a 5% significance level. The results indicated that both factors significantly influenced moisture content, protein content, antioxidant activity, elasticity, tensile strength, and sensory attributes. The best mixture was found by using 20% black soybean flour and adding 3% GMS, resulting in a moisture content of 57.23%, protein content of 15.97%, antioxidant activity (IC_{50}) of 312.66 ppm, elasticity of 23.67%, and tensile strength of 0.63 N. Organoleptic evaluations showed favorable responses with scores of 4.28 for color (like), 3.72 for aroma (neutral to like), 3.2 for taste (neutral), and 3.96 for texture (neutral to like).

Contribution to Sustainable Development Goals (SDGs):
SDG 2: Zero Hunger
SDG 3: Good Health and Well-being
SDG 9: Industry, Innovation, and Infrastructure
SDG 12: Responsible Consumption and Production

1. INTRODUCTION

1.1. Research Background

Noodles are one of the most popular flour-based processed food products enjoyed by people in many countries, including Indonesia. Noodle consumption has continuously increased yearly due to their practicality, ease of preparation, and affordability [1]. The high consumption of noodles has driven various product innovations, whether in raw materials, shapes, or nutritional content.

Black noodles are a type of noodle product developed as an alternative to conventional noodles. They are characterized by their dark or blackish color obtained by adding natural pigment-containing ingredients such as squid ink, activated charcoal, or black soybean flour. The natural colorants used in black noodles serve as colouring agents and provide health benefits due to their content of bioactive compounds such as anthocyanins, flavonoids, or activated carbon [2].

One effort to improve the nutritional value of noodles is by partially substituting wheat flour with black soybean flour. Black soybean flour is a nutritious and functional raw material. According to research, black soybean flour contains 38.88%

protein, 20.22% lipids, 8.84% starch, and bioactive compounds such as flavonoids and isoflavones, which possess antioxidant properties [3].

However, adding black soybean flour can also affect the physicochemical characteristics of the product, potentially resulting in suboptimal noodle texture and elasticity. Therefore, additional ingredients are needed to help improve the structure and chewiness of the noodles, one of which is Glycerol Monostearate (GMS). GMS is a plasticizer compound with amphipathic properties that can bond with amylose and act as a binder between starch granules to form a more stable and flexible dough matrix. In a previous study [4], the addition of GMS in dried noodle production was shown to improve elasticity.

1.2. Literature Review

Black noodle is a type of wet noodle that can be categorized as a product with high moisture content (± 60%), which results in a short shelf life—typically only around 2–3 days. Fresh noodles are classified as food products in the form of thin strips derived from flattened dough sheets cut into uniform sizes, made primarily from wheat flour, with preservatives such as table salt or alkaline salts [5]. The chemical composition of fresh noodles, whether raw or cooked, is specifically defined in the SNI 2987-2015.

As part of diversification efforts, producing fresh noodles can include the addition of black soybean flour. Black soybeans (Glycine max (L.) Merr) are one of the staple food commodities that have long been cultivated in Indonesia due to their high nutritional value, safety for consumption, and affordability [3]. Black soybeans contain bioactive compounds such as phenolics, tannins, anthocyanins, and isoflavones, which have higher antioxidant activity than yellow soybeans. These antioxidants play a significant role in preventing cardiovascular diseases, atherosclerosis, and other conditions caused by oxidative stress. Additionally, anthocyanins in black soybeans possess antioxidant activity greater than that of vitamins E and C and can inhibit LDL oxidation [6].

Glycerol monostearate (GMS) is a non-ionic surfactant commonly used in the food industry as an emulsifier, plasticizer, and texture modifier. GMS is formed from a reaction between glycerol and stearic acid, resulting in an amphipathic molecule—meaning it contains both a polar group (glycerol) and a nonpolar group (fatty acid chain). This property allows GMS to interact with hydrophilic and lipophilic compounds in food systems, making it a multifunctional ingredient in food product formulations. GMS forms complexes with amylose—the main component of starch—resulting in amylose–lipid complexes that are more heat-stable and less prone to retrogradation. This process prevents the hardening of the product during storage and helps maintain a chewy texture and elasticity, even after cooking or rehydration. Moreover, GMS increases the gelatinization temperature of starch and slows down excessive water absorption by starch granules, which contributes to products that are less likely to become mushy or break apart when boiled [7].

