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# Development of Antioxidant-Rich Steamed Brownies Based on *Kluwak*, Purple Sweet Potato, and Yellow Kepok Banana

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**ABSTRACT**

*This study aimed to develop antioxidant-rich steamed brownies utilizing local ingredients—Kluwak seed powder, purple sweet potato paste, and yellow kepok banana paste—to enhance nutritional value and reduce dependence on wheat flour imports. The research was driven by the need for functional foods that capitalize on Indonesia's abundant local resources while addressing health concerns such as degenerative diseases. The study employed the Simplex Lattice Design (SLD) method using Design Expert 13 software to optimize the brownie formulations. Subsequent analyses included physicochemical assessments (texture profile analysis, antioxidant activity measured via DPPH assay), sensory evaluations, and in vitro bioaccessibility tests to simulate gastrointestinal digestion. Results demonstrated that the optimal formulation comprised 4.5% Kluwak seed powder and 27.5% purple sweet potato paste, resulting in high antioxidant activity (97.96% inhibition at 10% Kluwak). However, antioxidant capacity declined during simulated digestion, likely due to changes in pH and enzymatic activity. Sensory evaluation indicated a higher preference for formulations with increased purple sweet potato content, attributed to improved texture and flavor. The study concluded that these steamed brownies have potential as a functional food; nonetheless, further research is necessary to enhance the bioaccessibility of antioxidants. The findings underscore the importance of utilizing local ingredients, supporting micro, small, and medium enterprises (MSMEs), and advancing food diversification strategies in South Sulawesi.*

**KEYWORDS** *antioxidant content, banana paste, Kluwak, purple sweet potato pastes, steamed brownies,*



## INTRODUCTION

*Kluwak* (*Pangium edule* Reinw) is a plant whose leaves, seeds, and fruits are widely used in cooking. *Kluwak* is commonly found in South Sulawesi, with Watu Toa Village in Soppeng Regency and Kalembang Village in Tana Toraja Regency serving as examples of areas where local communities cultivate *Kluwak* plants. According to Nawir et al. (2017), as many as 48.3% of farmers from two hamlets in Watu Toa Village own *pangi* agroforestry land ranging from 0.25 to 0.50 hectares.

In these regions, *Kluwak* seeds are utilized in various ways, such as ingredients for making *konro* or *rawon*, as vegetables, and in *dodol*. Meanwhile, Idris and Srigae (2023) reported that the average area of agroforestry land for *Kluwak* plants in Kalembang Village is between 0.25 and 1 hectare, with an average of 524 productive trees per plot, equivalent to 90% of the total 582 trees cultivated. The people of Kalembang Village commonly use the fruit or *pangi* seeds as vegetables or cooking spices.

According to Ramadhani et al. (2013), in addition to its use as a seasoning, *Kluwak* seeds are also employed as a natural preservative for fresh fish. These seeds contain antioxidant and antibacterial compounds. The antioxidant compounds identified in *Kluwak* seeds include vitamin C and β-carotene, while the antibacterial components consist of cyanide acid, hydrocarnic acid, khaulmogric acid, goric acid, and tannins. Furthermore, a study by Sampe and Th Watuguly (2016) indicated that *pangi* seed extract contains saponins and alkaloids. Other research conducted by Listyorini *et al.* (2021) shows that the fatty acid and glycoside content in *Kluwak* seeds has antifungal properties that have the potential to be preservatives in food and fishery products.

According to Wahdaningsih, *et al* (2011) The number of free radicals can increase due to stress factors, radiation, cigarette smoke and environmental pollution causing the body's defense system to be inadequate, so the body needs additional antioxidants from the outside that can protect against free radical attacks. Excessive exposure to free radicals can cause various types of diseases (Sanger *et al.* 2018). According to an article in 2022 from the Ministry of Health of the Republic of Indonesia (yankes.kemkes.go.id), there has currently been a pattern of shifting patterns of non-communicable diseases (NCDs) or degenerative diseases, such as hypertension, diabetes mellitus, cancer, and so on that are commonly experienced by the elderly age group, now starting to attack the productive age group.

Risk factors that cause degenerative diseases are divided into two parts, namely risk factors that cannot be changed, such as age, gender, and family history, and risk factors that can be changed, such as smoking habits, lack of physical activity, alcohol consumption, unhealthy diet, and so on (Boehme *et al.* 2017). The antioxidant properties possessed by *Kluwak* seeds are one of the opportunities to reduce the risk of various diseases, including degenerative diseases. Along with the development of science and technology, many experts are actively conducting research on bioactive compounds that are antioxidants from various plants in Indonesia and are widely used for the needs of the pharmaceutical industry in the form of medicines, antibiotics, cosmetic ingredients, and so on (Oktavianus, 2013). This shows that the use of various compound components in the food processing industry as functional food is still very necessary in an effort to introduce functional food to the community.

