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Effect of Wheat Flour and Modified Canna Flour Proportions and Glycerol Monostearate (GMS) Addition on the Physicochemical and Sensory Characteristics of Sweet Bread

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A B S T R A C T

Canna flour is a processed product derived from *Canna edulis* Kerr and can potentially be an alternative local carbohydrate source. It contains high starch content, ranging from 80–90%, with amylose levels around 20–30%. Modification of canna flour is carried out to address its limitations when used in sweet bread applications. Glycerol monostearate (GMS) aids in improving the volume expansion of sweet bread made with substitute flour. This research aimed to determine the effect of the proportion of wheat flour and modified canna flour on the physicochemical and sensory characteristics of sweet bread. This research used a completely random setup with two factors: the mix of wheat flour and modified canna flour in ratios of 90:10, 80:20, and 70:30, and the amount of GMS added at 3%, 4%, and 5%. The results of the research indicate that the optimal treatment involves a proportion of 90% wheat flour and 10% modified canna flour, along with the addition of 5% GMS, namely moisture content 26.24%, ash content 2.40%, fat content 3.48%, protein content 4.88%, carbohydrate content 63%, and sensory value with color 3.60, aroma 2.44, taste 2.60, and texture 2.90.

Contribution to Sustainable Development Goals (SDGs):
SDG 2 – Zero Hunger
SDG 12 – Responsible Consumption and Production
SDG 9 – Industry, Innovation and Infrastructure
SDG 3 – Good Health and Well-being
SDG 8 – Decent Work and Economic Growth

1. INTRODUCTION

1.1. Research Background

Sweet bread is a wheat flour-based food product that is fermented using yeast, enriched with sweet ingredients such as sugar, milk, and butter, and has soft texture and sweet taste. This bread is included in the categoru of yeast-leavened baked goods, which undergo a fermentation process to produce soft and fluff texture [1]. Wheat flour, derived from wheat, is the primary ingredient used in producing sweet bread. However, Indonesia relies heavily on imported wheat and wheat flour, contributing to an increasing dependence on food imports yearly [2].

One strategy to reduce the growing value of wheat and flour imports is to utilize locally available food sources. Canna edulis Kerr is one such local food ingredient with potential for development. Its use supports efforts to reduce import dependency and aligns with the growing public awareness of healthy lifestyles. Canna can serve as viable substitute for wheat flour in sweet bread production, as rich in complex carbohydrates, which results in a relatively low glycemic index, and contains dietary fiber that supports digestive health. Moreover, its gluten-free nature makes it suitable for individuals with gluten intolerance or those seeking healthier alternatives [3].

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Canna flour has certain limitations compared to wheat flour, particularly in its application to sweet bread products. urthermore, efforts to enhance the characteristics of canna flour are essential, which can be accomplished by modifying its functional properties. To inherent variability in the functional properties of different starch sources, modification techniques can be applied to overcome these limitations and produce products that are softer and more easily digestible [4]. One such technique is fermentation using the Bimo-CF starter culture, which can transform various compounds in the raw materials into simpler, more beneficial ones. Fermentation also produces volatile compounds that enhance flavor and aroma, while creating an acidic environment that contributes to the natural preservation of the product [5].

GMS is synthetic emulsifier composed of stearic acid radicals, which act as non-polar groups, and two hydroxyl groups. It interacts with amylose molecules during fermentation, helping to retain carbon dioxide gas, which promotes dough expansion [6]. In bread-making, GMS functions by forming a complex with starch, slowing down retrogradation, and preventing the bread from becoming hard and crumbly [7].

1.2. Research Objective

The purpose of this research was to determine the effect of the proportion of wheat flour and modified canna flour with the addition of GMS on the physicochemical and sensory of sweet bread and to determine the best treatment combination of the proportion of wheat flour and modified canna flour with the addition of GMS which produced good quality sweet bread.