1.3. Research Objective

This study was conducted to determine the effect of black soybean flour substitution and GMS addition on the physicochemical and organoleptic characteristics of black noodles, as well as identifying the best combination of black soybean flour substitution and GMS addition in producing optimal physicochemical and organoleptic properties of black noodles.

2. MATERIALS AND METHODS

2.1 Materials and Tools

The main ingredients used in this study were pure black soybean flour sourced from Situbondo Regency, *glycerol monostearate* (GMS) obtained from Sidoarjo Regency, "Cakra Kembar" wheat flour, eggs, black garlic acquired from a Black Garlic Agent in Mulyorejo District, Surabaya City, salt, and STPP (*Sodium Tripolyphosphate*). The materials used for chemical analysis included K_2SO_4, HgO, H_2SO_4, $Na_2S_2O_3$, NaOH, Zn, HCl, phenolphthalein indicator, ether solvent, ethanol, and DPPH, all purchased from chemical supply stores.

The equipment required included: a digital scale, roll press, noodle roller, mixing bowls, plastic containers, spoons, knives, pots, and tools for sensory testing. Additionally, chemical analysis equipment was used, such as: oven, porcelain crucibles, desiccator, analytical balance, furnace, tongs, Kjeldahl flask, condenser, filter paper, Soxhlet flask, stirrer, volumetric flasks, texture profile analyzer, Konica Minolta CR-10 color reader, and spectrophotometer.

Table 1. Treatment Combinations of Black Noodle

Black soybean flour substitution	GMS addition		
	B_1	B_2	B_3
A_1	A_1B_1	A_1B_2	A_1B_3
A_2	A_2B_1	A_2B_2	A_2B_3
A_3	A_3B_1	A_3B_2	A_3B_3

Description :
A1B1: 10% black soybean flour substitution and 1% GMS addition
A1B2: 10% black soybean flour substitution and 2% GMS addition
A1B3: 10% black soybean flour substitution and 3% GMS addition
A2B1: 20% black soybean flour substitution and 1% GMS addition
A2B2: 20% black soybean flour substitution and 2% GMS addition
A2B3: 20% black soybean flour substitution and 3% GMS addition
A3B1: 30% black soybean flour substitution and 1% GMS addition
A3B2: 30% black soybean flour substitution and 2% GMS addition
A3B3: 30% black soybean flour substitution and 3% GMS addition

The data obtained were processed using Analysis of Variance (ANOVA) and followed by Duncan's Multiple Range Test (DMRT) to determine the differences between treatments. The results of all tests were analyzed using the De Garmo method to determine the product with the best treatment outcome.

2.1.1 Making of Black Noodle

Black noodles are prepared by mixing black soybean flour, GMS, wheat flour, water, eggs, black garlic, salt, and STPP. All ingredients are mixed until evenly combined, followed by a kneading process to form a smooth, elastic dough. The dough is

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then shaped into sheets of approximately 1.5–2 mm thickness. These dough sheets are processed into noodle form using a roll press technique. The formed noodles are then boiled for 2 minutes to produce ready-to-eat black noodle.

2.2 Research Analysis

2.2.1 Raw Material Evaluation

The raw material analysis conducted included moisture content, protein content in black soybean flour and high-protein wheat flour, as well as antioxidant activity (IC_{50}) in black soybean flour.

2.2.2 Physicochemical Evaluation of Black Noodle

Physicochemical analysis consisted of moisture content, protein content, antioxidant activity, elasticity, and tensile strength analysis

2.2.3 Evaluation Sensory of Black Noodle

The sensory evaluation conducted included aroma, taste, color, and texture. A total of 25 panelists were assigned to assess the level of preference for the product using a 5-point scale ranging from "very like" to "very dislike"

3. RESULT AND DISCUSSION

3.1. Raw Material Analysis

The raw materials used were black soybean flour and wheat flour. The results of the raw material analysis can be seen in **Table 2.**

Table 2. Raw Material Analysis Results

Parameter	Black Soybean Flour	Wheat Flour
Moisture Content (%)	6.45±0.11	11.81±0.337
Protein Content (%)	39.57±0.22	13.52±0.218
Antioxidant Activity IC_{50} (ppm)	182.23±5.11	-

3.2. Results of Physicochemical Analysis of Black Noodle

3.2.1 Moisture Content

Based on the analysis of variance results, there is a significant interaction between the treatments of black soybean flour substitution and GMS addition on the moisture content of black noodles ($p<0.05$). According to Table 3, the moisture content values of the fresh noodles measured comply with the SNI for cooked fresh noodles 2987-2015 [8], which is below 65%. The treatment with 10% black soybean flour substitution and 3% GMS addition produced the highest moisture content value of 61.73%. The treatment with 30% black soybean flour substitution and 1% GMS addition resulted in the lowest moisture content value, 54.63%.