Food an Agricultural Organization (FAO) in (Temple, 2022) defines functional food as food that, in addition to containing nutrients, can also provide health benefits. One of the food products that has the potential to become functional food is brownies. BrownieMus is a food product that is favored by people from various walks of life and can be used as a choice of food that is rich in carbohydrates. One of the basic ingredients for manufacturing *brownies* is

wheat flour.

According to Yustisia (2013) wheat flour is a product that contains high gluten, but not everyone can consume and digest gluten properly. Some of them are, such as people with gluten intolerance and autism spectrum disorder (ASD). In addition, wheat flour is also made from wheat so that in its use, the government must import to meet the needs of wheat flour in Indonesia. Import activities of course have several negative impacts, for example, domestic products are competed by imported products and dependence on imported products which affects the country's foreign exchange growth.

The dependence on imports makes the Indonesian people unable to utilize local food ingredients to the fullest to become nutritious processed food and have a selling value that is not inferior to processed wheat flour products. In fact, various types of food, both tubers, cereals, fruits, and nuts, can be used as alternatives to reduce these import activities (Falestinia, 2016). One type of fruit that is good to use in flour making is bananas.

According to data from the Central Statistics Agency (bps.go.id) 2023, banana production in Indonesia in 2022 will reach 9,245,427 tons. From this data, information was also obtained that South Sulawesi was ranked 9th with banana production of 177,727 tons. This number is also the highest number of banana production in South Sulawesi if calculated from the last five years. Banana production is quite high and not proportional to the level of public consumption, resulting in many bananas that are not used because the shelf life of bananas is relatively short.

The solution that can be offered to this problem is to make bananas into processed products in the form of banana paste as an effort to extend the shelf life without eliminating the nutritional value of the product. One type of banana that can be used is the yellow kepok banana. Yellow kepok banana is one type of banana that is very easy to find in South Sulawesi. According to Kaleka (2013), yellow kepok bananas have a sweet taste in the flesh and are processed bananas. The use of yellow kepok bananas is mostly only used as an interlude, snack, or snack, and is also sometimes used as banana flour. In addition to yellow kepok bananas, one of the agricultural commodities that is easy to find in South Sulawesi is sweet potatoes.

According to data from the Central Statistics Agency (bps.go.id), in 2013 South Sulawesi produced around 70,767 tons of sweet potatoes. One type of sweet potato that is easy to find in South Sulawesi is purple sweet potato. Sweet potatoes not only contain macro elements such as carbohydrates, but are also rich in anthocyanins. This makes purple sweet potatoes have good functional value. In the study with different cooking methods (boiling, steaming, baking in the oven, and baking in the microwave), the total anthocyanins in purple sweet potatoes were higher than in orange sweet potatoes (Musilova *et al.* 2020).

This research aims to develop antioxidant-rich steamed brownies made from local raw materials, namely *Kluwak*, purple sweet potato, and yellow kepok bananas, as an alternative to wheat flour to reduce dependence on wheat imports and improve nutritional value and public health. The formulation of the problem is focused on the potential of *Kluwak* which has only been used in regional cuisine in South Sulawesi and the opportunity for its use in making modern brownies, where the use of purple sweet potatoes and kepok bananas also has the potential

to replace wheat flour. The objectives of the study include the production of steamed brownies with high antioxidant content, analysis of the effect of local ingredient addition on physical quality, antioxidant activity, and sensory profile, search for optimal formulations, and testing of antioxidant bioaccessibility. In addition, this research is expected to utilize appropriate technology through freezing technology to develop local products that are beneficial to health and produce steamed brownie formulations that can be developed by MSMEs, thus making a strategic contribution to food diversification in South Sulawesi.

## RESEARCH METHODS

The study employed the Simplex Lattice Design (SLD) method using Design Expert 13 software to optimize the formulations, followed by physicochemical analyses—including texture profile analysis and antioxidant activity assessment via the DPPH assay—sensory evaluations, and in vitro bioaccessibility tests. This research was conducted from December 2023 to March 2024 in several laboratories at the Faculty of Agricultural Technology, IPB University, utilizing various instruments such as analytical balances, blenders, ovens, and UV-Vis spectrophotometers, as well as primary raw materials including *Kluwak* seeds, yellow *kepok* bananas, purple sweet potatoes, and others. The research procedure consisted of three main stages: preparation of raw materials (producing *Kluwak* seed flour, banana paste, and sweet potato paste), preliminary research involving the development of steamed brownies with modified formulations, and formulation optimization using the Simplex Lattice Design method through the Design Expert 13 application.

Data collection involved a range of laboratory tests, including water content determination (AOAC gravimetric method), protein analysis (Kjeldahl AOAC), fat content (Soxhlet AOAC extraction), ash content, carbohydrate content (by difference), texture profile analysis, antioxidant activity testing (DPPH method), in vitro bioaccessibility testing, and organoleptic evaluation using the ranking test method. The data obtained were analyzed using ANOVA and the Design Expert software to ensure the optimal model, meeting criteria such as Lack of Fit, Adjusted $R^2$, Predicted $R^2$, and Adeq Precision.

