Production optimization of green coffee extracts from Jember robusta (*Coffea canephora*) coffee using foam mat drying method

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**Abstract.** Robusta coffee contains around 10% polyphenol compounds. The roasting process could change the chemical composition and biological activity of coffee thus reduced polyphenols and antioxidant activity. Production of the green coffee extract was performed by foam mat drying method, which requires encapsulating materials such as maltodextrin and foaming agent tween 80. This study aimed to determine the optimal concentration of maltodextrin and tween 80 to obtain high phenol content and strong antioxidant activity of green coffee extract powder. This research used Response Surface Methodology with Central Composite Design using two factors namely maltodextrin concentration (12%; 17%; 22%) and tween 80 (0.4%, 0.9%; 1.4%). The optimum solution results were obtained in the treatment of maltodextrin and tween 80 concentrations of 14.78% and tween 80 of 0.93% which produced green coffee extract powder with a total phenol content of 183.639 mg GAE/g and IC50 values of 25.187 ppm.

1. **Introduction**

Coffee is a refreshing ingredient widely cultivated in Indonesia because it is a promising export commodity[1]. In East Java Province, Jember Regency is the second largest coffee producer after Malang Regency. The majority of smallholder plantations in Jember Regency grow robusta coffee. According to data from the Directorate General of Plantations, in 2015, robusta coffee in Jember District reached 5,686 hectares and produced 2,845 tons of rice coffee[2]. Coffee provides a calming and refreshing effect for those who consume it due to the caffeine content in coffee. In addition to caffeine, coffee beans also contain polyphenol compounds, which are antioxidants. Antioxidants are needed to prevent oxidative stress, which plays an important role in the etiology of various degenerative diseases[3].

Jember robusta green coffee contains the highest phenol compounds and antioxidant activity compared to robusta green coffee from other regions in East Java. Robusta Jember green coffee contains 35,670 mg GAE/g phenol compound and IC50 value (which shows antioxidant activity) of...
62.507 ppm[4]. So far, the green coffee is only enjoyed by brewing it in warm water without added sugar. A more practical way to get nutrients from green coffee is to extract the polyphenol compounds contained in it.

In processing green coffee extract powder, it needs a coating (encapsulate) and foaming agent. The capsule material often used in the foam mat drying technique is maltodextrin, while tween 80 is used as a foaming agent. The reason for using maltodextrin as a coating material is due to its solubility to water that gives protection from oxidation and damage, additionally, maltodextrin is relatively cheap and affordable. Tween 80 was chosen because of its function other than as a foaming agent, and an emulsifier. Combining these two materials is often used in the drying process using the foam mat drying method. The principle of drying foam is to convert liquid products into stable foam by adding stabilizers and foaming agents [5].

Optimal concentrations of maltodextrin and tween 80 in the formulation of functional drinks from a mixture of Dutch eggplant juice and purple passion fruit are 17.48% and 0.87%[6]. A research is needed to optimize maltodextrin concentration and tween 80 in the green coffee extract to obtain green coffee extract with a total phenol content and high antioxidant activity.

2. Materials and Methods

2.1 Types of equipment
Tools used for the extraction of green coffee powder are disc mill (54 length\*75 width\*98 height cm), blender (Miyako BL 101 PL), glass bottle 1000 mL, filter cloth, measuring glass 250 mL (Pyrex Iwaki), beaker glass 500 mL (Pyrex Iwaki), beaker glass 1000 mL (Pyrex Iwaki), glass funnel (Pyrex Iwaki), cabinet dryer (120*50*180 cm), non-sticky baking sheet, dan mixer (Miyako HM 620). Tools used to measure a total of phenol and antioxidant include spectrophotometry UV-Vis (Thermo Scientific Genesys 10 UV), analytical scales (Tanita 1479Z), measuring glass 25 mL (Pyrex Iwaki), measuring pipette (Pyrex Iwaki), and test tube (Pyrex Iwaki).

2.2 Materials
The material used to make green coffee powder extract is green beans coffee robusta variety from Jember, maltodextrin, tween 80, and aquades. Materials used to measure total phenol, and antioxidant activity are Folin-Ciocalteu 10%, sodium carbonate 7.5%, standard of galat acid solution, methanol, DPPH solution, dan aquades.

