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Manuscript title: Factorial experimental design for optimizing the roasting condition of Banana Peel (Musa paradisiaca var Semeru): characteristics and antioxidant activity

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Factorial experimental design for optimizing the roasting condition of ~~Banana~~ banana ~~Peel~~ peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity

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Abstract

Banana peel is an organic waste that has not been widely used. The rich content of vitamins, minerals, antioxidants~~,~~ and tryptophan is the background for research utilizing organic waste for something useful. This study aims to determine the optimum banana peel roasting conditions with the content of antioxidants and antidepressants (tryptophan). Optimum conditions ~~will be~~was determined by factorial design. The variables analyzed were roasting temperature (180°C and 200°C) and roasting time (15 and 20 minutes). Responses to determine the optimum conditions were water content, color similarity with local coffee products~~,~~ and antioxidant activity (IC_{50}). Antioxidant activity was measured using the 2,2-diphenyl-1-picrylhydrazyl method. The characteristics of banana peel powder and roasted banana peel powder are determined by several parameters, indicating the presence of beneficial substances and even richness in vitamins and minerals, as well as the presence of tryptophan. The scavenging activity of roasted banana peel powder was higher at high temperatures and longer during roasting. The lowest water content was at 200°C and 20 minutes of roasting conditions. A brownish color resembling ground coffee

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is obtained with a roasting temperature of 200~~-~~°C. The interaction between temperature and roasting time affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The optimum conditions selected were 200~~-~~°C roasting conditions; 20 minutes will produce a water content of 2.00%, color similarity 11.80~~,~~ and IC_{50} 1979.2 (ppm). In addition, the presence of tryptophan in banana peel powder has the opportunity to be used as an antidepressant compound.

Keywords: ~~banana~~ Banana peel, ~~factorial~~ Factorial design, ~~roasting~~ Roasting condition, ~~antioxidant~~Antioxidant, ~~antidepressant~~Antidepressant

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1. Introduction

Banana peel from *Musa paradisiaca* L. var. Semeru is an organic waste produced from the processing of bananas. Banana peel is a third part of the banana fruit, with various nutritious substances, including carbohydrates, fats, proteins, vitamins, minerals, polyphenolic compounds~~,~~ and tryptophan. Polyphenol compounds can be used as a natural antioxidant, anti-bacterial, and anti-inflammatory compounds, while tryptophan is a compound with mood-improving effects (Someya *et al.*, 2002; Khawas and Deka, 2016~~; Someya *et al.*, 2002~~).

~~Until now~~To date, the utilization of banana peel waste still has low economic value. ~~One~~ A previous study made starch from banana peels (Hadisoewignyo *et al.*, 2017). This study uses banana peels as an ingredient that will function as a source of antioxidants and antidepressants. Banana peel will be made into powder and will be roasted. The roasting process will produce a unique taste, aroma, and darker color appearance. Moreover, the roasting process can affect the ingredients' water content, color~~,~~ and antioxidant activity.

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During the roasting process, heat transfer occurs from the roaster into the material, and water mass is transferred, affecting the moisture content of the roasted powder. The length of the roasting time will affect the water content in the roasted powder. In addition to the water content, the roasting process will also affect the color of the roasted material. The higher the roasting temperature and the longer the roasting time, the darker the material's color.

Free radicals are unstable, reactive molecules or atoms that can cause the degradation of body cells. Those radicals participate in the aging and pathogenesis of diseases (Halliwell, 2012). Our body needs antioxidants to catch those radicals through catalyzing the destruction of free radicals (binding free radicals), acting as a primary antioxidant (donates hydrogen protons), reducing agent (donates electrons), reducing the formation of singlet oxygen (^{1}O2), and binds metals (metal chelators) (Sharma *et al.*, 2018).

Banana peel has been made into a coffee analog drink through roasting, but the optimum roasting condition has not been determined yet (Mentari *et al.*, 2019; Sofa *et al.*, 2019). A previous study showed that cocoa bean shells roasted at temperatures of 110 °C, 140 °C, and 190 °C produced higher antioxidant activity than those not roasted (room temperature ± 25 °C). The optimum antioxidant activity was reached by roasting at 140 °C, not the highest temperature. Moreover, the temperature and roasting time greatly influence sensory properties. This study will determine the optimum roasting temperature of Agung banana peel (Utami *et al.*, 2017).

The temperature and the length of roasting time will cause acrylamide formation through the Maillard reaction. In this research, the roasting process will be optimized with the responses used: color, water content, and antioxidant power. After obtaining the optimum conditions, the characteristics of the roasted banana peel powder at optimum conditions will be compared with the banana peel powder before roasting.

2. Materials and methods

2.1 Materials

The raw material used is Agung banana peel from Lumajang, East Java, Indonesia. The ~~tested~~ chemicals used were of analytical grade, including DPPH reagent pa (Merck), methanol pa (Merck)~~,~~ and distilled water. The equipment used is a roaster, chopper, oven, analytical balance, spectrophotometer (UV-Vis Thermo Scientific, Genesys 10S UV), magnetic stirrer, colorimeter Linshang LS171, Ohaus moisture analyzer MB25, vortex Dlab MX-S, micropipette~~,~~ and glassware.

2.2 Optimization of ~~Banana~~ banana ~~Peel~~ peel ~~Powder~~ powder ~~Processing~~ processing with ~~Factorial~~ factorial ~~Design~~design

The roasting process was optimized using the factorial design method with two factors and two levels. The factors used are the temperature of the roaster and the roasting time. The temperature levels were 180 °C and 200 °C and the roasting time was 15 minutes and 20 minutes. Water content, powder color~~,~~ and antioxidant activity (IC_{50}) were the observed responses to obtain the optimum process. The optimum condition was analyzed using Design Expert software ver 10.0.1.

Banana peels are washed, chopped (1x1 cm), dried, ground~~,~~ and sieved with 80 mesh. The banana peel powder was roasted~~,~~ as mentioned in Table 2.

2.3~~.~~ Moisture ~~Content~~ content ~~Analysis~~analysis

The moisture content of the banana powder was determined after the roasting process using a moisture balance analyzer.

2.4 Color ~~Analysis~~analysis

The color of roasted banana peel powder was measured using a colorimeter. L*, a*, b* values obtained represent three dimentions:1. L* represents the light-dark spectrum with a range from 0 to 100 d(black to white), 2. a* value represents the green-re spectrum with a range from -60 to +60 (green to

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red), 3. b* value represents the blue-yellow spectrum with a range from -60 to +60 (blue to yellow). The L*, a*, and b* values were then converted into ΔE^*_{ab} Values using equation 1.

$$\Delta \boldsymbol{E}^*_{ab} = \sqrt{(\boldsymbol{L}^*_2 - \boldsymbol{L}^*_1)^2 + (\boldsymbol{a}^*_2 - \boldsymbol{a}^*_1)^2 + (\boldsymbol{b}^*_2 - \boldsymbol{b}^*_2)^2} \quad (1)$$

L*a*b* Color Difference Compare with Local Coffee Product

2.5 DPPH ~~Radical~~ radical ~~Scavenging~~ scavenging ~~Activities~~activities

The DPPH radical scavenging activity (DPPH-RSA) test was carried out using the Burda and Oleszek (2001) method. 12.5 mg of the sample was dissolved in 25 mL of methanol. Then 1 mL of the solution was pipetted~~,~~ and 2 mL of 0.1 mM DPPH solution was added. Then it was incubated in a dark room for 30 minutes at room temperature, and then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength (λ) of 517 nm. Antioxidant activity as a free radical scavenger was expressed as IC_{50} (µg/mL), which indicates the sample's concentration that can inhibit free radicals by 50%.