Table 3. Physicochemical Characteristics of Black Noodles

Sample	Moisture (%)	Protein (%)	Antioxidant Activity IC_{50} (ppm)	Elasticity (%)	Tensile Strength (N)
A1B1	58.69 ± 0.24	13.49 ± 0.01	404.90 ± 0.58	25,00 ± 0,00	0.63 ± 0.0129
A1B2	59.73 ± 0.23	13.50 ± 0.02	407.00 ± 1.99	26,67 ± 0,58	0.67 ± 0.0012
A1B3	61.73 ± 0.26	13.50 ± 0.04	406.59 ± 0.63	29,67 ± 0,58	0.74 ± 0.0040
A2B1	55.70 ± 0.21	15.92 ± 0.03	314.19 ± 1.86	18,33 ± 0,58	0.50 ± 0.0051
A2B2	56.27 ± 0.17	15.98 ± 0.05	313.44 ± 1.67	21,67 ± 0,58	0.59 ± 0.0031
A2B3	57.23 ± 0.11	15.97 ± 0.02	312.66 ± 1.36	23,67 ± 0,58	0.63 ± 0.0012
A3B1	54.63 ± 0.17	18.52 ± 0.01	266.14 ± 1.50	17,67 ± 0,58	0.47 ± 0.0020
A3B2	55.56 ± 0.23	18.50 ± 0.02	265.07 ± 0.82	19,67 ± 0,58	0.51 ± 0.0017
A3B3	57.61 ± 0.22	18.50 ± 0.01	266.37 ± 2.01	21,33 ± 0,58	0.57 ± 0.0048

The greater the substitution of black soybean flour, the lower the moisture content in black noodles, while the higher the addition of GMS, the higher the moisture content in black noodles. This is because increasing the substitution of black soybean flour reduces the use of wheat flour. Reducing wheat flour use also decreases the starch content, resulting in fewer hydrophilic groups. The fewer the hydrophilic groups, the lower the product's ability to absorb water. Additionally, this is due to GMS's ability to absorb water because of the presence of hydrophilic groups. This aligns with the statement in [9], which notes that adding *glycerol* monostearate in products can increase water absorption capacity compared to products without *glycerol monostearate*. This increase occurs because *glycerol monostearate* can inhibit the bonding between starch and protein molecules, so the number of free hydroxyl (OH) groups in *glycerol monostearate* available for bonding becomes relatively higher.

3.2.2 Protein Content

Based on the analysis of variance results, there is no significant interaction between the treatments of black soybean flour substitution and GMS addition on the protein content ($p>0.05$). According to Table 3, black noodles' measured protein content values comply with the SNI for cooked fresh noodles 2987-2015 (SNI, 2015), which is above 6%. The treatment with 30% black soybean flour substitution had the highest average protein content of 18.5%, while the treatment with 10% black soybean flour substitution had the lowest average protein content of 13.49%.

The higher the substitution of black soybean flour, the higher the protein content in black noodles. Black soybean flour has a higher protein content than wheat flour. The more black soybean flour substituted, the higher the resulting protein content. According to Ref. [10], black soybean flour is a food ingredient rich in protein and fiber because it contains many essential amino acids, including arginine, histidine, phenylalanine, isoleucine, methionine, leucine, tryptophan, and threonine.

Based on Table 3, the addition of GMS does not have a significant effect on increasing the protein content of black noodles. This is because *glycerol monostearate* does not contain protein and therefore does not affect the protein content of the fresh noodles produced. This aligns with the opinion in [9], where variations in the addition of *glycerol monostearate* (GMS) did not cause differences in protein content in sweet bread because *glycerol monostearate* is largely composed of non-protein fractions.

3.2.3 Antioxidant Activity (IC_{50})

Based on the analysis of variance results, there is no significant interaction between the treatment of black soybean flour substitution and GMS addition on the antioxidant activity IC_{50} ($p>0.05$). The IC_{50} value (Inhibitory Concentration 50) is the compound concentration required to inhibit 50% of free radical activity in a test system. In other words, it is a measure of the effectiveness of an antioxidant compound in neutralizing free radicals. The smaller the IC_{50} value, the stronger the antioxidant activity, because a lower concentration is needed to achieve 50% inhibition. The treatment with 10% black soybean flour substitution had the highest average IC_{50} value, or weakest antioxidant activity, at 406.90 ppm, while the treatment with 30% black soybean flour substitution had the lowest average IC_{50} value, or strongest antioxidant activity, at 265.86 ppm.