2.3 Research design
The research design uses the Response Surface Methodology (RSM) with a Central Composite Design. This study uses two variables, namely the concentration of maltodextrin (X1) and tween 80 (X2). The optimized response is total phenol content and antioxidant activity. The steps to determine the level of a factor are as follows:

Determine the level of factors to be examined and each factor is divided into three levels with codes +1, -1, and 0 as follows: Concentration of maltodextrin (A), the levels of maltodextrin are 12% (X1 = -1), 17% (X1 = 0), and 22% (X1 = +1) with distance between the levels 5%. Concentration of tween 80 (B), the levels of tween 80 are 0.4% (X2 = -1), 0.9% (X2 = 0), and 1.4% (X2 = +1) with distance between the level is 0.5%.

2.4 Research implementation
2.4.1 Making green coffee powder
Green coffee beans are sorted to separate green coffee beans that are no longer intact, and whole green coffee beans are mashed using a disc mill to get green skinless coffee beans. Skinless green coffee beans are refined using a disc mill to get coarse cracked green coffee beans. Then, coarse crushed green coffee beans are refined using a blender to get finely broken green coffee beans. Finally, finely chopped green coffee beans are sieved using a 40 mesh sieve to get green coffee powder.
2.4.2 Extraction of polyphenol compounds
Green coffee powder weighed 300 grams, and Green coffee powder added 3,000 mL aquades. The mixture of green coffee powder and distilled water macerated for 24 hours at room temperature (± 25 °C) without stirring. The extraction results are stored in glass bottles.

2.4.3 Microencapsulation of green coffee extract
Green coffee extract is measured as much as 250 mL. Green coffee extract then is mixed with maltodextrin and tween 80 with concentrations according to the experimental design. A mixture of green coffee extract, maltodextrin, and tween 80, is shaken to form a foam at maximum speed within 15 minutes. The mixture that has been shaken is made a layer on a baking sheet with a thickness of 1-3 mm. A mixture of green coffee extract, maltodextrin, and tween 80, dried using a cabinet dryer with a temperature of 70 ± 5 °C for 7 hours to 8 hours. Subsequently, dry green coffee extract is blended using a blender with a minimum speed of 5 minutes.

2.4.4 Observation and data analysis
Observation of green coffee extract powder is determined total phenol and antioxidant activity (IC 50). The testing of total phenolic content was carried out according to the modification procedure [7]. This test consists of 2 steps: making a standard curve and making a sample solution. Analysis of antioxidant activity was carried out by the DPPH method [8]. This method’s parameters are 50% inhibition concentration (IC50) or concentration that can reduce free radical activity by 50%. The data obtained from green coffee extract powder testing results were then processed using the Minitab 17 program.

Table 1. The response of total phenol and antioxidant activity (IC50).

| No | X1  | X2  | Concentration of Maltodextrin (%) | Concentration of Tween 80 (%) | Total Phenol (mg GAE/g) | IC50 (ppm) |
|----|-----|-----|----------------------------------|------------------------------|-------------------------|------------|
| 1  | 1   | -1  | 12.00                            | 0.40                         | 171                     | 59.19      |
| 2  | -1  | 1   | 22.00                            | 0.40                         | 145.13                  | 76.931     |
| 3  | -1  | 1   | 12.00                            | 1.40                         | 170.565                 | 59.156     |
| 4  | 1   | 1   | 22.00                            | 1.40                         | 137.957                 | 78.181     |
| 5  | -1.414 | 0  | 9.93                             | 0.90                         | 169.261                 | 27.908     |
| 6  | 1.414 | 0  | 24.07                            | 0.90                         | 135.565                 | 81.184     |
| 7  | 0   | -1.414 | 17.00                          | 0.19                         | 171.217                 | 68.774     |
| 8  | 0   | 1.414 | 17.00                          | 1.61                         | 170.783                 | 47.866     |
| 9  | 0   | 0   | 17.00                            | 0.90                         | 171.435                 | 25.716     |
| 10 | 0   | 0   | 17.00                            | 0.90                         | 174.043                 | 27.853     |
| 11 | 0   | 0   | 17.00                            | 0.90                         | 181.652                 | 25.159     |
| 12 | 0   | 0   | 17.00                            | 0.90                         | 189.696                 | 24.091     |
| 13 | 0   | 0   | 17.00                            | 0.90                         | 187.522                 | 39.273     |

3. Results and Discussion

3.1 Total phenol
Testing of total phenolic content (total phenol) aims to determine the concentration of phenol compounds in each gram of green coffee extract powder. The research data can be seen in Table 1. The increase in total phenol content in maltodextrin concentrations was 9.93%, and tween 80 was 0.90% to maltodextrin concentrations of 17.00%, and tween 80 0.90% showed that at these concentrations, the response was not yet the optimum. At maltodextrin concentration 17.00% and tween 80 0.90% to maltodextrin concentration 24.07%, and tween 80 0.90% the total phenol response
decreased. It is predicted that the optimum total phenol response value can be obtained at maltodextrin concentrations around 17.00% and tween 80 around 0.90%. The optimum response or the best conditions for optimization to obtain maximum results, characterized by an increase in response to a certain point, the response has decreased. The turning point is the optimum point of response.