## RESULTS AND DISCUSSION

### Formulation Determination by Simplex *Lattice Design* (SLD) Method

In this study, optimization was carried out using the simplex lattice design (SLD) method. According to Hajrin, et al (2021) the simplex lattice design method is a useful method in this type of research with the goal of optimizing the formula with the difference in the composition of the ingredients with the total number of materials used being the same. Before the optimization process, the composition of the mixture is determined by determining the minimum and maximum limits of the *Kluwak* seed powder and purple sweet potato paste used. The determination of the upper and lower limits will determine the results of the test parameters or the response of each treatment.

The results of each treatment were continued by conducting an ANOVA (Analysis of variance) test to determine the significance between variables. The next condition that needs to be met is that the Lack of Fit value must be insignificant or a value of >0.05 which indicates that there is a correspondence of response data with the model used (S., Keshani, et al., 2010). In addition, the Adjusted $R^2$ value minus the Predicted R2 value must be less than 0.2 and the Adeq Precision value must be above the 4 value. The optimal formula is obtained from the results of software evaluation that are within the limit range in each test parameter. A formula with a degree of desirability value close to one is the best formula or optimal formula (Hidayat, et al., 2021). The following is the treatment obtained after determining the upper and lower limits of the formula used.

**Table 1. Expert Software Design Output Formula with Simplex Lattice Design (SLD) Method**

| No | Component A: *Kluwak* Seed Powder (%) | Component B: Pasta Ubi Jalar (%) |
|---|---|---|
| 1 | 5,5 | 26,5 |
| 2 | 10 | 22 |
| 3 | 4 | 28 |
| 4 | 8,5 | 23,5 |
| 5 | 10 | 22 |
| 6 | 7 | 25 |
| 7 | 7 | 25 |
| 8 | 4 | 28 |

Source: Analysis Results *software* Design Expert

The selection of the lower and upper limits of the formulation is based on the results of the experiment. Research related to modern food products made from *Kluwak* is still very limited. One of the studies using *Kluwak* paste showed that in the manufacture of *crispy almonds*, the addition of *Kluwak* paste by 0.07% of the total ingredients is the best treatment for consumer acceptability Ali, *et al* (2023). The lower and upper limits of *Kluwak* seed powder are 4% and 10% of the total ingredients, respectively. The lower and upper limits of purple sweet potato paste are 22% and 28% of the total ingredients.

**1. *Texture Profile Analysis***

In the test using texture profile analysis, there are four parameters tested, namely hardness, adhesiveness, and cohesiveness. These four parameters are parameters for the main characteristics in landfill testing.

**a. *Hardness***

According to Haliza, *et al* (2012) the hardness parameter is generally used to describe the unsmoothness of pastry crumbs. The hardness value is the amount of force needed to press the brownies from the original height. The difference in formula has a significant effect on the difference in hardness parameters in steamed brownies. The following are the results of the software design expert analysis of the product hardness test.

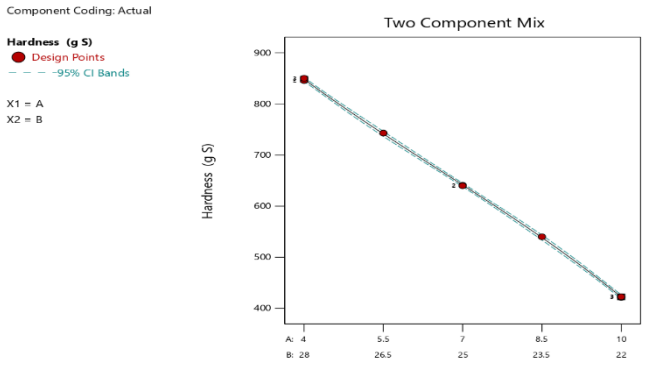

Figure 1. Hardness Chart of *Steamed* Brownies

The graph above shows the hardness of steamed *brownies*. The high and low use of purple sweet potato paste and *Kluwak* seed powder affects the hardness level of the product produced. The higher the use of *Kluwak* powder in the dough, the lower the hardness level of the resulting product. This happens because of the oil content in *Kluwak* powder.

The existence of oil content in *Kluwak* is supported by research conducted by Hamzah, *et al* (2018) which shows the potential use of *Kluwak* pulp as a raw material for making cooking oil and alternative fuel for biodiesel. Therefore, as the percentage of purple sweet potato paste in the steamed *brownie* formulation increases, the higher the hardness parameter value of the test carried out. On the other hand, the higher the percentage of *Kluwak* powder in the brownie dough, the softer the product will be. In addition, the use of the main ingredient in the form of pasta and the use of the steaming method makes the brownie products produced have a fairly high-water content. It also affects the level of hardness *of* the products produced. The following are statistical tests generated by *software* for product optimization.

