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Effect of Different Types and Concentrations of Emulsifiers on the Physicochemical and Organoleptic Quality of Steamed Brownies Based on Cowpea Flour (*Vigna unguiculata* L.)

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Abstract. In order to reduce imports, diversify non-gluten products especially for celiac and autism sufferers, it is necessary to replace wheat flour, especially in making steamed brownies, including with cowpea flour. However, cowpea does not contain gluten which makes the cake elastic and soft, so it is necessary to add emulsifiers to maintain its elasticity. This study aims to determine the effect of different types and concentrations of emulsifiers on the physicochemical and organoleptic quality of brownies based on white cowpea flour and determine which composition is the best. The method used in this study is a completely randomized design (CRD) with one factor, namely the formulation of emulsifier types (J1 = SP and J2 = ovalet) and concentrations (K1 = 1% and K2 = 2%), each of which was repeated three times. The research variables observed were the analysis of the physical quality of brownies on their rising power, chemical analysis including water content, crude fiber and protein content, while the organoleptic quality analysis included tenderness, aroma, taste and color. The results showed that different types and concentrations of emulsifiers had a significant effect on water content, swelling power and tenderness. While the parameters of protein content, crude fiber, taste, color and aroma did not have a significant difference. The results showed that the best formulation was in the J2K2 treatment (Ovalet emulsifier with a concentration of 2%) with an average swelling power value of 39.42%, water content of 7.47%, crude fiber content of 3.97%, protein content of 1.21%, with an average value of organoleptic parameters of taste of 5.6 (like), aroma of 6.1 (like), tenderness of 5.53 (rather like) and color of 6.6 (very like).

Keywords: brownies, white cowpea flour, emulsifier, free gluten

1 Introduction

Steamed brownies are a popular food product, but they are generally made from wheat flour, which is low in fiber [1]. Food innovations involving the replacement of wheat flour with flours based on local commodities are important for several reasons, including supporting food security programs by reducing the consumption of imported products, including wheat flour [2] and diversifying products based on local commodities as a gluten-free alternative for gluten-intolerant/celiac consumers [3,4]. One local commodity that can replace wheat flour in making brownies is cowpeas (*Vigna unguiculata* L.) [5, 6].

Cowpeas contain 24.2 g of protein per 100 g of material, much higher than wheat flour [7, 8], contain important minerals such as iron (Fe) 3.6 mg, 77 mg calcium (Ca), 399 mg phosphorus and crude fiber 3.7-6.46% [9]. In addition, the fiber content helps facilitate digestion [10]. The results of research on the use of cowpeas, including [8], produced steamed brownies from substituting cowpea tempeh flour and corn oil. [3], the type and concentration of hydrocolloids on the physicochemical and organoleptic quality of steamed sponge cakes. [4], produced steamed brownies with a proportion of wheat flour and cowpea flour.

The use of non-wheat flour, including cowpea flour, can change the properties of the dough due to the low or absence of gluten, which affects the structure and texture of the final product. Another ingredient in making brownies that affects the structure and texture of the final product is the emulsifier. [6] stated that emulsifiers play a crucial role in stabilizing the dough by uniting the oil and water phases, as well as improving the texture and volume of the cake so that it is soft and not easily collapsed. The results of [8], study proved that the use of SP

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and ovalet emulsifiers at a concentration of 5-7% significantly influenced the panelists' acceptance of Swiss role cake.

Based on the above, the use of emulsifiers in maintaining the stability and quality of brownies, especially with the use of alternative flours, so it is very necessary to research further regarding the optimal type and concentration of emulsifiers. This study aims to determine the best treatment of the combination of different types and concentrations of emulsifiers on the physicochemical quality (swelling power, water content, protein and crude fiber) and organoleptic (level of preference for tenderness, color, aroma, and taste) of steamed brownies based on cowpea flour. The results of this study are expected to provide an optimal formulation for the development of steamed brownie products with high nutritional value with quality that is acceptable to consumers.