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3. Results and discussion

3.1 Characteristics of ~~Banana~~ banana ~~Peel~~ peel ~~Powder~~ powder and ~~Roasted~~ roasted ~~Banana~~ banana ~~Peel~~ peel ~~Powder~~powder

The characteristics of banana peel powder and roasted banana peel powder (Figure 1) were determined by several parameters, as shown in Table 1. Banana peels contain high amounts of minerals, especially sodium, potassium, calcium, magnesium, iron~~,~~ and zinc. In addition, there are also several vitamins, including vitamin C and beta-carotene~~,~~ in a reasonably high amount. Dietary and insoluble dietary fiber is available in relatively high quantities in roasted and non-roasted banana peel powder. The insoluble dietary fiber in banana peels was high enough to benefit the body, especially the digestive system. In addition, heavy metal contamination is determined for roasted and non-roasted banana peel powder. The content of lead, cadmium, copper, tin~~,~~ and mercury does not exceed the required provisions.

The test on microbial contamination (Table 2) showed that the total plate count and the number of yeast molds were lower in the roasted banana peel powder. That was related to the use of high temperatures in the roasting process.

The presence of high carbohydrate content in banana peel powder and the heat during processing allows the formation of acrylamide, which is formed through various reactions, one of which is the Millard reaction (reaction between amino acids and reducing sugars). In the roasting process, the temperature used ~~is~~ was 200 °C, where high temperatures can increase the formation of acrylamide, so the acrylamide content is higher in roasted banana peel powder (0.475 µg/g).

The presence of tryptophan in banana peels can relieve symptoms of depression and mood disorders. Tryptophan turns into serotonin when it breaks down, which can improve mood. The presence of tryptophan in banana peels can be used as an antidepressant. The tryptophan content in unroasted banana peel powder was higher than that of roasted banana peel powder, 0.1% and 0.01% (w/w), respectively. The roasting process can reduce the tryptophan content because tryptophan is unstable at high temperatures.

3.2 Moisture ~~Content~~ content and ~~Color~~ color ~~Determination~~determination

The moisture content of the roasted banana peel was determined using a moisture content analyzer (Table 4). The moisture content is lowest in the fourth roasting condition (200 °C, 20 minutes). Controlling moisture content was essential for optimal process control, maintaining high product quality, and compliance with regulations (Wernecke and Wernecke, 2014). Although roasting can kill microbe's toxins and deactivate enzymes, the process can affect the nutrition status. A roasting process can influence color, aroma, taste~~,~~ and antioxidant properties (Sruthi *et al.*, 2021).

The brownish color resembling ground coffee is achieved with 200 degrees of roasting (Table 4, Figure 2). The visual appearance of the color could be an indicator of the roasting degrees and play as an indicator to stop the roasting process. During roasting, some important reactions are the Maillard reaction which induces aroma, the caramelization that creates the color, and pyrolysis, which creates a signature aroma and taste (Tarigan *et al.*, 2022). Maillard reaction has melanoidins as the end product with reducing properties, absorbing oxygen~~,~~ and metal chelating capacity. Color can be an index of the antioxidant properties of food (Pokorný and Schmidt, 2003).

3.2 Antioxidant ~~Activity~~activity

The scavenging activity of roasted banana peel powder was higher in high temperatures and more prolonged during the duration of roasting (Table 4). This result was ~~in line~~in agreement with ~~the~~ a previous study, which reported a lower IC_{50} value with a longer drying time for banana peel (Mentari *et al.*, 2019). Some compounds with antioxidant properties can get lost during roasting, but new compounds with antioxidant activity were created during the Maillard reaction. Maillard reaction is also responsible for forming volatile compounds that contribute to the aroma of the food (Diaz-de-Cerio *et al.*, 2019).

Some antioxidant molecules are formed during the roasting process, ~~namely~~ such as phenylalanine and heterocyclic compounds (Poncet *et al.*, 2021). Phenolic compounds were considered one of the quality markers of the roasting process (Diaz-de-Cerio *et al.* 2019). Although enzymatic or chemical oxidation of polyphenols can reduce the antioxidant capacity, higher antioxidant activity is shown by partially oxidized polyphenols (Pokorný and Schmidt, 2003). A previous study reported that the maximum antioxidant activity was in medium-roasted coffee, and dark-roasted coffee has a lower antioxidant value (Nicoli *et al.*, 1997; del Castillo *et al.*, 2002~~; Nicoli *et al.*, 1997~~). Other studies reported the highest antioxidant capacity in lightly roasted coffee (Duarte *et al.*, 2005).

3.3 Optimization of the roasting condition using factorial design

Roasting temperature and time will significantly affect several parameters of the roasted powder, such as the resulting color and antioxidant content. The roasting conditions must be optimal per the standard criteria to produce the roasted powder. Therefore, optimizing the roasting process will provide optimal conditions to make the desired roasted powder. Optimization is carried out using a factorial design with two factors and two levels. The temperature and time of the roasting optimization condition were analyzed using the factorial design method using the software Design Expert ver 10.0.1. Polynomial equations (Table 5) were built based on the moisture content, color similarity~~,~~ and IC_{50} value. Y is the response~~,~~ and X is the value of the level of concentration. Roasting time and temperature influenced color similarity, moisture content~~,~~ and IC_{50} value. A longer roasting time resulted in lower moisture content.

Based on the polynomial equation, it can be seen that the interaction between temperature and roasting time dominantly affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The color change of the roasted powder depends on the length of the roasting time. The longer the roasting time, the darker color will appear, in this case, giving a darker brown color. The contour plot of moisture content, color similarity~~,~~ and IC_{50} have been established based on polynomial equations (Figure 3).

Optimum conditions were gained with superimposed (Figure 4). The yellow area on the superimposed contour plot depicts the optimum area. The optimum condition chosen was 200°C for 20 minutes of roasting temperature. The optimum condition will result in moisture content of 2.00%, color similarity of 11.80~~,~~ and IC_{50} of 1979.2 (ppm). The previous hedonic test study showed that panelists prefer a darker color, a more pungent aroma~~,~~ and a bitter coffee analog from the banana peel (Hasbullah *et al.*, 2021). So, it is probable that panelists will also prefer this optimum condition of the Agung banana peel coffee analog.

4. Conclusion

Roasted banana peel can be considered a food raw material with antioxidant activity and an antidepressant. The optimum condition chosen was the roasting condition of 200°C; 20 minutes will result in moisture content of 2.00%, color similarity of 11.80, and IC_{50} of 1979.2 (ppm). A hedonic test will be required to gain panelist preference for the taste and aroma of this Agung banana peel coffee analog. The presence of tryptophan in banana peel powder has the opportunity to be used as an antidepressant compound.

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The authors declare no conflict of interest.

Acknowledgments

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Table 1. Characteristics of non-roasted and ~~Roasted~~ roasted ~~Banana~~ banana ~~Peel~~ peel ~~Powder~~powder

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Water content (%)	4.42	2.38
Ash content (%)	10.24	10.59
Acid insoluble ash (%)	0.07	0.09
Protein (%)	6,98	7.12
Fat (%)	3.37	3.04
Carbohydrate (%)	74.99	76.87
Sugar content (%)	3.48	1.83
Reducing sugar (%)	0.90	0.73

Dietary fiber (%)	28.39	30.07
Insoluble dietary fiber (%)	27.40	28.01
Amylose (%)	14.89	15.51
Amylopectin (%)	27.46	25.77
pH	6.74	6.58
Density (g/mL)	0.7308	0.6903
Caffeine (mg/Kg)	<1.20	<1.20
Sodium (mg/Kg)	1099	1066
Potassium (mg/Kg)	113585	135073
Calcium (mg/Kg)	973	1174
Magnesium (mg/Kg)	1420	1544
Iron (mg/Kg)	30.09	34.80
Zinc (mg/Kg)	20,69	22.18
Vitamin A (IU/100 g)	<0.50	<0.50
Betacarotene	76.5	60.7
Vitamin B1 (mg/Kg)	< 0.25	< 0.25
Vitamin B2 (mg/Kg)	<0.25	<0.25
Vitamin B6 (mg/Kg)	<0,20	<0,20
Vitamin C (mg/Kg)	75.5	69.3
Vitamin D (µg/100g)	11.3	3.69
Vitamin E (mg/100g)	3.88	6.20
Folic acid (mg/Kg)	<0.25	<0.25
Tryptophan (%)	0.1	0.01
Acrylamide (µg/g)	0.127	0.475