**Table 2. ANOVA Test Results of Hardness Response of Steamed Brownies with Design Expert 13 software**

| Parameter | Hardness of Steamed Brownies | Information |
|---|---|---|
| Model | < 0,0001 | Significant |
| Lack of fit | 0,2410 | Not significant |
| Adjusted R-square | 0,9998 | |
| Predicted R-square | 0,9995 | |
| Adeq precision | 284,1699 | |

Based on the results of the ANOVA test generated by the software, it can be seen that the product optimization requirements for the hardness parameter are met. The requirements for model conformity show a significant value, the Lack of Fit value is not significant or the value is

>0.05, the Adjusted $R^2$ value minus the Predicted R2 value is less than 0.2 and the Adeq Precision value is above the 4 value. When associated with sensory test data, the hardness response had a relationship with the panelists' preference level in the texture hedonic rating test. The higher the use of *Kluwak* powder in the sample, the lower the texture preference value obtained. On the other hand, the higher the percentage of purple sweet potato paste used in brownies, the higher the level of preference for the texture of the brownies. This shows that the level of preference of the panelists for the texture is influenced by the hardness parameters of the steamed brownies produced. The softer the product produced, the lower the level of preference for the texture of the product.

**b. Adhesiveness (Stickiness or Sticky State)**

According to Haliza, et al (2012) adhesiveness is the force needed to pull food from its surface. The adhesiveness value is the area that is between the first and second compression areas. Below is the optimization data obtained from software design experts for adhesiveness parameters.

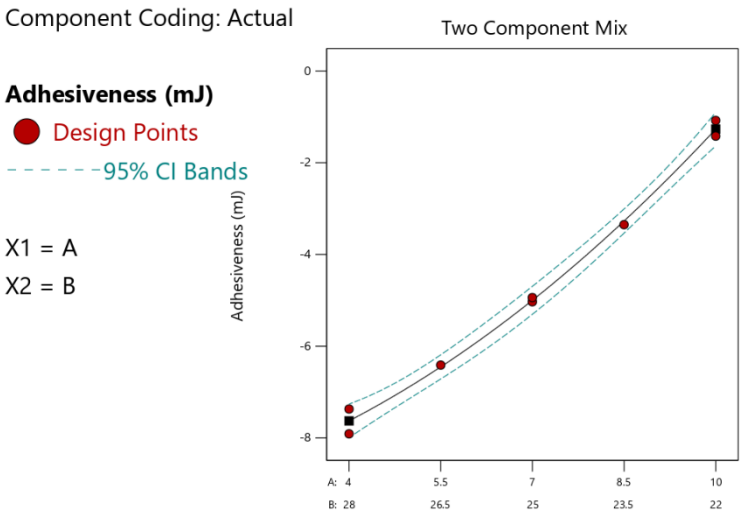


**Figure 2. Stickiness Chart of *Steamed* Brownies**

In texture measurements, the adhesiveness is obtained from the area of the curve below the line and is usually negative, the greater the negative value means the greater the measurable product adhesiveness value. Below is the optimization data obtained from the ANOVA test results for the adhesiveness parameter.

**Table 3. ANOVA Test Results of Adhesiveness Response of Steamed Brownies with Design Expert 13 software**

| Parameter | Adhesiveness of Steamed Brownies | Information |
|---|---|---|
| Model | < 0,0001 | Significant |
| Lack of fit | 0,9369 | Not significant |
| Adjusted R-square | 0,9934 | |

| | |
|---|---|
| Predicted R-square | 0,9839 |
| Adeq precision | 49,8675 |

Based on the results of the ANOVA test generated by the *software,* it can be seen that the product optimization requirements for *the adhesiveness* parameter are met. The conditions for model conformity show a *significant value,* a Lack of Fit *value is not significant or a value of >0.05,* an *Adjusted* $R^2$ value minus a *Predicted R2* value of less than 0.2 and *an Adeq Precision value* above a value of 4.

According to Dewi and Hery (2014) In Indonesia there are several types of clones or varieties of purple sweet potatoes. Among them, namely antique clones, ayamurasaki clones, and local clones. Based on research conducted by Richana and Widaningrum (2009), the starch content in sweet potato pasta with four varieties (left-handed, Ayamurasaki, Sati, and Jago) is in the range of 84-90%. This content affects the *adhesiveness value* of the product, namely the higher the percentage of purple sweet potato and the lower the percentage of *Kluwak* seed powder, the *greater the adhesiveness* value produced.

Purple sweet potato paste has a sticky nature. This is because purple sweet potatoes contain relatively high starch. In a study conducted by Yuliansar, *et al* (2020) the starch content in fresh sweet potatoes is around 20%. Starch is a condensing polymer of a glucose composed of anhydroglucose units. This starch is able to bind or absorb water (hygroscopic properties), so that the purple sweet potato paste becomes stickier. The low amylose content in purple sweet potato starch can also cause the paste to become stickier.