2 Methods

2.1 Time and Place

This research included formulation development conducted in the Processing Laboratory, and physicochemical and organoleptic quality analysis conducted in the Chemistry and Food Technology Laboratory, Faculty of Agriculture, Dr. Soetomo University, Surabaya, from November to December 2024.

2.2 Equipment and Materials

The equipment used in this research included a basin, pan, sieve, baking pan, analytical balance, flour mill, spatula, mixer, steamer, knife, small bowl, stove, LPG gas cylinder, baking paper. The equipment used in this chemical quality analysis included an oven, analytical balance, porcelain cup, desiccator, Erlenmeyer flask, pipette, beaker funnel, vacuum pump, KJ flask, acid chamber, distillation apparatus, volumetric flask, beaker glass, burette, and filter paper. The materials used in this research included cowpeas, water, chicken eggs, granulated sugar, cake emulsifier, chocolate bars, cocoa powder, and butter. The materials used in this chemical quality analysis are concentrated H_2SO_4 solution, 40% NaOH, 96% ethanol, 0.2 N NaOH, phenolphthalein indicator, 0.2 N HCl solution, 10% Ba(OH) solution, 10% BaCl solution, boric acid solution and Kjeldhal tablets.

2.3 Research Design

The research design used a completely randomized design (CRD) with one factor, namely formulation type (J) and emulsifier concentration (K), arranged as follows: J1K1 = J1 : K1 = SP : 1%; J1K2 = J1 : K2 = SP : 2%; J2K1 = J2 : K1 = Ovalet : 1%; J2K2 = J2 : K2 = Ovalet : 2%. Based on the formula (t-1)(n-1) ≥15, where t is the number of groups or levels of the first factor and n is the number of levels of the second factor in each observation group or unit in each group, the number of replications was three.

2.4 Research Procedure

The procedure in this study consisted of several stages: making cowpea flour [4], making steamed brownies with different types and concentrations of emulsifiers, referring to the research by [12], with modifications to the emulsifier used according to the treatment, and testing of observational variables (figure 1).

The observation variables in this study included physical parameters, namely the determination of swelling power [12]; Chemical parameters included the determination of water content using the gravimetric method, crude fiber using the extraction method, and protein content using the Formol method (SNI 01-2891-1992). The organoleptic test used a hedonic test covering taste, color, aroma, and texture. Twenty-five untrained panelists were selected, with a preference scale of 1 = very dislike, 2 = dislike, 3 = somewhat dislike, 4 = neutral, 5 = somewhat like, 6 = like, 7 = very like [13].

The parametric data obtained, namely water content, crude fiber, and protein, were analyzed using Analysis of Variance (ANOVA) using Statistical Product and Service Solution (SPSS) version 24. If the analysis results showed a significant or very significant difference between treatments, further testing was carried out depending on the Correlation Coefficient (CC) value at a confidence level of $\alpha = 95\%$. If the CC value was not more than 5 then use the Least Significant Difference Test (LSD), if the KK value is between 5-10 use the Honestly Significant Difference Test (HSD), if the KK value is more than 10 then use the Duncan difference test. Non-parametric data including organoleptic tests of tenderness, color, aroma and taste are tested based on the panelists' level of preference, to determine whether or not a treatment has an effect on the organoleptic test using the Kruskal 28 Wallis Test [13]. Determination of the best treatment from all research treatments, using the Effectiveness Test [14].