Table 2. Microbial Contamination on non-roasted and ~~Roasted~~ roasted ~~Banana~~ banana ~~Peel~~ peel ~~Powder~~powder

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Total plate count (colony/g)	7.2×10^{-6}	3.0×10^{-4}
Escherichia coli (APM/g)	<3	<3
Staphylococcus aureus (colony/g)*	0	0
Bacillus cereus (colony/g)**	0	0
Pseudomonas aeruginosa (colony/g)*	0	0
Salmonella sp. (/25g)	Negative	Negative
Mold (colony/g)	7	<10
Yeast (colony/g)	17	<10

Table 3. Factorial design for the roasting condition

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Factors		Selected levels	
		-1	+1
A	Roasting temperature (°C)	180	200
B	Roasting time (min)	15	20

Table 4. Color space, moisture content after roasted, and antioxidant activity after roasting

Roasting Condition	Color Similarity	Moisture Content After Roasted (%)	IC_{50} (ppm)
180°C, 15 minutes	13.47 ± 4.41	1.96 ± 0.06	2450 ± 919.24
180°C, 20 minutes	12.32 ± 3.91	3.00 ± 0.68	2250 ± 495.98
200°C, 15 minutes	11.18 ± 3.82	1.99 ± 1.03	2050 ± 354.55
200°C, 20 minutes	11.81 ± 0.49	1.93 ± 0.18	1950 ± 70.71

Table 5. Polynomial Equation

Response	Polynomial Equation
Moisture Content after roasted (%)	$Y = 2,22 - 0,26(X_a) + 0,25(X_b) - 0,28 (X_a)(X_b)$
Color Similarity	$Y = 12,20 - 0,70(X_a) - 0,13(X_b) + 0,44 (X_a)(X_b)$
IC_{50} (ppm)	$Y = 2175 - 175(X_a) - 75(X_b) + 25 (X_a)(X_b)$

Xa: level value for temperature, Xb: level value for time

Figure 1.Roasted banana peel powder.

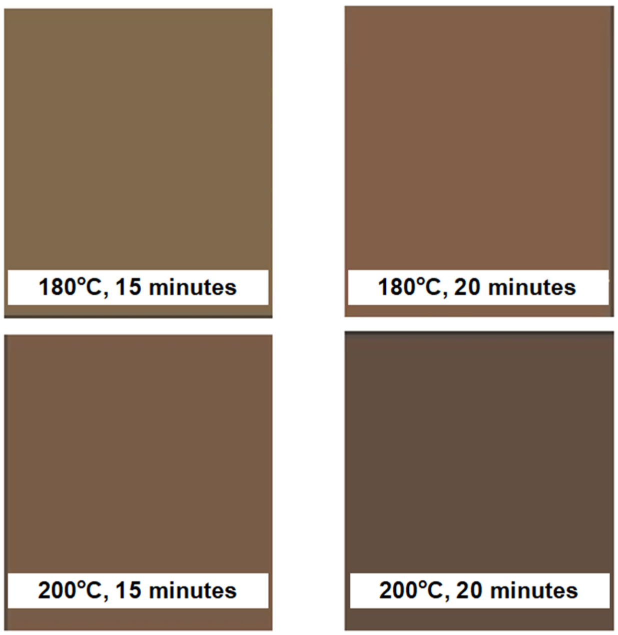
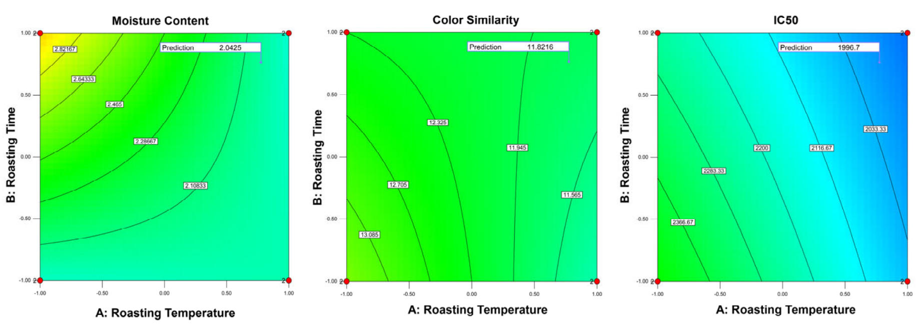


Figure 2. Color of banana peel after roasting.



(A) (B) (C)

Figure 3. Contour plot of moisture content (A), color similarity (B), and IC_{50} (C) of roasting conditions (roasting time and roasting temperature).

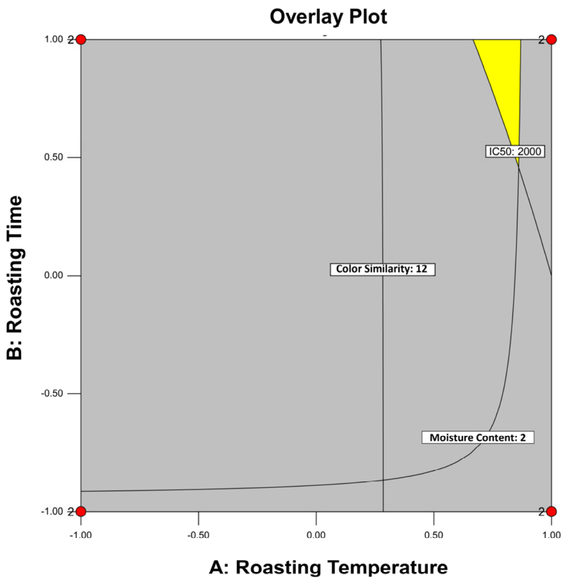


Figure 4. Superimposed contour plot.

3. Revised version received - Oct 15, 2022

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Dear Dr. Lannie Hadisoewignyo,

Thank you for the revised copy of your manuscript. We will contact you again for further processing.
Please expect some delay as we are experiencing a high volume of publications at this time.
Thank you for your understanding.

Best regards,
Son Radu, PhD
Chief Editor

4. Second revision: Minor revisions Oct 18, 2022

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to me

Oct 18, 2022, 3:32 PM

Dear Dr Lannie Hadisoewignyo,

Please address the remaining comments raised in the manuscript and return them to us as soon as possible and we can discuss the invoice.

Best regards,
Son Radu, PhD
Chief Editor

Factorial experimental design for optimizing the roasting condition of Banana Peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity

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Abstract

Banana peel is an organic waste that has not been widely used. The rich content of vitamins, minerals, antioxidants~~,~~ and tryptophan is the background for research utilizing organic waste for something useful. This study aims to use a factorial design to find the optimum conditions for the banana peel roasting process. The variables analyzed were roasting temperature (180°C and 200°C) and roasting time (15 and 20 mins). Responses to determine the optimum conditions were water content, color similarity with local coffee products~~,~~ and antioxidant activity (IC_{50}). Antioxidant activity was measured using the 2,2-diphenyl-1-picrylhydrazyl method. The characteristics of banana peel powder and roasted banana peel powder ~~are determined by several parameters, indicating~~showed the presence of beneficial substances and even richness in vitamins and minerals, as well as the presence of tryptophan. The scavenging activity of roasted banana peel powder was higher at high temperatures and longer during roasting. The lowest water content was at 200°C and 20 mins of roasting conditions. A brownish color resembling ground coffee is obtained with a roasting temperature of 200°C. The interaction between temperature and roasting time affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The optimum conditions selected were 200°C roasting conditions; 20 mins will produce a water content of 2.00%, color similarity 11.80~~,~~ and IC_{50} 1979.2 (ppm). In addition, the presence of tryptophan in banana peel powder has the opportunity to be used as an antidepressant compound.

***Keywords*:** Banana peel, Factorial design, Roasting condition, Antioxidant, Antidepressant

1. Introduction

Banana peel from *Musa paradisiaca* L. var. Semeru is an organic waste produced from the processing of bananas. Banana peel is a third part of the banana fruit, with various nutritious substances, including carbohydrates, fats, proteins, vitamins, minerals, polyphenolic compounds, and tryptophan. Polyphenol compounds can be used as a natural antioxidant, anti-bacterial, and anti-inflammatory compounds, while tryptophan is a compound with mood-improving effects (Someya *et al.*, 2002; Khawas and Deka, 2016).