This can happen because the more purple sweet potato paste is used, the higher the starch content that is able to bind water and protein in the *brownie* dough, while at the same time the *Kluwak* powder which has a small percentage in the dough, does not have a great influence on the adhesiveness value Steamed brownies. If it is analogous to the state in the mouth, the higher the percentage of purple sweet potatoes and the lower the percentage of *Kluwak* seed powder in the steamed *brownie* dough, the resulting *brownies* will be stickier and easier to stick to the teeth.

**c. *Cohesiveness***

According to Haliza, et al (2012) Cohesiveness is an indication of the strength of the internal bonds that make up food. Cohesiveness is measured from the ratio between two compression areas so that it has no units. Cohesiveness describes the compactness of the resulting product. The presentation of the optimization data obtained from the software can be seen in the following figure.

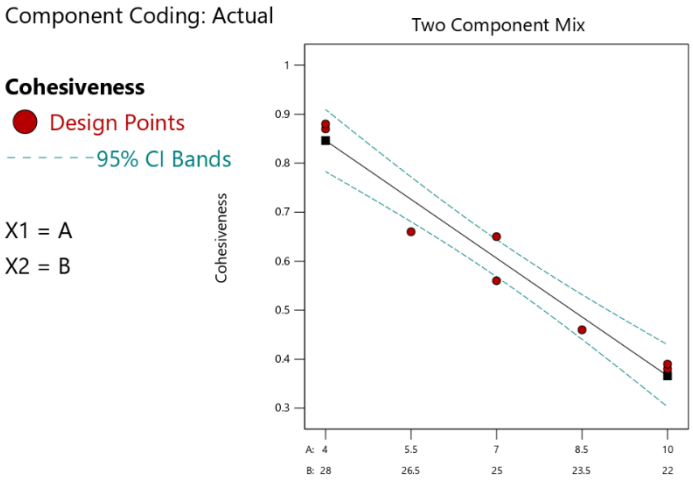


**Figure 3. *Cohesiveness Chart of* Steamed Brownies**

Based on the data obtained, the higher the use of purple sweet potato paste, the higher the compactness of the product produced. This compactness can be interpreted as a product that is not easily destroyed. The following are the results of the ANOVA test for the cohesiveness parameter can be seen in Table 4 below.

**Table 4. ANOVA Test Results of Cohesiveness Response of Steamed Brownies with Design Expert 13 software**

| Parameter | Cohesiveness Steamed Brownies | Information |
|---|---|---|
| Model | < 0,0001 | Significant |
| Lack of fit | 0,3218 | Not significant |
| Adjusted R-square | 0,9501 | |
| Predicted R-square | 0,9312 | |
| Adeq precision | 21,8450 | |

Based on the results of the ANOVA test generated by the *software,* it can be seen that the product optimization requirements for *the cohesiveness* parameter are met. The condition of the model used has significant data*, the* Lack of Fit *value* must be insignificant or a value of >0.05, the *Adjusted* $R^2$ value minus the *Predicted R2* value less than 0.2 and *the Adeq Precision value* above the 4 value. According to Iswara, *et al* (2019) the making of sweet bread with a higher amylopectin content than the amylose content in purple sweet potatoes will affect the compactness of the product produced. In addition, the high fiber content in purple sweet potatoes also affects the compactness of the products produced. Therefore, the more percentage of purple sweet potato compared to the *Kluwak* seed powder used, the product produced will show a higher *cohesiveness* value, on the contrary, the higher the percentage of *Kluwak* powder compared to the percentage of purple sweet potato paste used, the *cohesiveness* produced will also be lower or the product produced is easily destroyed.

## 2. DPPH Antioxidant Activity Test (% Inhibition)

Antioxidants are compounds that can absorb or neutralize free radicals, so they can prevent degenerative diseases such as cardiovascular disease, cancer, and other diseases. This compound is very important for the body to neutralize free radicals and avoid damage caused by free radicals to normal cells, proteins, and fats (Pratiwi, *et al,* 2023). The following is the data of optimization results obtained from *software design experts* for the antioxidant test parameters of the DPPH method.