The higher the substitution of black soybean flour, the lower the IC_{50} value of the black noodles, indicating stronger antioxidant activity. This is because black soybean flour is known to contain anthocyanins, phenolic compounds, and isoflavones. These compounds are natural antioxidants capable of neutralizing free radicals by donating electrons or hydrogen, thereby neutralizing oxidative effects. This aligns with the statement in [11] that black-skinned soybeans contain anthocyanins.

According to [12], the obtained antioxidant activity (IC50) value is categorized as very weak because it has an IC_{50} value above 200 ppm. The weak antioxidant activity may be due to several factors, particularly the raw material, black soybean flour used. The environmental quality where the soybeans are grown affects the content of these bioactive compounds. According to [13], plants grown in nutrient-poor soil or under environmental stress may produce fewer antioxidant compounds. Additionally, the processing method of the black soybean flour significantly influences the content. Heating or drying processes during flour production can reduce the amount of active compounds.

The addition of GMS does not have a significant effect on the IC_{50} value of black noodles. This is because GMS is not an antioxidant compound and does not react with free radicals. This aligns with the findings in [14], where GMS addition statistically had no significant effect on the antioxidant content of rice from analog rice.

3.2.4 Elasticity

Based on the analysis of variance results, there is a significant interaction between the treatment of black soybean flour substitution and GMS addition on the elasticity of black noodles ($p<0.05$). The treatment with 10% black soybean flour substitution and 3% GMS addition produced the highest elasticity value of 29.67%, while the treatment with 30% black soybean flour substitution and 1% GMS addition resulted in the lowest elasticity value of 17.67%.

The higher the substitution of black soybean flour and the lower the addition of GMS, the lower the elasticity of the black noodles. This is because the higher the substitution of black soybean flour, the less wheat flour is used, which reduces the gluten content from the wheat flour, thereby decreasing the elasticity of the black noodles. The elastic property of gluten in noodle dough causes the resulting noodles to be less prone to breaking during shaping and cooking. If wheat flour usage is reduced and replaced with black soybean flour, the noodles produced become more fragile and decrease elasticity. This aligns with research [15], which states that the less wheat flour used in noodle production, the lower the gluten content in the dough, resulting in reduced noodle elasticity. Wheat flour can form elastic dough when hydrated with water due to its gluten content.

Although black soybean flour substitution can decrease the elasticity of black noodles, this decrease can be overcome by adding a plasticizer in the form of GMS. Table 3 shows that increasing GMS levels can increase the average elasticity of black noodles. GMS functions as a plasticizer that can improve the flexibility and stretchability of the noodle product. This corresponds with research [4], which states that higher GMS addition can increase the elasticity of the dried noodles produced. This is because adding *glycerol monostearate* results in the final product's compact and chewy texture. According to [16], *glycerol monostearate* acts as a binder between starch granules, having two groups: polar and nonpolar. The polar group interacts with the amylose fraction to form complex bonds and a matrix (film), making the texture firmer and enhancing elasticity.

3.2.5 Tensile Strength

Based on the analysis of variance results, there is a significant interaction between the treatment of black soybean flour substitution and GMS addition on the tensile strength of black noodles ($p<0.05$). The treatment with 10% black soybean flour substitution and 3% GMS addition produced the highest tensile strength value of 0.74 N, while the treatment with 30% black soybean flour substitution and 1% GMS addition resulted in the lowest tensile strength value of 0.47 N.

The higher the substitution of black soybean flour and the lower the addition of GMS, the more the tensile strength tends to decrease. The tensile strength of noodles is closely related to the elasticity value. The higher the elasticity formed, the greater the pulling force required until the noodle breaks. This is caused by the higher substitution of black soybean flour leading to lower use of wheat flour, which reduces the gluten content in the black noodles.

In Table 3, it is shown that increasing the amount of GMS can increase the average tensile strength value of black noodles. The table shows that the higher the concentration of GMS added, the greater the average tensile strength value produced. GMS functions as a plasticizer that can increase the flexibility and extensibility of the noodle product. This is in line with research [4], which states that the higher the addition of GMS, the greater

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the elasticity of the dried noodles produced. This is because adding *glycerol monostearate* results in the final product's compact and chewy texture.