2. MATERIALS AND METHOD

2.1 Material and Tools

The raw materials used in this research are wheat flour, canna flour from "Kusuka" Ubiku in Bantul, Bimo-CF, GMS, water, sugar, salt, egg, skimmed milk, yeast from Toko Kue in Surabaya. The chemicals materials used for sweet bread's analysis are distilled water, pretoleum ether, K_2SO_4, H_2SO_4, NaOH, HCl.

The tools used in this research include tools for processing and for analysis. Tools for processing include digital scales, cabinet dryer, oven, spoon, knife, roll pin, alumunium foil, 80 mesh sieve, cake pan and baking paper. Tools used in the analysis include beaker glass, cabinet dryer, desicator, furnace, digital scales, filter paper, soxhlet, condenser, fat flask, measuring cup, kjeldahl flask, and erlenmeyer.

2.2 Methodology

This research used a completely randomized design (CRD) factorial pattern with two factors and two replications. Factor I is the proportion of wheat flour and modified canna flour consisting of 90:10, 80:20, 70:30. Factor II is the concentration of GMS, namely 3%, 4%, 5%. If there is a significant difference, it will be continued with the DMRT 5% further test. The samples in this study from the treatment of the proportion of wheat flour and modified canna flour with the addition of GMS obtained 9 samples from the combination of the two treatments.

Description:

A1B1 = Proportion of wheat flour : modified canna flour = 90:10 with the addition of GMS 3%
A1B2 = Proportion of wheat flour : modified canna flour = 90:10 with the addition of GMS 4%
A1B3 = Proportion of wheat flour : modified canna flour = 90:10 with the addition of GMS 5%
A2B1 = Proportion of wheat flour : modified canna flour = 80:20 with the addition of GMS 3%
A2B2 = Proportion of wheat flour : modified canna flour = 80:20 with the addition of GMS 4%
A2B3 = Proportion of wheat flour : modified canna flour = 80:20 with the addition of GMS 5%
A3B1 = Proportion of wheat flour : modified canna flour = 70:30 with the addition of GMS 3%
A3B2 = Proportion of wheat flour : modified canna flour = 70:30 with the addition of GMS 4%
A3B3 = Proportion of wheat flour : modified canna flour = 70:30 with the addition of GMS 5%

The data obtained were processed using Analysis of Variance (ANOVA) and continued with 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 results.

2.3 Modified Canna Flour Production

Canna flour is soaked in a solution containing Bimo–CF starter at a concentration of 0.1% per 100 grams of flour in 100 ml of water. The mixture is fermented for 12 hours, then drained. The fermented flour is dried in a cabinet dryer at 70°C for 2 hours, and subsequently sieved using an 80-mesh sieve.

2.4 Sweet Bread Making

The ingredients are prepared according to the specified proportions. Wheat flour, modified canna flour, water, sugar, yeast, and glycerol monostearate are combined and mixed to form a dough. Then, salt, shortening, skim milk, and egg yolk are added to the dough and kneaded again until smooth. The dough is fermented at 27°C for 30 minutes. After that, it is flattened using a rolling pin to thickness of 2 cm, then rolled. The dough is fermented again at 27°C for 60 minutes. Finally, it is baked in oven at 180°C for 25 minutes.

2.5 Research Analysis

2.5.1 Physicochemical Evalution of Sweet Bread

Parameters analyzed include water, ash, fat, protein, carbohydrate, volume expansion, number of pores.

2.5.2 Sensory Evaluation of Sweet Bread

Sensory characteristics selected to evaluate the quality of sweet bread include color, aroma, flavor, and texture. Data analysis included the use of the Friedman test. 25 panelists were assigned to rate the acceptability of the product using 5-point scale.