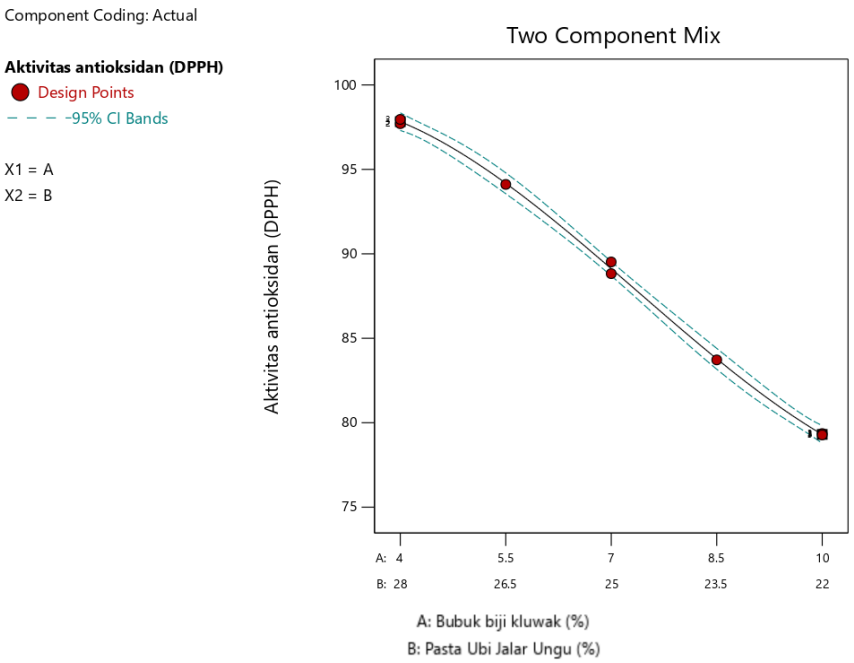


Figure 7. *Cohesiveness Chart of Steamed Brownies*

The high and low levels of antioxidants in food are influenced by several things, such as raw materials, storage processes, and processing processes. In this study, there are several sources of antioxidants, namely purple sweet potato, yellow kepok bananas, *Kluwak* seed powder, and *cocoa powder*. According to Arifianti *et al.* 2018 *Kluwak* contains flavonoids, saponins, coumarins, emodols, reducing sugars, phenols, tannins as well as several fatty acids such as oleic acid, linoleic acid, and palmitic acid. The results of this study show that the antioxidant activity of IC50 *Kluwak* powder is influenced by total phenols, total flavonoids and total tannins where the highest oration value is found in total phenols, which is 0.973 or 97.3%. Like *Kluwak*, purple sweet potatoes also have some bioactive content, but the dominant bioactive content in purple sweet potatoes is anthocyanins (Samber, *et al*., 2016). Yellow kepok bananas as one of the ingredients in steamed *brownie* products also have antioxidant compounds, namely *quercetine* from the flavonoid group (Handayani and Ayustaningwarno 2014). The following is a table of the results of the ANOVA test and the antioxidant activity test (% Inhibition) obtained.

**Table 8. ANOVA Test Results of Antioxidant Activity Response (DPPH) of Steamed Brownies with Design Expert 13 software**

| Parameter | Antioxidant Activity (DPPH) of Steamed Brownies | Information |
|---|---|---|
| Model | < 0,0001 | Significant |
| Lack of fit | 0,7085 | Not significant |
| Adjusted R-square | 0,9987 | |
| Predicted R-square | 0,9981 | |
| Adeq precision | 97,6068 | |

Table 9. Comparison of Antioxidant Activity (% Inhibition) *of Steamed* Brownies

| No | *Kluwak* (%) | Purple sweet potato (%) | Sample Code | % Inhibition |
|---|---|---|---|---|
| 1 | 4 | 28 | 312 | 79,28 |
| 2 | 4 | 28 | 175 | 79,36 |
| 3 | 5,5 | 26,5 | 427 | 83,72 |
| 4 | 7 | 25 | 809 | 88,83 |
| 5 | 7 | 25 | 654 | 89,52 |
| 6 | 8,5 | 23,5 | 209 | 94,11 |
| 7 | 10 | 22 | 717 | 97,96 |
| 8 | 10 | 22 | 581 | 97,71 |

Based on the data in the table above, it can be observed that the higher the percentage of *Kluwak* powder in *steamed brownies* , the lower the ability to inhibit free radicals obtained. On the other hand, the higher the percentage of purple sweet potatoes in the product, the higher the free radical inhibition obtained. Therefore, the product with the lowest percentage of *Kluwak* seed powder and the highest sweet potato paste has the highest free radical inhibition ability.

**3. Sensory Tests**

**a. Aroma**

Aroma is an odor produced by chemical stimuli when food enters the mouth and is smelled by the olfactory nerve in the nasal cavity (Saputra et al., 2019). Aroma can also be understood as the distinctive smell of a product that is released after the product has been processed. The role of aroma in a food is very important because aroma can determine consumer acceptance of a food. Olfactory is a sense of taste and smell, and it is difficult to measure because it is very subjective and everyone has different sensitivities and preferences (Wahyuni, 2012).

**Table 10. ANOVA Test Results of Aroma Response of Steamed Brownies with Design Expert 13 software**

| Parameter | Aroma of Steamed Brownies | Information |
|---|---|---|

| | | |
|---|---|---|
| Model | < 0,0001 | Significant |
| Lack of fit | 0,7085 | Not significant |
| Adjusted R-square | 0,9902 | |
| Predicted R-square | 0,9670 | |
| Adeq precision | 32,2045 | |

The aroma of the steamed brownies produced comes from a combination of the main ingredients, namely *Kluwak*, purple sweet potato, and banana. Based on the hedonic test data, it can be seen that along with the increase in the percentage of *Kluwak* seeds and the decrease in the percentage of purple sweet potatoes, the level of panelists' preference for the aroma decreased. On the other hand, along with the increase in the percentage of purple sweet potato paste and the decrease in the percentage of *Kluwak* seed powder, the level of the panelists' preference for the aroma increased.