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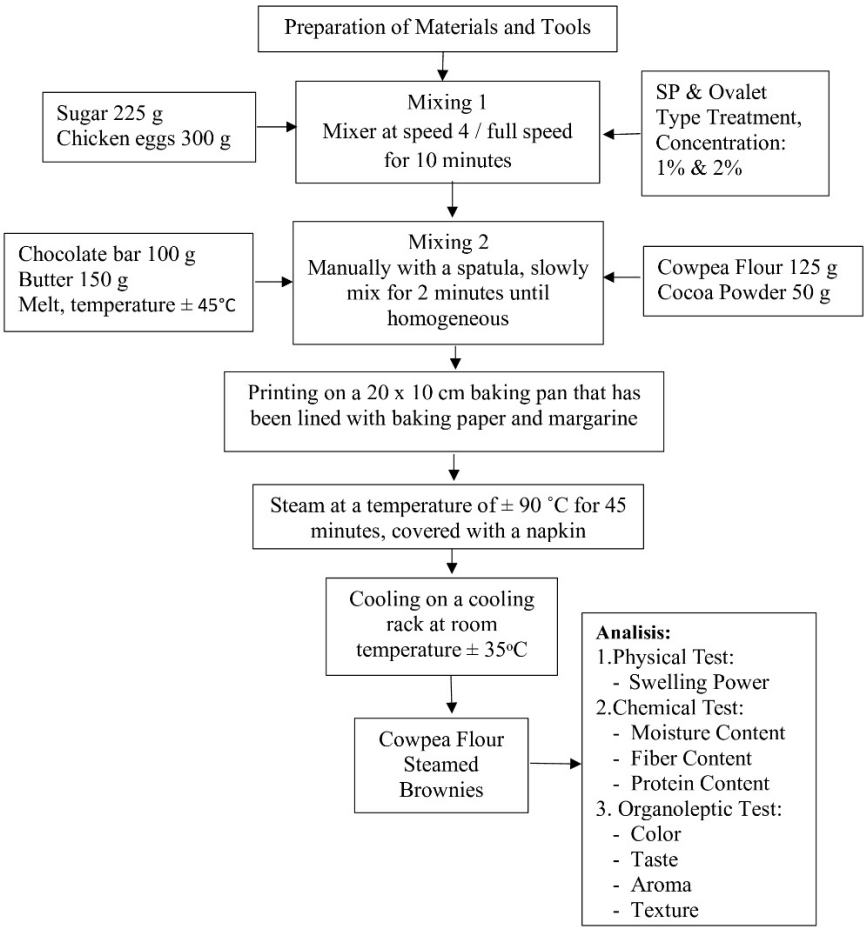

Figure 1. Research Procedure Flowchart

3 Results And Discussion

The results of observations of the physicochemical and organoleptic quality of steamed brownies based on cowpea flour with different types and concentrations of emulsifiers showed that different types and concentrations of emulsifiers had a very significant effect on water content, and a significant effect on rise power, but did not affect the crude fiber content and protein content of steamed brownies based on cowpea flour. The significance of the physicochemical test of the research variables can be seen in Table 1 below:

Table 1. Table of Significance of Physicochemical Tests

Physicochemical Test	Significance	Highest/Lowest Criteria	Average value (%)	Treatment
	Type (J) and concentration of emulsifier (K)			
Water Content	HS	Highest	9.8133	J2K2
Protein Content	NS	Highest	1.203	J2K2
Crude Fiber Content	NS	Highest	3.973	J2K2
Development Power	S	Highest	43.861	J1K2

Note: NS = Non Significant, S = Significant, HS = High Significant

The results of the non-parametric data analysis in the organoleptic test which included taste, color, aroma, and softness showed that the steamed brownies based on cowpea flour were rated 5 and 6 by the panelists, which means they liked them quite a bit, as presented in Table 2 below.

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Table 2. Table of Significance of Organoleptic Test

Variables	Test Value	Test Criteria	Treatment
Flavor	5	Kinda like it	J1K2
Aroma	6	Like	J2K1
Color	6	Like	J1K1, J2K1
Tenderness	5	Kinda like it	J1K2

3.1 Water Content

The average water content of steamed brownies based on cowpeas using various emulsifier types and concentrations is shown in Table 3 below.