3. RESULT AND DISCUSSION

3.1 Physicochemical of Sweet Bread

3.1.1. Water Content

Based on the results, it can be seen that the average water content of sweet bread ranged from 19.39% - 26.24%. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS produced the highest water content value of 26.24%, while the proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS produced the lowest water content value of 19.39%. Based on the research data, the lower the proportion of wheat flour and the higher the proportion of modified canna flour, the lower the water content of sweet bread. However, increasing the amount of GMS (Glycerol Monostearate) results in higher water content in sweet bread. This occurs because wheat flour contains relatively high levels of protein, which has water-binding properties. Therefore, when the proportion of wheat flour decreases, the ability to retain water also decreases, leading to lwer water content in the bread. On the other hand, GMS possesses hydrophilic properties that enable it to bind water. As a result, increasing the amount of GMS enhances the water retention capacity of sweet bread. According to [8], wheat flour contains proteins with hydrophilic characteristics, which allow them to bind free water. Free water can easily be lost during drying, whereas bound water is more stable and less likely to lost due to its interaction with food components. Moreover, [9] stated that bread with added GMS shows higher water absorption capacity compared to bread without GMS. This is because GMS prevents the interaction between starch molecules and the protein matrix, preserving the availability of free –OH groups in GMS that can bind water effectively.

Table 1. Physicochemical Characteristics of Sweet Bread

Samples	Water (%)	Ash (%)	Fat (%)	Protein (%)	Carbohydrate (%)	Volume Expansion (%)	Number of Pores
A1B1	25.06 ± 0.10^{g}	2.17±0,04^{a}	3.76±0.06^{g}	4.69 ± 0.03	64.32 ± 0.09^{c}	104.84 ± 0.14^{g}	10.00 ± 100^{a}
A1B2	25.55 ± 0.03^{h}	2.34±0,05^{b}	3.57±0.04^{f}	4.77 ± 0.07	63.76 ± 0.04^{b}	112.70 ± 2.76^{h}	12.33 ± 0.57^{b}
A1B3	26.24 ± 0.01^{i}	2.40±0,03^{b}	3.48±0.04^{e}	4.88 ± 0.04	63.00 ± 0.04^{a}	123.81 ± 0.00^{i}	15.00 ± 1.00^{c}
A2B1	22.30 ± 0.10^{d}	2.40±0,07^{b}	3.39±0.06^{d}	4.42 ± 0.04	67.49 ± 0.17^{e}	89.78 ± 1.22^{d}	17.33 ± 0.57^{d}
A2B2	23.52 ± 0.07^{e}	2.48±0,06^{c}	3.18±0.05^{c}	4.59 ± 0.04	66.23 ± 0.10^{e}	92.20 ± 1.13^{e}	19.00 ± 1.00^{d}
A2B3	23.76 ± 0.09^{f}	2.89±0,08^{d}	3.05±0.04^{b}	4.68 ± 0.04	65.62 ± 0.19^{d}	95.31 ± 0.12^{f}	20.67 ± 1.16^{d}
A3B1	19.39 ± 0.04^{a}	2.99±0,04^{e}	3.04±0.03^{b}	4.03 ± 0.05	70.54 ± 0.02^{h}	77.94 ± 0.28^{a}	21.67 ± 1.16^{e}
A3B2	21.44 ± 0.05^{b}	3.16±0,05^{f}	2.99±0.03^{b}	4.25 ± 0.04	68.16 ± 0.05^{g}	81.95 ± 0.23^{b}	23.67 ± 0.57^{e}
A3B3	21.91 ± 0.06^{c}	3.31±0,04^{g}	2.91±0.02^{a}	4.34 ± 0.02	67.58 ± 0.08^{f}	86.56 ± 0.35^{c}	24.33 ± 0.57^{f}

3.1.2. Ash Content

Based on the results, it can be seen that the average ash content of sweet bread ranged from 2.17% - 3.31%. The proportion of 70% wheat flour and 30% modified canna flour with the addition of 5% GMS produced the highest ash content value of 2.17%, while the proportion of 90% wheat flour and 10% modified canna flour with the addition of 3% GMS produced the lowest ash content value of 2.17%.

The results showed that the lower the proportion of wheat flour and the higher the proportion of modified canna flour and the higher the addition of GMS, the ash content of sweet bread has increased. This occured because modified canna flour contains relatively high ash content compared to wheat flour, as well as GMS which contains minerals, so the higher the proportion of modified canna flour and the addition of GMS, the higher the ash content of sweet bread. The amount of ash content of food products depends on the amount of mineral content used. The addition of GMS which is increasingly high can increase the ash content of sweet bread because of the minerals contained in GMS. According to [10], the more GMS that is added, the higher the ash content in bread. GMS contains 2.75% minerals which can strengthen the tissue and are hygroscopic so that the ash content increases.