**b. Texture (*Mouthfeel*)**

The process of texture formation is influenced by the presence of starch, fiber and protein molecules by requiring water. So that during the texture formation process, starch, fiber and protein components compete with each other to bind water to form texture. When wheat flour is mixed with water, gluten will form a viscoelastic mass that binds all the dough ingredients, especially starch, into a dough, the film layer formed is impermeable to gas, so the gas can be trapped and form pores. Pores are small holes that are formed due to CO2 gas produced by yeast in the fermentation process and the air trapped in it. The presence of pores in bread causes the texture to become soft (Wijayanti, 2007).

**Table 11. ANOVA Test Results of Steamed Brownies Texture Response with Design Expert 13 software**

| Parameter | Texture of Steamed *Brownies* | Information |
|---|---|---|
| Model | 0,0002 | Significant |
| Lack of fit | 1,0000 | Not significant |
| Adjusted R-square | 0,9816 | |
| Predicted R-square | 0,9709 | |
| Adeq precision | 23,8598 | |

The resulting brownie product is not soft in texture, but stiff. This is related to the absence of gluten used in the product. Texture often gives an image of the product which will certainly increase consumer interest. The texture produced by breads is influenced by the fat content, bread-based ingredients, and moisture content (Budianto, 2009). The texture in brownies is moist. This is due to the heavy dough, namely melted chocolate, as well as the water content in the paste used. This makes the texture of brownies moist and less fluffy (Mas'ud and Alya, 2021). The higher the percentage of *Kluwak* seed powder used, the softer the

product produced. It also shows that the higher the purple sweet potato paste used, the stiffer the texture produced.

**c. Taste**

According to Andriani (2012), taste arises due to chemical stimuli that can be received by the sense of taste or tongue. Taste is a factor that affects the acceptance of food products. If the aroma, color and texture components are good but consumers do not like the taste, then consumers will not accept the food product. Based on the data obtained, the taste of steamed brownies shows a significant difference. The higher the percentage of use of *Kluwak* seed powder, the less favored it was by the panelists. This is related to the pungent and oily base aroma of *Kluwak* that will be felt in the mouth when consuming steamed brownies. The following is the data from the statistical test of the *taste of steamed* brownies obtained.

**Table 12. ANOVA Test Results Taste Response of Steamed Brownies with software Design Expert 13**

| Parameter | Breed Brownies Steamed | Information |
|---|---|---|
| Model | 0,0002 | Significant |
| Lack of fit | 0,1702 | Not significant |
| Adjusted R-square | 0,9830 | |
| Predicted R-square | 0,9466 | |
| Adeq precision | 23,9407 | |

**d. Overall Liking**

According to Wulansari, *et al* (2023) the hedonic organoleptic testing of overall acceptance aims to determine the level of consumer preference for a product from all attributes. This is supported by research conducted by Derlean, *et* al (2024) which states that the combination of sensory properties, namely taste, color, texture, aroma, and overall appearance is a provision for consumer acceptance of a product.

Table 13. ANOVA Test Results Overall liking *Steamed* Brownies with *Design Expert 13* software

| Parameter | Overall liking Steamed Brownies | Information |
|---|---|---|
| Model | <0,0001 | Significant |
| Lack of fit | 0,7049 | Not significant |
| Adjusted R-square | 0,9939 | |
| Predicted R-square | 0,9905 | |
| Adeq precision | 41,6808 | |

Based on the hedonic test data, it can be seen that along with the increase in the percentage of *Kluwak* seeds and the decrease in the percentage of purple sweet potatoes, the level of preference among the panelists for the overall acceptance of the product has decreased. On the other hand, along with the increase in the percentage of purple sweet

potato paste and the decrease in the percentage of *Kluwak* seed powder, the level of preference of the panelists for the percentage of product acceptance has increased.

**4. Determination of the Best Formulation and Verification**

Brownie *optimization* is carried out by determining the (significant) response of the product as well as *the highest or closest desirability* value (Haliza *et al*., 2012). Formula verification is carried out with a comparison that has been provided by *the software* based on the optimization results. The formula in question is also the optimal formula. Here is a table showing the optimal formula of an *optimized steamed* brownie product.

**Table 14. Best Steamed Brownie Formulations Obtained from Software Design Expert 13**

| ***Kluwak* Seed Powder (%)** | **Purple Sweet Potato Paste (%)** |
|---|---|
| 4,5 | 27,5 |

After the optimization stage, the best treatment was obtained with a percentage of *Kluwak* seed powder of 4.5% and purple sweet potato paste of 27.5% with a *desirability value* of 0.986. After that, it was continued by carrying out a bio accessibility test of antioxidant activity in the gastrointestinal tract, namely the gastric phase and the small intestine phase, as well as a proximate test (water content, ash content, protein content, fat content, and carbohydrate content).