Variance analysis (ANOVA) was carried out to test whether the tested factors had a significant effect on the responses produced. The analysis also shows the lack of fit to test the accuracy of the second-order regression model. Table 2 presents the analysis of variance data on the total phenol response.

Based on Table 2, it is known that the quadratic model has a significant effect (P-value < 0.05) which is 0.0018. This means that the quadratic model can accurately describe the total phenol response. Maltodextrin concentration factor has a (p-value < 0.05), which is equal to 0.0010. This means that the maltodextrin concentration factor has a significant effect on the total phenol response. Tween 80 concentration factor has a (p-value > 0.05), which is equal to 0.6893, so it can be said that the tween 80 concentration factor has no significant effect on the total phenol response. The lack of fit (p-value >0.05) means that the quadratic model has no significant difference in the total phenol response and can explain a problem from the analysis under study. The result of Table 2 means that the quadratic model can accurately describe the total phenol response model.

Table 2. ANOVA of total phenol responses.

| Sources      | P-Value (Prob>F) |
|--------------|-----------------|
| Model        | 0.002           |
| Maltodextrin | 0.001           |
| Tween 80     | 0.689           |
| Quadrat      | 0.002           |
| Lack-of-fit  | 0.746           |

The relationship between maltodextrin and tween 80 concentration factors with the total phenol response is illustrated through the actual equation (Equation 1) as well as the contour and surface response maps shown in Figure 1 and Figure 2.

\[
Y_1 = 16.5 + 19.19A + 54.9B - 0.625A^2 - 25.3B^2 - 0.67AB
\] (1)
Figure 2 shows the relationship or interaction between maltodextrin and tween 80 concentration factors on the total phenol response in 3D graphics. Brightly colored areas indicate the higher total phenol content and become the optimum point. Based on Figure 2, it appears that the total phenol content increases with increasing maltodextrin and tween 80 concentrations to a certain point (concentration), the total phenol content decreases.

The higher the capsule (maltodextrin), the total phenol content will be lower because the ratio of the encapsulant to extract ratio is greater. In the microencapsulation process of green coffee extract, maltodextrin acts as a coating to coat the core substance [9]. Maltodextrin positions were enveloping phenolic compounds that are sensitive to light, oxygen, and heat during the heating process to protect the coated compound. The use of maltodextrin has advantages in the form of low viscosity and high solubility [10], and a high binding capacity in forming the microencapsulate matrix [11].

3.2 Antioxidant activity (IC$_{50}$)
Antioxidant activity was tested using the DPPH method (2,2-diphenyl-1-picrylhydrazyl) in which the value of free radical scavenging activity was expressed as IC$_{50}$. The IC$_{50}$ value is defined as the magnitude of the test compound’s concentration that can reduce free radicals as much as 50% of the total DPPH used in testing (1 mL DPPH 0.2 mM in methanol). The smaller the IC$_{50}$ value, the higher the free radical scavenging activity, so that the level of antioxidant strength is greater [12]. Based on Table 1, it is known that a decrease in IC$_{50}$ content occurred at maltodextrin concentrations of 9.93% and tween 80 0.90% to maltodextrin concentrations of 17.00% and tween 80 0.90%. This shows that at this concentration, an optimum response has not been obtained. At maltodextrin concentration 17.00% and tween 80 0.90% to maltodextrin concentration 24.07% and tween 80 0.90% IC$_{50}$ value experienced an increase. It is predicted that the optimum response value of antioxidant activity (IC$_{50}$ value) can be obtained at maltodextrin concentrations around 17.00% and tween 80 around 0.90%. The optimum response for optimization, which aims to obtain the minimum value, is characterized by a decrease in response to a certain point. The response has increased. The turning point is the optimum point of response.