3.1.3. Fat Content

Based on the results, it can be seen that the average fat content of sweet bread ranged from 2.91% - 3.76%. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 3% GMS produced the highest fat content value of 3.76%, while the proportion of 70% wheat flour and 30% modified canna flour with the addition of 5% GMS produced the lowest fat content value of 2.91%.

The results of the showed that the decrease in fat content in sweet bread was observed with a lower proportion of wheat flour, higher proportion of modified canna flour, and increased addition of GMS. This occurred because wheat flour contains relatively higher fat content compared to modified canna flour; therefore, reducing the proportion of wheat flour led to lower overall fat content in the bread. Additionally, the increased addition of GMS also contributed to the reduction in fat content. GMS, which functions as an emulsifier, effectively binds fat and water within the dough structure. As more GMS is added, the fat in the dough becomes more evenly distributed and better integrated, thereby decreasing the amount of free fat in the final product. According to [11], GMS stabilizes the emulsion between fat and water in bread dough. When GMS is incorporated, fat molecules are more uniformly dispersed and firmly bound within the dough matrix, which minimizes fat migration and separation during baking and storage. As a result, the final product contains significantly less free fat. Furthermore, GMS contributes to the formation of more stable gluten structure and enhances gas retention, resulting in softer and more tender crumb texture. By reducing the amount of separated free fat, the occurrence of excess surface oil is minimized.

3.1.4. Protein Content

Based on the results, it can be seen that the average protein content of sweet bread ranged from 4.03% - 4.88%. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS produced the highest protein content value of 4.88%, while the proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS produced the lowest protein content value of 4.03%.

The higher the proportion of wheat flour and the lower the proportion of modified canna flour, the higher the resulting protein content. This is because wheat flour has significantly higher protein content compared to modified canna flour. According to [12], the use of flours with high starch content tends to reduce the overall protein content. When flours other than wheat are used in bread making, the resulting protein content is lower due to the limited gluten and protein present in those flours significantly. Additionally, increasing the amount of GMS also leads to higher measured protein content. This occurs because GMS has the ability to enhance protein retention in bread products, helping to minimize protein loss during the baking process. According to [11], GMS can help maintain structural integrity and reduce protein degradation during baking. It can bind to proteins present in flour or eggs, thereby stabilizing them and reducing breakdown during heating. Moreover, GMS may alter the distribution or availability of proteins by interacting with gluten, which can influence the final protein content observed in the product.

3.1.5. Carbohydrate Content

Based on the results, it can be seen that the average carbohydrate content of sweet bread ranged from 63% - 70.54%. The proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS produced the highest carbohydrate content value of 70.54%, while the proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS produced the lowest carbohydrate content value of 63%.

s the proportion of wheat flour decreases and the proportion of modified canna flour increases, the carbohydrate content of sweet bread also increases. However, with higher GMS addition, the carbohydrate content tends to decrease. This occurs because modified canna flour contains higher carbohydrate content compared to wheat flour. On the other hand, greater GMS addition leads to increased water content in the dough, which dilutes the concentration of other components, including carbohydrates. GMS contains hydrophilic groups that can bind water, contributing to this increase in moisture. As water content increases, the relative percentage of carbohydrates and other dry matter components decreases. According to [13], carbohydrate content determined using the by-difference method is influenced by other nutritional components such as water, ash, fat, and protein that are negatively correlated with carbohydrate values. In other words, an increase in these components results in a decrease in calculated carbohydrate content.

3.1.6. Volume Expansion

Based on the results, it can be seen that the average volume expansion of sweet bread ranged from 77.94% - 123.81%. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS produced the highest volume expansion of 123.81%, while the proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS produced the lowest volume expansion of 77.94%.