**5. Antioxidant Activity of Steamed Brownies Before and After Digestive Simulation**

Bio accessibility is a term that describes how much of a compound is released and can be absorbed by the body. It refers to the part of the compound that can be released from the food matrix in the digestive tract and is available for absorption in the small intestine. (Odriozola-Serrano et al. 2023). The following is the bio accessibility test data obtained.

**Table 15. Antioxidant Capacity in the Digestive Phase and Recovery Index (RI), and Antioxidant Bio accessibility Index (BI)**

| **Antioxidant Capacity (%Inhibition)** | | | | **Recovery Index (%)** | **Bio accessibility Index (%)** | |
|---|---|---|---|---|---|---|
| **Non Digest** | **Gastric Phase** | **Small Intestine Phase** | | | | |
| | | **1** | **2** | | **1** | **2** |
| 85,82±0,75 | 85, 39±0,33 | 66,36±0,33 | 60,43±4,13 | 99,5±1,26 | 77,32±1,06 | 70,41±2,78 |

Based on the table above, it can be seen that from the non-digestible phase, gastric phase, to the small intestine phase, there is a decrease in the ability of antioxidants to reduce DPPH free radicals. The release of phenolic compounds in the gastric digestive phase is determined based on the

recovery index (RI) value, while its release in the small intestine phase is determined based on the bio accessibility index (BI) value. The recovery index and bio accessibility of products are more influenced by their resistance and degradation to pH and digestive enzymes without any increase in quantity during the process (Rialdi, 2023). A high recovery index (RI) value compared to the BI value can indicate several things, namely not all antioxidants measured in the recovery index can survive through the digestive process to the small intestine, the stability of antioxidant compounds that can deteriorate due to pH and enzymes, and the interaction of other components, such as fats or proteins with antioxidant compounds that have the potential to reduce the amount of antioxidants that are readily absorbed by the body (Fauziah, *et al.,* 2023; Rialdi, 2023)

## 6. In the Exhibition Test

**Table 16. Proximate Steamed Brownies Test Up Test Results**

| Water | Ash | Fat | Protein | Carbohydrates |
|---|---|---|---|---|
| | | % | | |
| 47,30 | 1,58 | 7,55 | 6,97 | 36,62 |

According to Witono, et al. (2012) the size of the granules will increase to a certain extent before finally the starch granules burst. The rupture of the granules causes the amylose and amylopectin parts to diffuse out. The process of water entering the starch causes the granules to expand and eventually break because the number of hydroxyl groups in the starch molecules is very large, so the ability to absorb water is also very large. During the steaming process, the water contained in the steamed brownies will evaporate. However, the moisture content of steamed brownies has a product. The high and low moisture content in steamed brownies can affect the growth of microorganisms in the bread. If the moisture content is high, then microorganisms can grow and develop easily on steamed brownies. Similarly, if the moisture content is low, then the growth and development of microorganisms becomes slower.

According to Andriani (2012), carbohydrates are compounds formed from carbon, hydrogen and oxygen molecules. Carbohydrates also play an important role in determining the characteristics of a food, besides that several groups of carbohydrates produce dietary fiber that is useful for digestion. Based on the data obtained, the value of carbohydrate content, which is 36.62%, is influenced by the heating process during the making of pasta and steamed brownie products. The carbohydrate value was obtained from the calculation by difference with a value of 0.47%.

In the combustion process, organic materials are burned but inorganic substances are not (Andriani, 2012). High and low ash levels can affect food. The ash content in food can be used to determine whether a food is processed well and the cleanliness of the ingredients used.

Fats have insoluble properties in water. The basic structure of fats is triesters and glycerols called triglycerides (Andriani, 2012). The fat content of the product is influenced by the oil content contained in the *Kulwak* seed

powder and the use of chocolate and margarine in the dough. Fat content is closely related to the resistance of processed products made from rancidity due to fat oxidation.

Protein is a source of amino acids that contain elements C, H, O, and N that do not have types of metal proteins such as iron and copper (Wahyuni, 2009). can increase tensile strength, so that the higher the protein content in the product, the less easily the product breaks (Nuringtyas and Annis, 2017). The protein content in brownies is influenced by various ingredients used during the processing process.

## CONCLUSION

This study concludes that utilizing local raw materials such as *kluwak* seeds, purple sweet potatoes, and yellow *kepok* bananas in steamed brownies results in products with notable health benefits, where variations in the concentration of *kluwak* seed powder and *kepok* banana paste significantly influence the physical properties, antioxidant capacity, and sensory characteristics of the brownies. Bioaccessibility tests revealed a reduction in antioxidant capacity from the non-digestible phase to the small intestine phase, suggesting that not all antioxidants remain stable during digestion due to factors like pH changes, enzymatic activity, and interactions with other components such as fats or proteins; additionally, processing leads to decreased carbohydrate, fat, and protein content compared to the raw ingredients. For future research, it is recommended to include a simulation of the oral phase in digestion studies to gain more comprehensive insights into the interactions between steamed brownie ingredients and the body's absorption processes, thereby supporting more effective product development.

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