During the roasting process, heat transfer occurs from the roaster into the material~~,~~ and water mass is transferred, affecting the moisture content of the roasted powder. The length of the roasting time will affect the water content in the roasted powder. In addition to the water content, the roasting process will also affect the color of the roasted material. The higher the roasting temperature and the longer the roasting time, the darker the material's color.

Free radicals are unstable, reactive molecules or atoms that can cause the degradation of body cells. Those radicals participate in the aging and pathogenesis of diseases (Halliwell, 2012). Our body needs antioxidants to catch those radicals through catalyzing the destruction of free radicals (binding free radicals), acting as a primary antioxidant (donates hydrogen protons), reducing agent (donates electrons), reducing the formation of singlet oxygen ($^1O_2$)~~,~~ and binds metals (metal chelators) (Sharma *et al.*, 2018).

Banana peel has been made into a coffee analog drink through roasting, but the optimum roasting condition has not been determined yet (Mentari *et al.*, 2019; Sofa *et al.*, 2019). A previous study showed

that cocoa bean shells roasted at temperatures of 110~~ ~~°C, 140°C~~,~~ and 190°C produced higher antioxidant activity than those not roasted (room temperature ± 25°C). The optimum antioxidant activity was reached by roasting at 140°C, not at the highest temperature. Moreover, the temperature and roasting time greatly influence sensory properties. This study will determine the optimum roasting temperature of Agung banana peel (Utami *et al.*, 2017).

~~The temperature and the length of roasting time will cause acrylamide formation through the Maillard reaction. In this research, the roasting process will be optimized with the responses used, color, water content, and antioxidant power. After obtaining the optimum conditions, the characteristics of the roasted banana peel powder at optimum conditions will be compared with the banana peel powder before roasting.~~

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To date, the utilization of banana peel waste still has low economic value. One previous study made starch from banana peels (Hadisoewignyo *et al*., 2017). This study ~~will~~ use banana peels as an ingredient that ~~will~~ work as a source of antioxidants and antidepressants. Banana peel ~~will be~~is made into powder and ~~will be~~ roasted. ~~The roasting process will produce a unique taste, aroma, and color appearance. In addition, t~~The roasting process can affect the air content, color, and antioxidant activity of the ingredients, it is necessary to determine the optimal conditions of the roasting process.

2. Materials and methods

2.1 Materials

The raw material used is Agung banana peel from Lumajang, East Java, Indonesia. The chemicals used were of analytical grade, including DPPH reagent pa (Merck), methanol pa (Merck), and distilled water. The equipment used is a roaster, chopper, oven, analytical balance, spectrophotometer (UV-Vis Thermo Scientific, Genesys 10S UV), magnetic stirrer, colorimeter Linshang LS171, Ohaus moisture analyzer MB25, vortex Dlab MX-S, micropipette, and glassware.

2.2 Optimization of banana peel powder processing with factorial design

The roasting process was optimized using the factorial design method with two factors and two levels. The factors used are the temperature of the roaster and the roasting time. The temperature levels were 180°C and 200°C and the roasting time was 15 mins and 20 mins. Water content, powder color, and antioxidant activity (IC_{50}) were the observed responses to obtain the optimum process. The optimum condition was analyzed using Design Expert software ver 10.0.1.

Banana peels are washed, chopped (1×1 cm), dried, ground~~,~~ and sieved with 80 mesh. The banana peel powder was roasted~~,~~ as mentioned in Table 2.

2.3. Moisture content analysis

The moisture content of the banana powder was determined after the roasting process using a moisture balance analyzer.

2.4 Color analysis

The color of roasted banana peel powder was measured using a colorimeter. L*, a*, b* values obtained represent three dimentions:1. L* represents the light-dark spectrum with a range from 0 to 100 d(black to white), 2. a* value represents the green-re spectrum with a range from -60 to +60 (green to red), 3. b* value represents the blue-yellow spectrum with a range from -60 to +60 (blue to yellow). The L*, a*, and b* values were then converted into $\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$ Values using equation 1.

$$\Delta \boldsymbol{E}^*_{\boldsymbol{ab}} = \sqrt{(\boldsymbol{L}^*_2 - \boldsymbol{L}^*_1)^2 + (\boldsymbol{a}^*_2 - \boldsymbol{a}^*_1)^2 + (\boldsymbol{b}^*_2 - \boldsymbol{b}^*_2)^2} \qquad (1)$$

L*a*b* Color Difference Compare with Local Coffee Product

2.5 DPPH radical scavenging activities

The DPPH radical scavenging activity (DPPH-RSA) test was carried out using the Burda and Oleszek (2001) method. A weight of 12.5 mg of the sample was dissolved in 25 mL of methanol. Then 1 mL of the

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solution was pipetted, and 2 mL of 0.1 mM DPPH solution was added. Then it was incubated in a dark room for 30 mins at room temperature, and then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength (λ) of 517 nm. Antioxidant activity as a free radical scavenger was expressed as IC_{50} (μg/mL), which indicates the sample's concentration that can inhibit free radicals by 50%.

3. Results and discussion

3.1 Characteristics of banana peel powder and roasted banana peel powder

The characteristics of banana peel powder and roasted banana peel powder (Figure 1) were determined by several parameters, as shown in Table 1. Banana peels contain high amounts of minerals, especially sodium, potassium, calcium, magnesium, iron~~,~~ and zinc. In addition, there are also several vitamins, including vitamin C and beta-carotene, in a reasonably high amount. Dietary and insoluble dietary fiber is available in relatively high quantities in roasted and non-roasted banana peel powder. The insoluble dietary fiber in banana peels was high enough to benefit the body, especially the digestive system. In addition, heavy metal contamination is determined for roasted and non-roasted banana peel powder. The content of lead, cadmium, copper, tin, and mercury does not exceed the required provisions.

The test on microbial contamination (Table 2) showed that the total plate count and the number of yeast molds were lower in the roasted banana peel powder. That was related to the use of high temperatures in the roasting process.

The presence of high carbohydrate content in banana peel powder and the heat during processing allows the formation of acrylamide, which is formed through various reactions, one of which is the Millard reaction (reaction between amino acids and reducing sugars). In the roasting process, the temperature used was $200^{o}C$, where high temperatures can increase the formation of acrylamide, so the acrylamide content is higher in roasted banana peel powder (0.475 μg/g).

The presence of tryptophan in banana peels can relieve symptoms of depression and mood disorders. Tryptophan turns into serotonin when it breaks down, which can improve mood. The presence of tryptophan in banana peels can be used as an antidepressant. The tryptophan content in unroasted banana peel powder was higher than that of roasted banana peel powder, 0.1% and 0.01% (w/w), respectively. The roasting process can reduce the tryptophan content because tryptophan is unstable at high temperatures.

3.2 Moisture content and color determination

The moisture content of the roasted banana peel was determined using a moisture content analyzer (Table 4). The moisture content is lowest in the fourth roasting condition (200^{o}C, 20 mins). Controlling moisture content was essential for optimal process control, maintaining high product quality, and compliance with regulations (Wernecke and Wernecke, 2014). Although roasting can kill microbe's toxins and deactivate enzymes, the process can affect the nutrition status. A roasting process can influence color, aroma, taste~~,~~ and antioxidant properties (Sruthi *et al.*, 2021).

The brownish color resembling ground coffee is achieved with 200 degrees of roasting (Table 4, Figure 2). The visual appearance of the color could be an indicator of the roasting degrees and play as an indicator to stop the roasting process. During roasting, some important reactions are the Maillard reaction which induces aroma, the caramelization that creates the color, and pyrolysis, which creates a signature aroma and taste (Tarigan *et al.*, 2022). Maillard reaction has melanoidins as the end product with reducing properties, absorbing oxygen, and metal chelating capacity. Color can be an index of the antioxidant properties of food (Pokorný and Schmidt, 2003).