The lower the proportion of wheat flour and the higher the proportion of modified canna flour, the lower the volume expansion of the sweet bread. However, increasing the amount of GMS results in greater volume expansion. This occurs because wheat flour contains a relatively high amount of gluten protein compared to modified canna flour; therefore, reducing the proportion of wheat flour leads to reduced gluten content, which in turn lowers the bread's volume expansion. GMS functions by binding amylose molecules, helping the dough retain more air and expand more effectively. Thus, the higher the addition of GMS, the greater the volume expansion of the sweet bread. Increasing the proportion of wheat flour also increases the gluten content in the dough, enhancing its ability to trap CO_2 gas and resulting in increased bread volume. According to [14], gluten has elastic and extensible properties that allow the dough to retain CO_2, enabling it to rise. [15], states that GMS improves dough quality by enhancing the bonding between gluten and starch components. The volume of sweet bread can be increased by adding GMS, which strengthens the gluten network and enhances gas retention.

3.1.7. Number of Pores

Based on the results, it can be seen that the average carbohydrate content of sweet bread ranged from 10 – 24.33. The proportion of 70% wheat flour and 30% modified canna flour with the addition of 5% GMS produced the highest number of pores 24.33, while the proportion of 90% wheat flour and 10% modified canna flour with the addition of 3% GMS produced the lowest number of pores 24.33.

The lower the proportion of wheat flour and the higher the proportion of modified canna flour and GMS, the greater the number of pores in the sweet bread. This occurs because modified canna flour contains porous starch molecules as result of the modification process. Therefore, increasing the amount of GMS also increases the number of pores. On the other hand, higher proportion of wheat flour leads to more gluten formation, which creates matrix that traps CO_2, resulting in larger pore sizes. According to [16], the amount of gluten in bread dough influences its ability to absorb CO_2 gas. Modified canna flour is produced through fermentation by lactic acid bacteria. The higher concentration of these bacteria leads to increased starch breakdown. This breakdown causes the starch granules to become porous, resulting in greater number of pores [17].

The addition of GMS to sweet bread can increase its volume; the greater the expansion, the more pores are formed in the bread. According to [9], GMS acts as a surfactant and enhances the interaction between gluten and starch in trapping CO_2 produced during fermentation, thereby promoting pore formation.

3.2. Sensory Analysis of Meatballs

3.2.1. Color

Based on the results shows the level of panelists preference for the color of sweet bread, the results of the number of rankings range from 2.60-3.60. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS has the highest score and the proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS has the lowest score (Table 2). The color of the bread is influenced by the raw materials used, namely wheat flour and modified canna flour. Wheat flour is naturally white, while modified canna flour has brown color. An increasing proportion of modified canna flour tends to reduce panelists' preference for the color of the sweet bread.

Table 2. Sensory test result of Meatballs

Samples	Color	Aroma	Taste	Texture
A1B1	3.24	2.84	2.60	2.56
A1B2	3.16	2.60	2.50	2.72
A1B3	3.60	2.44	2.60	2.90
A2B1	2.76	2.36	2.40	2.48
A2B2	3.00	2.32	2.24	2.48
A2B3	3.20	2.12	2.30	2.60
A3B1	2.60	2.08	2.08	2.08
A3B2	2.72	1.96	2.00	2.20
A3B3	2.88	1.80	1.84	2.20

The change in crust color of the sweet bread is primarily due to the Maillard reaction, which causes the crust to brown. The Maillard reaction is non-enzymatic browning process that occurs between carbohydrates particularly reducing sugars (such as aldose and ketose sugars) and primary amine groups (found in amino acids, proteins, or other compounds containing amine groups). The reaction begins with the interaction between reducing sugars and amine groups, forming an intermediate compound. This intermediate can further react to form other compounds, influenced by factors such as temperature, sugar concentration, amino concentration, pH, and the type of sugar used. Ultimately, the reaction results in the formation of brown pigment called melanoidin, which has high molecular weight [18]. Heating activates the reactive sites of several amino acids in the flour's protein content, allowing them to react with reducing sugars and form melanoidin compounds [19]. The addition of GMS does not affect the taste of the resulting sweet bread, as it does not influence the bread's color, aroma, or flavor [22].