Similar to the total phenol response, antioxidant activity has also performed an analysis of variance (ANOVA). Based on Table 3, it is known that the quadratic model has a significant effect because of the (p-value < 0.05), which is 0.002. This means that the quadratic model can accurately describe the response of antioxidant activity. Maltodextrin concentration factor has a (p-value < 0.05), which is equal to 0.006. This means that the maltodextrin concentration factor has a significant effect on the total phenol response.
Table 3. ANOVA responses of antioxidant activity (IC\textsubscript{50}).

| Sources       | Value of P (Prob>F) |
|---------------|---------------------|
| Model         | 0.005               |
| Maltodextrin  | 0.006               |
| Tween 80      | 0.363               |
| Quadrat       | 0.002               |
| Lack-of-fit   | 0.075               |

Tween 80 concentration factor has a (p-value > 0.05) equal to 0.363, so it can be said that the tween 80 concentration factor does not significantly affect the total phenol response. The lack of fit (p-value > 0.05) means that the quadratic model has no significant effect on antioxidant activity responses and can explain a problem from the type of analysis being studied. The results Table 3 means that the quadratic model can accurately describe the response of antioxidant activity.

The relationship between maltodextrin and tween 80 concentration factors with antioxidant activity responses is illustrated through the actual equation (Equation 2) and the contour and surface response maps shown in Figure 3 and Figure 4.

\[
Y_2 = 232.7 - 19.14A + 138.4B + 0.642A^2 + 71.7B^2 + 0.13AB
\]  

(2)

Figure 3 shows the interaction between maltodextrin and tween 80 concentration factors on antioxidant activity response in a 3D graphic. Brightly colored areas indicate the lower IC\textsubscript{50} value and become the optimum point. Based on Figure 4, it appears that the IC\textsubscript{50} value decreases with increasing concentration of maltodextrin and tween 80 to a certain point (concentration) IC\textsubscript{50} value increases. The higher the concentration of maltodextrin added, the lower the measured antioxidant activity. This relates to the total solids contained in an ingredient[13]. The more total solids in the powder, the fewer antioxidant compounds such as phenol and vitamin C are measured so that antioxidant activity decreases.

Maltodextrin coating materials can maintain the functional value of the core material more resistant to damage during storage [14], and maltodextrin can protect the release of nutritional components, protect important compounds such as antioxidant components due to extreme temperatures because it can form a protective layer (body) and has a strong binding capacity to compounds the coated one[15].

3.3 Optimization of response
The total phenol response was chosen with a maximum target because the study aimed to obtain a formula with a high total phenol content. For the response of the antioxidant activity, the minimum target was to obtain a low IC\textsubscript{50} value (strong antioxidant activity). The optimum solution obtained
was the concentration of maltodextrin of 14.78% and tween 80 0.93%. This solution produces green coffee extract powder with a total phenol content of 183.639 mg GAE / g and an IC50 value of 25.187.

After obtaining the program’s optimum solution results for both factors, it is necessary to verify to try and see how accurate the program is in predicting results. A Comparison of actual verification results with optimum predictions in the program is presented in Table 4. Accuracy values obtained in all replications exceed 50%, so it can be said that the model is sufficiently accurate to predict the optimum results.

Table 4. Verification result.

| Parameter     | Total Phenol | IC50       |
|---------------|--------------|------------|
|               | value        | accuracy (%) | value        | accuracy (%) |
| Verification 1| 199.261      | 92.16      | 23.234       | 92.24        |
| Verification 2| 196.000      | 93.69      | 25.436       | 99.01        |
| Verification 3| 201.217      | 91.26      | 25.148       | 98.86        |
| Average of verification | 198.826 | -          | 24.606       | -            |

3.4 Comparison of optimum solution results with green coffee capsules

After testing the total phenol content and antioxidant activity of the optimum solution, a comparison was made between the study results with green coffee capsules on the market. This is done because there is no Indonesian National Standard (SNI) regulating the minimum nutrient content in green coffee extracts. As a comparison, "X" brand green coffee capsules are used on the market. A Comparison of the content of green coffee capsules can be seen in Table 5.

Table 5. Comparison of research results with green coffee capsules X.

| Parameter     | Result | Brand “X” |
|---------------|--------|-----------|
| Total phenol(mg GAE/g) | 198.826 | 57.52 |
| IC50 (ppm)    | 24.606 | 87.65 |

The antioxidant activity of the green coffee capsules brand "X" on the market is classified as active antioxidant activity, while the optimum solution results in very active antioxidant activity. However, this study’s final results still need to be investigated further to become a preparation that can be directly consumed to obtain a product that is ready to be used by patients and achieved the desired therapeutic effect.

4. Conclusions
The optimization factor of maltodextrin concentration and tween 80 concentration showed optimum results at maltodextrin concentration of 14.78% and tween 80 concentration of 0.93%. This formula produces green coffee extract ingredients containing 198.826 mg GAE / g total phenols and IC50 values representing the antioxidant activity of 24,606 ppm and classified as very active antioxidants.

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