Table 3. Average Water Content (%) of Steamed Brownies Based on Cowpea Flour

Treatment Code	Test			Total (%)	Average (%)
	1	2	3		
J1K1	6.70	6.61	6.28	19.60	6.53[b]
J1K2	10.02	9.50	9.92	29.44	9.81[d]
J2K1	5.90	6.16	5.67	17.73	5.91[a]
J2K2	7.42	7.69	7.30	22.41	7.47[c]
KK Value = 10,07% (Duncan α=5%)					

Note: The letters behind the numbers that have the same notation on the mean indicate that there is no difference in the Duncan test >10%

The ANOVA results of the water content of brownies based on cowpea flour have a significance value (Sig.) of 0.902 (α>0.05), meaning that the treatments show a very significant difference so that a further Duncan test (α=5) is needed because it has a CC value of 10.07%. The results of the different test analysis are shown by the differences in the notations presented in Table 3 above, where the average water content between treatments appears to be very significantly different.

The average water content of brownies based on cowpea flour, with the same type of emulsifier, the higher the concentration, the higher the water content. The higher the use of emulsifiers in the process of making steamed brownies, the more water can be incorporated and maintained in the dough structure. Emulsifiers act as emulsifying agents that facilitate the dispersion of water into the fat phase, forming a stable emulsion. Emulsifiers are classified as surfactants that have hydrophilic and lipophilic sides. Emulsifiers in cake batter help stabilize thermodynamically unstable systems by concentrating on the phase between water and oil to mix the two phases [15]. One function of cake emulsifiers is to soften cake crumbs and prevent staling/changes in sensory characteristics [16]. At higher emulsifier concentration levels, emulsifier molecules are able to form a more effective protective layer around water droplets, preventing clustering and coalescence. This allows the steamed brownie batter to retain more water, which is ultimately reflected in the moisture content test results.

3.2 Crude Fiber Content

The average crude fiber content of steamed brownies based on cowpea flour with different emulsifier types and concentrations is presented in Table 4 below.

Table 4. Average Crude Fiber Content (%) of Steamed Brownies Based on Cowpea Flour

Treatment Code	Test			Total (%)	Average (%)
	1	2	3		
J1K1	3.53	3.78	3.47	10.78	3.59
J1K2	3.71	2.58	4.52	10.81	3.60
J2K1	3.00	3.46	3.54	10.01	3.34
J2K2	3.64	3.52	4.76	11.92	3.97

The ANOVA results of the crude fiber content of brownies based on cowpea flour showed that different types and concentrations of emulsifiers did not have a significant effect on the crude fiber content in each treatment. Emulsifiers are not directly involved in the formation of crude fiber in steamed brownies based on cowpea flour. The crude fiber content in steamed brownies is more likely to be influenced by the main source of crude fiber, namely cowpea flour. The main crude fiber in cowpea flour is not affected by emulsifiers. Crude fiber tends to be

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resistant to the influence of substances such as emulsifiers because it is insoluble in water and does not undergo significant structural changes when exposed to emulsifiers. This can be explained by the fact that the type and concentration of flour used, namely cowpea flour, remain consistent in all treatments so that the crude fiber content in each treatment has almost the same value.

The Tests of Between-Subjects Effects table provides information about the between-subjects effects of the treatments on the dependent variable (Fiber). The ANOVA test results indicate that there is no significant difference between the treatment groups (Treatment) in their effect on the dependent variable (Crude Fiber). This is evident from the low F value (0.544) with a significance greater than alpha (0.05). Post hoc analysis was conducted to compare each pair of treatment groups and determine whether there is a significant difference between them. In this table, it can be seen that there is no significant difference between the treatment groups based on the Duncan test at the 0.05 significance level. The Sig. value is greater than alpha, indicating that there is no significant difference between the treatment groups. The type and concentration of emulsifier do not have a direct effect on the crude fiber content in the product. This is because the use of the same cowpea flour in all treatments means that the main fiber source remains consistent across treatments.