3.2.2. Aroma

Based on the results shows the level of panelists preference for the aroma of sweet bread, the results of the number of rankings range from 1.80-2.84. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 3% GMS has the highest score and the proportion of 70% wheat flour and 30% modified canna flour with the addition of 5% GMS has the lowest score. Canna has distinctive aroma due to its volatile compounds, which means that the addition of modified canna flour influences the aroma of sweet bread.

The Maillard reaction that occurs during baking contributes to unique and desirable aroma in the final product [20]. The higher the protein content of the ingredients used, the more intense the aroma produced by the Maillard reaction. Yeast used in bread making contains key enzyme called invertase, which initiates fermentation by converting sucrose dissolved in water into simple sugars, namely glucose and fructose. These simple sugars are then broken down into carbon dioxide and alcohol. The alcohol produced plays a role in the development of bread aroma [21]. The addition of GMS does not influence the aroma of sweet bread, as GMS does not significantly affect the color, aroma, or taste of the bread [22].

3.2.3. Taste

Based on the results shows the level of panelists preference for the taste of sweet bread, the results of the number of rankings range from 1.84-2.60. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 3% GMS has the highest score and the proportion of 70% wheat flour and 30% modified canna flour with the addition of 5% GMS has the lowest score. Increasing the proportion of modified canna flour results in decreased taste preference. This is due to the slightly bitter taste of modified canna flour, which reduces panelist acceptance as its proportion increases in the sweet bread.

The sweet taste of bread is influenced not only by the amount of added sugar but also by the quantity of yeast used. Yeast primarily contains the microorganism Saccharomyces cerevisiae, which converts compounds in the dough, leading to the development of the bread's distinctive flavor and aroma through the formation of acids, aldehydes, and esters [23]. Flavor components are also produced through the caramelization of sugars and the Maillard reaction between sugars and proteins. The addition of GMS does not affect the taste of the resulting sweet bread, as it does not influence the bread's color, aroma, or flavor [22].

3.2.4. Texture

Based on the results shows the level of panelists preference for the texture of sweet bread, the results of the number of rankings range from 2.08-2.90. The proportion of 90% wheat flour and 10% modified canna flour with the addition of 5% GMS has the highest score and the proportion of 70% wheat flour and 30% modified canna flour with the addition of 3% GMS has the lowest score. The addition of modified canna flour decreases the level of acceptance of the texture of the sweet bread. This occurs because the higher proportion of modified canna flour leads to poorer texture quality, resulting in lower evaluation scores.

The amount of modified canna flour increases, the gluten protein content decreases, causing the bread to become less soft. According to [10], increasing the proportion of non-wheat flour can reduce the gluten content in the dough. Variations in bread texture or firmness are influenced by the volume of expansion during baking. The greater expansion volume typically results in softer bread texture. According to [24], increased bread hardness is due to reduced expansion and lower gluten content, which limits the dough's ability to retain gas. Gas formation during fermentation is critical, as it creates foam-like structure that facilitates heat transfer during baking. As heat enters the dough, gas and water vapor are expelled, while starch gelatinization occurs, forming porous (foam-like) structure that contributes to softer texture. An improvement in texture is observed with the addition of GMS (Glycerol Mono stearate) to the sweet bread. The higher the GMS content, the softer the resulting texture. According to [10], increasing the proportion of non-wheat flour reduces the gluten content in the dough, enhancing its ability to trap air. This results in more uniform pores and softer overall texture.

4. CONCLUSION

The proportion of wheat flour 90% and modified canna flour 10% with the addition of 5% GMS is the best treatment with moisture content of 26.24%, ash content 2.40%, fat content 3.48%, protein content 4.88%, carbohydrate content 63%, volume expansion 123.81%, number of pores 15 and sensory values with color 3.60, aroma 2.44, taste 2.60, taste 2.90.

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