3.3 Sensory Evaluation Results of Black Noodle

The highest hedonic color score was found in the treatment with 20% black soybean flour substitution and 1% GMS addition, scoring 4.44. This indicates that the higher the substitution of black soybean flour, the higher the panelists' color rating, because black soybean contains anthocyanin pigments that give a natural dark black color which is more attractive in the noodles. According to study [17], a darker black color is produced in analog jerky made using black soybean tempeh flour when the amount of black soybean used is increased. This is due to the black soybean tempeh used, which causes the skin to turn black due to the accumulation of anthocyanin pigments. Conversely, in the treatment with 10% black soybean flour substitution, the noodle color tended to be pale and less appealing. However, at 30% black soybean flour substitution, the color score decreased, possibly because the color was too dark and thus less preferred by panelists.

Table 4. Sensory Evaluation Results of Black Noodle

Sample	Color	Aroma	Taste	Texture
A1B1	2.80±1.26	3.84±1.25	3.76±1.13	4.12±0.83
A1B2	2.96±1.43	3.76±1.16	3.76±1.27	4.16±0.75
A1B3	3.04±1.21	3.84±0.99	3.64±1.35	4.28±0.74
A2B1	4.44±0.71	3.76±0.97	3.20±1.04	2.44±1.00
A2B2	4.32±0.75	3.64±0.91	3.20±0.96	3.84±0.75
A2B3	4.28±0.84	3.72±1.06	3.20±0.96	3.96±0.79
A3B1	3.24±1.36	2.36±1.04	2.48±1.16	2.24±1.05
A3B2	3.20±1.32	2.60±0.96	2.40±1.29	2.92±1.04
A3B3	3.32±1.22	2.56±1.04	2.48±1.23	3.24±0.97

The highest aroma score was shown by the treatments with 10% black soybean flour substitution combined with either 1% or 2% GMS addition, both scoring 3.84. In comparison, the lowest score was found in the treatment with 30% black soybean flour substitution and 1% GMS addition at 2.56. This indicates that a large addition of black soybean causes the noodle aroma to be less liked due to the strong characteristic bean aroma or beany off-flavor of black soybean. The beany odor in black soybean is caused by lipoxygenase enzyme activity. This is in line with statement [18] that lipoxygenase enzymes use linoleic acid and linolenic acid substrates to form hydroperoxides. Furthermore, GMS addition did not significantly affect aroma, as differences among 1%, 2%, and 3% GMS within the same black soybean flour : wheat flour proportion group were not very significant.

The highest taste score was obtained from treatments with 10% black soybean flour substitution and either 1% or 2% GMS addition, scoring 3.76, which contained the least amount of black soybean flour. The taste decreased with 20% and 30% black soybean flour substitutions. This indicates that the higher the substitution of black soybean flour, the lower the acceptance of the noodle taste. This could be due to the typical aftertaste of soy, such as bitterness. This aligns with study [19] where the bitter taste in black soybean is attributed to glycosides like saponins and isoflavones.

The highest texture score was found in the treatment with 10% black soybean flour substitution and 3% GMS addition, scoring 4.28, indicating that the lower the substitution of black soybean flour and the higher the GMS addition, the better the noodle texture was perceived by panelists. GMS acts as an emulsifier and binder that can improve the dough structure and elasticity, especially when used in sufficiently high amounts. Conversely, the lowest texture score was found in the treatment with 30% black soybean flour substitution and 1% GMS addition, scoring 2.24, showing that high substitution of black soybean flour without enough GMS made the noodle texture brittle, less chewy, or easily broken. This is because black soybean flour does not contain gluten, thus weakening the noodle structure without GMS support. This agrees with the study [15], which states that the less wheat flour used in noodle making, the lower the gluten content in the dough, causing reduced noodle elasticity.

4. CONCLUSION

The treatment of black soybean flour substitution and GMS addition showed a significant interaction on moisture content, elasticity, tensile strength, and organoleptic characteristics including color, aroma, taste, and texture. Still, there was no significant interaction on protein content and antioxidant activity. The black noodle treatment with 20% black soybean flour substitution and 3% GMS addition was the best, having a moisture content of 57.23%, protein content of 15.97%, antioxidant activity IC_{50} of 312.66 ppm, elasticity of 23.67%, and tensile strength of 0.6303 N, as well as organoleptic test scores of color 4.28 (like), aroma 3.72 (neutral-like), taste 3.2 (neutral), and texture 3.96 (neutral-like).

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