3.2 Antioxidant ~~Activity~~activity

The scavenging activity of roasted banana peel powder was higher in high temperatures and more prolonged during the duration of roasting (Table 4). This result was in agreement with a previous study, which reported a lower IC_{50} value with a longer drying time for banana peel (Mentari *et al.*, 2019). Some compounds with antioxidant properties can get lost during roasting, but new compounds with antioxidant activity were created during the Maillard reaction. Maillard reaction is also responsible for forming volatile compounds that contribute to the aroma of the food (Diaz-de-Cerio *et al.*, 2019).

Some antioxidant molecules are formed during the roasting process, such as phenylalanine and heterocyclic compounds (Poncet *et al.*, 2021). Phenolic compounds were considered one of the quality markers of the roasting process (Diaz-de-Cerio *et al.* 2019). Although enzymatic or chemical oxidation of polyphenols can reduce the antioxidant capacity, higher antioxidant activity is shown by partially oxidized polyphenols (Pokorný and Schmidt, 2003). A previous study reported that the maximum antioxidant activity was in medium-roasted coffee~~,~~ and dark-roasted coffee has a lower antioxidant value (Nicoli *et al.*, 1997; del Castillo *et al.*, 2002). Other studies reported the highest antioxidant capacity in lightly roasted coffee (Duarte *et al.*, 2005).

3.3 Optimization of the roasting condition using factorial design

Roasting temperature and time will significantly affect several parameters of the roasted powder, such as the resulting color and antioxidant content. The roasting conditions must be optimal per the standard criteria to produce the roasted powder. Therefore, optimizing the roasting process will provide optimal conditions to make the desired roasted powder. Optimization is carried out using a factorial design with two factors and two levels. The temperature and time of the roasting optimization condition were analyzed using the factorial design method using the software Design Expert ver 10.0.1. Polynomial equations (Table 5) were built based on the moisture content, color similarity~~,~~ and IC_{50} value. Y is the response, and X is the value of the level of concentration. Roasting time and temperature influenced color similarity, moisture content~~,~~ and IC_{50} value. A longer roasting time resulted in lower moisture content.

Based on the polynomial equation, it can be seen that the interaction between temperature and roasting time dominantly affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The color change of the roasted powder depends on the length of the roasting time. The longer the roasting time, the darker color will appear, in this case, giving a darker brown color. The contour plot of moisture content, color similarity~~,~~ and IC_{50} have been established based on polynomial equations (Figure 3).

~~Optimum conditions were gained with superimposed (~~In Figure 4~~). ~~, ~~The~~ the yellow area on the superimposed contour plot depicts the optimum area. The optimum condition chosen was 200^{o}C for 20 mins of roasting temperature. The optimum condition will result in moisture content of 2.00%, color similarity of 11.80~~,~~ and IC_{50} of 1979.2 (ppm). The previous hedonic test study showed that panelists prefer a darker color, a more pungent aroma~~,~~ and a bitter coffee analog from the banana peel (Hasbullah *et al.*, 2021). Hence, it is probable that panelists will also prefer this optimum condition of the Agung banana peel coffee analog.

4. Conclusion

Roasted banana peel can be considered a food raw material that has antioxidant and antidepressant activity. The optimum conditions selected based on the factorial design were 200~~ ~~°C; 20 mins. The presence of tryptophan in banana peel powder can be used as an antidepressant compound. It is recommended that further study should be carried out on a hedonic test for the taste and aroma of Agung banana peel coffee analog.

Conflict of interest - Disclose any potential conflict of interest appropriately.

The authors declare no conflict of interest.

Acknowledgments

The research was funded by Ministry of Education, Culture, Research, and Technology of Indonesia under the National Competition Scheme (PDKN, 2022).

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Table 1. Characteristics of non-roasted and roasted banana peel powder

Parameter	**Banana Peel Powder**	**Roasted Banana Peel Powder**
Water content (%)	4.42	2.38
Ash content (%)	10.24	10.59
Acid insoluble ash (%)	0.07	0.09
Protein (%)	6.98	7.12
Fat (%)	3.37	3.04
Carbohydrate (%)	74.99	76.87
Sugar content (%)	3.48	1.83
Reducing sugar (%)	0.90	0.73
Dietary fiber (%)	28.39	30.07
Insoluble dietary fiber (%)	27.40	28.01
Amylose (%)	14.89	15.51
Amylopectin (%)	27.46	25.77
pH	6.74	6.58
Density (g/mL)	0.7308	0.6903
Caffeine (mg/Kg)	<1.20	<1.20
Sodium (mg/Kg)	1099	1066
Potassium (mg/Kg)	113585	135073
Calcium (mg/Kg)	973	1174
Magnesium (mg/Kg)	1420	1544
Iron (mg/Kg)	30.09	34.80
Zinc (mg/Kg)	20.69	22.18

Vitamin A (IU/100 g)	<0.50	<0.50
Betacarotene	76.5	60.7
Vitamin B1 (mg/Kg)	< 0.25	< 0.25
Vitamin B2 (mg/Kg)	<0.25	<0.25
Vitamin B6 (mg/Kg)	<0,20	<0,20
Vitamin C (mg/Kg)	75.5	69.3
Vitamin D (μg/100g)	11.3	3.69
Vitamin E (mg/100g)	3.88	6.20
Folic acid (mg/Kg)	<0.25	<0.25
Tryptophan (%)	0.1	0.01
Acrylamide (μg/g)	0.127	0.475

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Table 2. Microbial contamination on non-roasted and roasted banana peel powder

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Total plate count (colony/g)	7.2×10^{-6}	3.0×10^{-4}
Escherichia coli (APM/g)	<3	<3
Staphylococcus aureus (colony/g)*	0	0
Bacillus cereus (colony/g)**	0	0
Pseudomonas aeruginosa (colony/g)*	0	0
Salmonella sp. (/25g)	Negative	Negative
Mold (colony/g)	7	<10
Yeast (colony/g)	17	<10

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Table 3. Factorial design for the roasting condition

	Factors	Selected levels	
		-1	+1
A	Roasting temperature (°C)	180	200
B	Roasting time (min)	15	20

Table 4. Color space, moisture content after roasted, and antioxidant activity after roasting

Roasting Condition	Color Similarity	Moisture Content After Roasted (%)	IC_{50} (ppm)
180°C, 15 mins	13.47 ± 4.41	1.96 ± 0.06	2450 ± 919.24
180°C, 20 mins	12.32 ± 3.91	3.00 ± 0.68	2250 ± 495.98
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Table 5. Polynomial equation

Response	Polynomial Equation
Moisture Content after roasted (%)	$Y = 2{,}22 - 0{,}26(X_a) + 0{,}25(X_b) - 0{,}28\ (X_a)(X_b)$
Color Similarity	$Y = 12{,}20 - 0{,}70(X_a) - 0{,}13(X_b) + 0{,}44\ (X_a)(X_b)$
IC_{50} (ppm)	$Y = 2175 - 175(X_a) - 75(X_b) + 25\ (X_a)(X_b)$

Xa: level value for temperature, Xb: level value for time

Figure 1.Roasted banana peel powder

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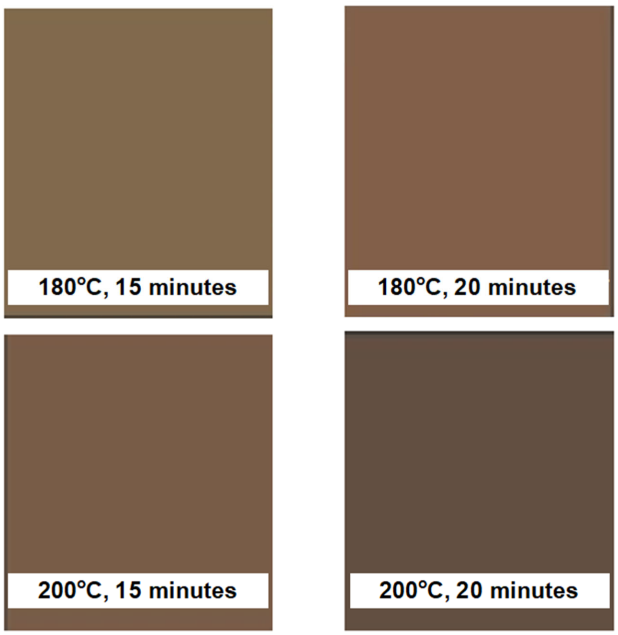

Figure 2. Color of banana peel after roasting

(A) (B) (C)

Figure 3. Contour plot of moisture content (A), color similarity (B), and IC_{50} (C) of roasting conditions (roasting time and roasting temperature)

Figure 4. Superimposed contour plot

5. Second revision submitted - Oct 18, 2022

Dr. Y. Lannie Hadisoewignyo, S.Si., M.Si., Apt <lannie@ukwms.ac.id> Oct 18, 2022, 4:28 PM

to Food

Dear Prof. Son

I agree to the deleted part, while for the lack of literature, and the error in writing a comma which should be a dot, I have corrected it.
Thank you for your cooperation.