3.3 Protein Content

Data analysis showed that the different treatments (J1K1, J1K2, J2K1, and J2K2) did not significantly affect the protein content of the steamed brownies in this study. In this context, the emulsifier used did not significantly affect the amount of protein in the final product. The average protein content of steamed brownies based on cowpea flour is presented in Table 5 below.

Table 5. Average Protein Content of Steamed Brownies Based on Cowpea Flour

Treatment Code	Test			Total	Average
	1	2	3		
J1K1	1.27	1.05	0.83	3.16	1.05[a]
J1K2	1.22	1.02	1.04	3.27	1.09[a]
J2K1	1.24	1.01	1.19	3.44	1.15[a]
J2K2	1.40	1.07	1.14	3.62	1.21[a]

The Tests of Between-Subjects Effects table provides information about the between-subjects effects of the treatment on the dependent variable (Protein). The ANOVA test results indicate that there is no significant difference between the treatment groups (Treatment) in their effects on the dependent variable (Protein). This is evident from the low F value (0.502) with a significance greater than alpha (0.05). Post hoc analysis was conducted to compare each pair of treatment groups and determine whether there is a significant difference between them. This table shows that there is no significant difference between the treatment groups based on the Duncan test at a significance level of 0.05. The Sig. value is greater than alpha, indicating that there is no significant difference between the treatment groups.

Proteins are polymers composed of long chains of amino acids. Cowpea flour, as a protein source in steamed brownies, provides essential amino acids for protein formation. Under conditions where the type and concentration of emulsifiers remain consistent, there are no significant changes in the condition or composition of the raw materials (such as cowpea flour), so no differences in protein content are observed. This indicates that the emulsifier does not have a significant impact on protein synthesis or degradation in steamed brownies.

3.4 Development Power

The average rise power results for steamed brownies based on cowpea flour can be seen in Table 6 below.

Table 6. The Rising Power of Steamed Brownies Based on Cowpea Flour

Treatment Code	Test	Before (cm)	After (cm)	Unit (%)
J1K1	1	3.1	4.1	32.26[a]
J1K1	2	3.2	4.3	34.38[a]
J1K1	3	3	4.2	40.00[a]
J1K2	1	3.4	5	47.06[b]
J1K2	2	3.6	5.1	41.67[b]
J1K2	3	3.5	5	42.86[b]

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J2K1	1	3.1	4.2	35.48[a]
J2K1	2	3.2	4.1	28.13[a]
J2K1	3	3	4	33.33[a]
J2K2	1	3.2	4.5	40.63[ab]
J2K2	2	3.3	4.6	39.39[ab]
J2K2	3	3.4	4.7	38.24[ab]
KK Value = 8,34% (BNJ Tukey >10%)				

The ANOVA test results showed that there was a significant difference between the treatment groups on the dependent variable (Swelling Power). This was evident from the high F value (7.495) with a significance less than alpha (0.05). Tukey's post hoc test was conducted to compare all pairs of treatment groups and determine whether there was a significant difference between them. Based on these observations, it can be shown that different types and concentrations of emulsifiers can affect the rising power of steamed brownies based on cowpea flour. The higher the concentration of emulsifier used, the higher the rising power of the resulting brownies [17].

3.5 Organoleptic Testing

The organoleptic test aims to determine the panelists' level of preference for a treatment. In this test, panelists are asked to provide their personal, subjective responses regarding their preferences. The information from this hedonic scale analysis is transformed into a numerical scale based on their level of preference. These steamed brownies made from cowpea flour were organoleptically tested, with the average results presented in Table 7.

Table 7. Average Organoleptic Test Results of Steamed Brownies Based on Cowpea Flour

Treatment Code	Falvor	Aroma	Tenderness	Color
J1K1	5.57	6.43	3.85	6.72
J1K2	5.95	6.4	5.85	6.52
J2K1	5.87	6.53	5.12	6.72
J2K2	5.6	6.51	5.53	6.6

A Kruskal-Wallis test was conducted to evaluate significant differences in ratings between treatment groups on the four measured variables: Flavor, Aroma, Tenderness, and Color. A significant difference was found only in the Tenderness variable, while the other variables showed no significant differences.