Best regards,
Dr. Lannie Hadisoewignyo, M.Si., Apt.
Pharmaceutical Department
Faculty of Pharmacy
Widya Mandala Surabaya Catholic University

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Manuscript Title	Factorial experimental design for optimizing the roasting condition of Banana Peel (Musa paradisiaca var Semeru): characteristics and antioxidant activity		
Authors	Hadisoewignyo, L., Foe, K., Prasetyo, J. and Soeliono, I.		

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Factorial experimental design for optimizing the roasting condition of banana peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity

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Abstract

Banana peel is an organic waste that has not been widely used. The rich content of vitamins, minerals, antioxidants and tryptophan is the background for research utilizing organic waste for something useful. This study aimed to use a factorial design to find the optimum conditions for the banana peel roasting process. The variables analyzed were roasting temperature (180°C and 200°C) and roasting time (15 and 20 mins). Responses to determine the optimum conditions were water content, color similarity with local coffee products and antioxidant activity (IC_{50}). Antioxidant activity was measured using the 2,2-diphenyl-1-

picrylhydrazyl method. The characteristics of banana peel powder and roasted banana peel powder showed the presence of beneficial substances and even richness in vitamins and minerals, as well as the presence of tryptophan. The scavenging activity of roasted banana peel powder was higher at high temperatures and longer during roasting. The lowest water content was at 200°C and 20 mins of roasting conditions. A brownish color resembling ground coffee was obtained with a roasting temperature of 200°C. The interaction between temperature and roasting time affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The optimum conditions selected were 200°C roasting conditions; 20 mins will produce a water content of 2.00%, color similarity 11.80 and IC_{50} 1979.2 (ppm). In addition, the presence of tryptophan in banana peel powder has the opportunity to be used as an antidepressant compound.
Keywords: Banana peel, Factorial design, Roasting condition, Antioxidant, Antidepressant

1. Introduction

Banana peel from *Musa paradisiaca* L. var. Semeru is an organic waste produced from the processing of bananas. Banana peel is a third part of the banana fruit, with various nutritious substances, including carbohydrates, fats, proteins, vitamins, minerals, polyphenolic compounds, and tryptophan. Polyphenol compounds can be used as natural antioxidant, anti-bacterial, and anti-inflammatory compounds, while tryptophan is a compound with mood-improving effects (Someya *et al.*, 2002; Khawas and Deka, 2016).

During the roasting process, heat transfer occurs from the roaster into the material and water mass is transferred, affecting the moisture content of the roasted powder. The length of the roasting time will affect the water content in the roasted powder. In addition to the water content, the roasting process will also affect the color of the roasted material. The higher the roasting temperature and the longer the roasting time, the darker the material's color.

Free radicals are unstable, reactive molecules or atoms that can cause the degradation of body cells. Those radicals participate in the aging and pathogenesis of diseases (Halliwell, 2012). Our body needs antioxidants to catch those radicals through catalyzing the destruction of free radicals (binding free radicals), acting as a primary antioxidant (donates hydrogen protons), reducing agent (donates electrons), reducing the formation of singlet oxygen ($^1O_2$) and binds metals (metal chelators) (Sharma *et al.*, 2018).

Banana peel has been made into a coffee analog drink through roasting, but the optimum roasting condition has not been determined yet (Mentari *et al.*, 2019; Sofa *et al.*, 2019). A previous study showed

that cocoa bean shells roasted at temperatures of 110°C, 140°C and 190°C produced higher antioxidant activity than those not roasted (room temperature ± 25°C). The optimum antioxidant activity was reached by roasting at 140°C, not at the highest temperature. Moreover, the temperature and roasting time greatly influence sensory properties. This study will determine the optimum roasting temperature of Agung banana peel (Utami *et al.*, 2017).

To date, the utilization of banana peel waste still has low economic value. One previous study made starch from banana peels (Hadisoewignyo *et al*., 2017). This study used banana peels as an ingredient that works as a source of antioxidants and antidepressants. Banana peel is made into powder and roasted. The roasting process can affect the air content, color, and antioxidant activity of the ingredients, it is necessary to determine the optimal conditions of the roasting process.

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2. Materials and methods

2.1 Materials

The raw material used is Agung banana peel from Lumajang, East Java, Indonesia. The chemicals used were of analytical grade, including DPPH reagent pa (Merck), methanol pa (Merck), and distilled water. The equipment used is a roaster, chopper, oven, analytical balance, spectrophotometer (UV-Vis Thermo Scientific, Genesys 10S UV), magnetic stirrer, colorimeter Linshang LS171, Ohaus moisture analyzer MB25, vortex Dlab MX-S, micropipette, and glassware.

2.2 Optimization of banana peel powder processing with factorial design

The roasting process was optimized using the factorial design method with two factors and two levels. The factors used are the temperature of the roaster and the roasting time. The temperature levels were 180°C and 200°C and the roasting time was 15 mins and 20 mins. Water content, powder color, and antioxidant activity (IC_{50}) were the observed responses to obtain the optimum process. The optimum condition was analyzed using Design Expert software ver 10.0.1.

Banana peels are washed, chopped (1×1 cm), dried, ground and sieved with 80 mesh. The banana peel powder was roasted as mentioned in Table 2.

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2.3. Moisture content analysis

The moisture content of the banana powder was determined after the roasting process using a moisture balance analyzer.

2.4 Color analysis

The color of roasted banana peel powder was measured using a colorimeter. L*, a*, b* values obtained represent three dimentions:1. L* represents the light-dark spectrum with a range from 0 to 100 d(black to white), 2. a* value represents the green-re spectrum with a range from -60 to +60 (green to red), 3. b* value represents the blue-yellow spectrum with a range from -60 to +60 (blue to yellow). The L*, a*, and b* values were then converted into $\boldsymbol{\Delta E^*_{ab}}$ Values using equation 1.

$$\Delta \boldsymbol{E^*_{ab}} = \sqrt{(\boldsymbol{L^*_2} - \boldsymbol{L^*_1})^2 + (\boldsymbol{a^*_2} - \boldsymbol{a^*_1})^2 + (\boldsymbol{b^*_2} - \boldsymbol{b^*_2})^2} \qquad (1)$$

L*a*b* Color Difference Compare with Local Coffee Product

2.5 DPPH radical scavenging activity

The DPPH radical scavenging activity (DPPH-RSA) test was carried out using the Burda and Oleszek (2001) method. A weight of 12.5 mg of the sample was dissolved in 25 mL of methanol. Then 1 mL of the solution was pipetted, and 2 mL of 0.1 mM DPPH solution was added. Then it was incubated in a dark room for 30 mins at room temperature, and then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength (λ) of 517 nm. Antioxidant activity as a free radical scavenger was expressed as IC_{50} (µg/mL), which indicates the sample's concentration that can inhibit free radicals by 50%.

3. Results and discussion

3.1 Characteristics of banana peel powder and roasted banana peel powder

The characteristics of banana peel powder and roasted banana peel powder (Figure 1) were determined by several parameters, as shown in Table 1. Banana peels contain high amounts of minerals, especially sodium, potassium, calcium, magnesium, iron and zinc. In addition, there are also several vitamins, including vitamin C and beta-carotene, in a reasonably high amount. Dietary and insoluble dietary fiber is available in relatively high quantities in roasted and non-roasted banana peel powder. The insoluble dietary fiber in banana peels was high enough to benefit the body, especially the digestive system. In addition, heavy metal contamination is determined for roasted and non-roasted banana peel powder. The content of lead, cadmium, copper, tin, and mercury does not exceed the required provisions.

The test on microbial contamination (Table 2) showed that the total plate count and the number of yeast molds were lower in the roasted banana peel powder. That was related to the use of high temperatures in the roasting process.

The presence of high carbohydrate content in banana peel powder and the heat during processing allows the formation of acrylamide, which is formed through various reactions, one of which is the Millard

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reaction (reaction between amino acids and reducing sugars). In the roasting process, the temperature used was 200°C, where high temperatures can increase the formation of acrylamide, so the acrylamide content is higher in roasted banana peel powder (0.475 µg/g).

The presence of tryptophan in banana peels can relieve symptoms of depression and mood disorders. Tryptophan turns into serotonin when it breaks down, which can improve mood. The presence of tryptophan in banana peels can be used as an antidepressant. The tryptophan content in unroasted banana peel powder was higher than that of roasted banana peel powder, 0.1% and 0.01% (w/w), respectively. The roasting process can reduce the tryptophan content because tryptophan is unstable at high temperatures.

3.2 Moisture content and color determination

The moisture content of the roasted banana peel was determined using a moisture content analyzer (Table 4). The moisture content is lowest in the fourth roasting condition (200°C, 20 mins). Controlling moisture content was essential for optimal process control, maintaining high product quality, and compliance with regulations (Wernecke and Wernecke, 2014). Although roasting can kill microbe's toxins and deactivate enzymes, the process can affect the nutrition status. A roasting process can influence color, aroma, taste and antioxidant properties (Sruthi *et al.*, 2021).

The brownish color resembling ground coffee is achieved with 200 degrees of roasting (Table 4, Figure 2). The visual appearance of the color could be an indicator of the roasting degrees and play as an indicator to stop the roasting process. During roasting, some important reactions are the Maillard reaction which induces aroma, the caramelization that creates the color, and pyrolysis, which creates a signature aroma and taste (Tarigan *et al.*, 2022). Maillard reaction has melanoidins as the end product with reducing properties, absorbing oxygen, and metal chelating capacity. Color can be an index of the antioxidant properties of food (Pokorný and Schmidt, 2003).

3.2 Antioxidant activity

The scavenging activity of roasted banana peel powder was higher in high temperatures and more prolonged during the duration of roasting (Table 4). This result was in agreement with a previous study, which reported a lower IC_{50} value with a longer drying time for banana peel (Mentari *et al.*, 2019). Some compounds with antioxidant properties can get lost during roasting, but new compounds with antioxidant activity were created during the Maillard reaction. Maillard reaction is also responsible for forming volatile compounds that contribute to the aroma of the food (Diaz-de-Cerio *et al.*, 2019).

Some antioxidant molecules are formed during the roasting process, such as phenylalanine and heterocyclic compounds (Poncet *et al.*, 2021). Phenolic compounds were considered one of the quality markers of the roasting process (Diaz-de-Cerio *et al.* 2019). Although enzymatic or chemical oxidation of polyphenols can reduce the antioxidant capacity, higher antioxidant activity is shown by partially oxidized polyphenols (Pokorný and Schmidt, 2003). A previous study reported that the maximum antioxidant activity was in medium-roasted coffee and dark-roasted coffee has a lower antioxidant value (Nicoli *et al.*, 1997; del Castillo *et al.*, 2002). Other studies reported the highest antioxidant capacity in lightly roasted coffee (Duarte *et al.*, 2005).

3.3 Optimization of the roasting condition using factorial design

Roasting temperature and time will significantly affect several parameters of the roasted powder, such as the resulting color and antioxidant content. The roasting conditions must be optimal per the standard criteria to produce the roasted powder. Therefore, optimizing the roasting process will provide optimal conditions to make the desired roasted powder. Optimization is carried out using a factorial design with two factors and two levels. The temperature and time of the roasting optimization condition were analyzed using the factorial design method using the software Design Expert ver 10.0.1. Polynomial equations (Table 5) were built based on the moisture content, color similarity and IC_{50} value. Y is the response, and X is the value of the level of concentration. Roasting time and temperature influenced color similarity, moisture content and IC_{50} value. A longer roasting time resulted in lower moisture content.

Based on the polynomial equation, it can be seen that the interaction between temperature and roasting time dominantly affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The color change of the roasted powder depends on the length of the roasting time. The longer the roasting time, the darker color will appear, in this case, giving a darker brown color. The contour plot of moisture content, color similarity and IC_{50} have been established based on polynomial equations (Figure 3).

In Figure 4, the yellow area on the superimposed contour plot depicts the optimum area. The optimum condition chosen was 200^{o}C for 20 mins of roasting temperature. The optimum condition will result in moisture content of 2.00%, color similarity of 11.80 and IC_{50} of 1979.2 (ppm). The previous hedonic test study showed that panelists prefer a darker color, a more pungent aroma and a bitter coffee analog from the banana peel (Hasbullah *et al.*, 2021). Hence, it is probable that panelists will also prefer this optimum condition of the Agung banana peel coffee analog.

4. Conclusion

Roasted banana peel can be considered a food raw material that has antioxidant and antidepressant activity. The optimum conditions selected based on the factorial design were 200°C; 20 mins. The presence of tryptophan in banana peel powder can be used as an antidepressant compound. It is recommended that further study should be carried out on a hedonic test for the taste and aroma of Agung banana peel coffee analog.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

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Table 1. Characteristics of non-roasted and roasted banana peel powder

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Water content (%)	4.42	2.38
Ash content (%)	10.24	10.59
Acid insoluble ash (%)	0.07	0.09
Protein (%)	6.98	7.12
Fat (%)	3.37	3.04
Carbohydrate (%)	74.99	76.87
Sugar content (%)	3.48	1.83
Reducing sugar (%)	0.90	0.73
Dietary fiber (%)	28.39	30.07
Insoluble dietary fiber (%)	27.40	28.01
Amylose (%)	14.89	15.51
Amylopectin (%)	27.46	25.77
pH	6.74	6.58
Density (g/mL)	0.7308	0.6903
Caffeine (mg/Kg)	<1.20	<1.20
Sodium (mg/Kg)	1099	1066
Potassium (mg/Kg)	113585	135073
Calcium (mg/Kg)	973	1174
Magnesium (mg/Kg)	1420	1544
Iron (mg/Kg)	30.09	34.80
Zinc (mg/Kg)	20.69	22.18
Vitamin A (IU/100 g)	<0.50	<0.50
Betacarotene	76.5	60.7
Vitamin B1 (mg/Kg)	< 0.25	< 0.25
Vitamin B2 (mg/Kg)	<0.25	<0.25
Vitamin B6 (mg/Kg)	<0.20	<0.20
Vitamin C (mg/Kg)	75.5	69.3
Vitamin D (µg/100g)	11.3	3.69

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Vitamin E (mg/100g)	3.88	6.20
Folic acid (mg/Kg)	<0.25	<0.25
Tryptophan (%)	0.1	0.01
Acrylamide (μg/g)	0.127	0.475

Table 2. Microbial contamination on non-roasted and roasted banana peel powder

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Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Total plate count (colony/g)	7.2×10^{-6}	3.0×10^{-4}
Escherichia coli (APM/g)	<3	<3
Staphylococcus aureus (colony/g)*	0	0
Bacillus cereus (colony/g)**	0	0
Pseudomonas aeruginosa (colony/g)*	0	0
Salmonella sp. (/25g)	Negative	Negative
Mold (colony/g)	7	<10
Yeast (colony/g)	17	<10

Table 3. Factorial design for the roasting condition

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Factors		Selected levels	
		-1	+1
A	Roasting temperature (°C)	180	200
B	Roasting time (min)	15	20