The type and concentration of emulsifier used in making steamed brownies based on cowpea flour did not significantly affect color differences. Because the main ingredient, chocolate, was used in the brownies, which had the same concentration in each treatment, the resulting brownies remained the same color as the original, dark chocolate.

In the Kruskall-Wallis test of tenderness, it shows that there is a very significant difference between the treatment groups, because the p value (0.000) is smaller than the generally set significance level (0.05) therefore a further test has been carried out using Mann Whitney. This shows that the type of emulsifier used in the steamed brownie recipe can have a significant impact on tenderness, each emulsifier has different chemical properties, so it can affect the interaction between water and fat in the brownie dough. In addition to the type of emulsifier, the concentration of the emulsifier is also a factor that affects the tenderness of brownies. The right concentration will ensure that the emulsifier functions optimally to form and maintain the emulsion, so that the texture of the steamed brownies becomes soft and delicious [17].

The mechanism of action of emulsifiers in the brownie-making process is very complex. When an emulsifier is added to the batter, its molecules interact with both water and fat molecules simultaneously. The hydrophilic portion of the emulsifier interacts with water molecules, while the hydrophobic portion interacts with fat molecules. This helps create an emulsion, where fat particles are dispersed in water in a stable manner. During the steaming process of steamed brownies [5]., emulsifiers also help maintain softness by preventing the formation of excessively large fat crystals. Excessively large fat crystals can give brownies a grainy texture. Thus, emulsifiers act as emulsifying and smoothing agents, ensuring that the oil and water are evenly mixed, resulting in soft and chewy steamed brownies.

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3.6 Effectiveness Test

Effectiveness tests were conducted to determine the best treatment for all research parameters, including physicochemical tests (swelling power, water content, protein content, and crude fiber content) and organoleptic tests, as presented in Table 8 below.

Table 8. Results of the Effectiveness Test of Steamed Brownies Based on Cowpea Flour

Parameter	Yield Value (NH) of Treatment			
	J1K1	**J1K2**	**J2K1**	**J2K2**
Development Power	0.040	0.143	0.000	0.088
Tenderness	0.000	0.143	0.091	0.120
Water content	0.020	0.127	0.000	0.051
Protein Content	0.000	0.032	0.079	0.127
Crude Fiber Content	0.050	0.052	0.000	0.127
Flavor	0.000	0.111	0.088	0.009
Aroma	0.026	0.000	0.111	0.094
Color	0.111	0.000	0.111	0.044
Total bobot	0.247	0.608	0.480	**0.660**

Table 8 shows that the highest yield value (NH) was found in the ovalet emulsifier type treatment with a concentration of 2% (J2K2), which had an average value of swelling power of 39.42%, water content of 7.47%, crude fiber content of 3.97%, protein content of 1.21%, with an average value of organoleptic parameters of taste of 5.6 (like), aroma of 6.1 (like), tenderness of 5.53 (somewhat like) and color of 6.6 (like very much).

4 Conclusion

Steamed brownies based on cowpea flour with different emulsifier types and concentrations showed significant differences in water content, significant differences in rise rate, and no significant differences in protein and crude fiber content. Meanwhile, organoleptic test results showed that the different emulsifier types and concentrations did not show significant differences in taste and color parameters, but did show significant differences in aroma parameters and significant differences in tenderness parameters. Based on the effectiveness test, the highest Yield Value (NH) was found in the ovalet emulsifier treatment with a concentration of 2% (J2K2), which had an average rise rate of 39.42%, water content of 7.47%, crude fiber content of 3.97%, and protein content of 1.21%. The organoleptic parameters were 5.6 (like), 6.1 (like), 5.53 (somewhat like), and 6.6 (very like) for taste.

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