Table 4. Color space, moisture content after roasted, and antioxidant activity after roasting

Roasting Condition	Color Similarity	Moisture Content After Roasted (%)	IC_{50} (ppm)
180°C, 15 mins	13.47 ± 4.41	1.96 ± 0.06	2450 ± 919.24

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200°C, 20 mins	12.32 ± 3.91	3.00 ± 0.68	2250 ± 495.98
200°C, 15 mins	11.18 ± 3.82	1.99 ± 1.03	2050 ± 354.55
200°C, 20 mins	11.81 ± 0.49	1.93 ± 0.18	1950 ± 70.71

Table 5. Polynomial equation

Response	Polynomial Equation
Moisture Content after roasted (%)	$Y = 2.22 - 0.26(X_a) + 0.25(X_b) - 0.28\ (X_a)(X_b)$
Color Similarity	$Y = 12.20 - 0.70(X_a) - 0.13(X_b) + 0.44\ (X_a)(X_b)$
IC_{50} (ppm)	$Y = 2175 - 175(X_a) - 75(X_b) + 25\ (X_a)(X_b)$

Xa: level value for temperature, Xb: level value for time

Figure 1.Roasted banana peel powder

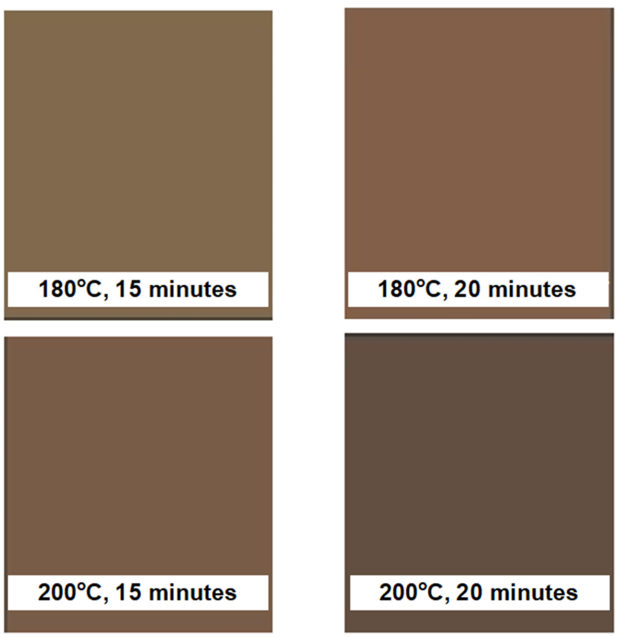
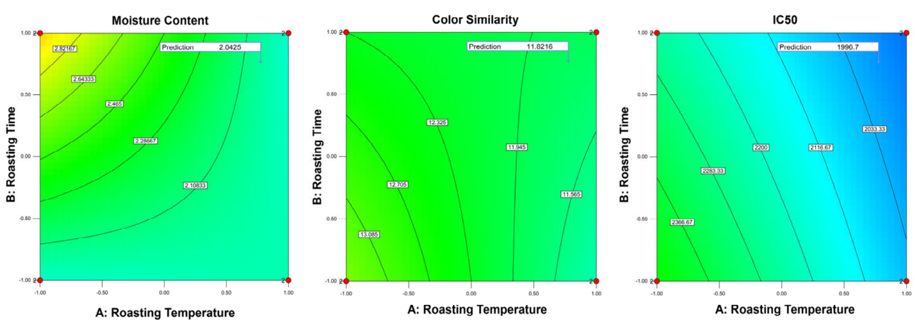


Figure 2. Color of banana peel after roasting



(A) (B) (C)

Figure 3. Contour plot of moisture content (A), color similarity (B), and IC_{50} (C) of roasting conditions (roasting time and roasting temperature)

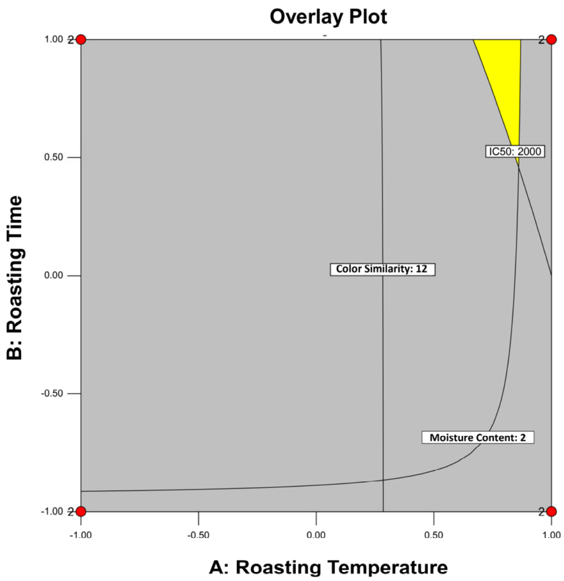


Figure 4. Superimposed contour plot

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Factorial experimental design for optimizing the roasting condition of banana peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity

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Abstract

Banana peel is an organic waste that has not been widely used. The rich content of vitamins, minerals, antioxidants and tryptophan is the background for research utilizing organic waste for something useful. This study aimed to use a factorial design to find the optimum conditions for the banana peel roasting process. The variables analyzed were roasting temperature (180°C and 200°C) and roasting time (15 and 20 mins). Responses to determine the optimum conditions were water content, color similarity with local coffee products and antioxidant activity (IC_{50}). Antioxidant activity was measured using the 2,2-diphenyl-1-

picrylhydrazyl method. The characteristics of banana peel powder and roasted banana peel powder showed the presence of beneficial substances and even richness in vitamins and minerals, as well as the presence of tryptophan. The scavenging activity of roasted banana peel powder was higher at high temperatures and longer during roasting. The lowest water content was at 200°C and 20 mins of roasting conditions. A brownish color resembling ground coffee was obtained with a roasting temperature of 200°C. The interaction between temperature and roasting time affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The optimum conditions selected were 200°C roasting conditions; 20 mins will produce a water content of 2.00%, color similarity 11.80 and IC_{50} 1979.2 (ppm). In addition, the presence of tryptophan in banana peel powder has the opportunity to be used as an antidepressant compound.
Keywords: Banana peel, Factorial design, Roasting condition, Antioxidant, Antidepressant

1. Introduction

Banana peel from *Musa paradisiaca* L. var. Semeru is an organic waste produced from the processing of bananas. Banana peel is a third part of the banana fruit, with various nutritious substances, including carbohydrates, fats, proteins, vitamins, minerals, polyphenolic compounds, and tryptophan. Polyphenol compounds can be used as natural antioxidant, anti-bacterial, and anti-inflammatory compounds, while tryptophan is a compound with mood-improving effects (Someya *et al.*, 2002; Khawas and Deka, 2016).

During the roasting process, heat transfer occurs from the roaster into the material and water mass is transferred, affecting the moisture content of the roasted powder. The length of the roasting time will affect the water content in the roasted powder. In addition to the water content, the roasting process will also affect the color of the roasted material. The higher the roasting temperature and the longer the roasting time, the darker the material's color.

Free radicals are unstable, reactive molecules or atoms that can cause the degradation of body cells. Those radicals participate in the aging and pathogenesis of diseases (Halliwell, 2012). Our body needs antioxidants to catch those radicals through catalyzing the destruction of free radicals (binding free radicals), acting as a primary antioxidant (donates hydrogen protons), reducing agent (donates electrons), reducing the formation of singlet oxygen ($^1O_2$) and binds metals (metal chelators) (Sharma *et al.*, 2018).

Banana peel has been made into a coffee analog drink through roasting, but the optimum roasting condition has not been determined yet (Mentari *et al.*, 2019; Sofa *et al.*, 2019). A previous study showed

that cocoa bean shells roasted at temperatures of 110°C, 140°C and 190°C produced higher antioxidant activity than those not roasted (room temperature ± 25°C). The optimum antioxidant activity was reached by roasting at 140°C, not at the highest temperature. Moreover, the temperature and roasting time greatly influence sensory properties. This study will determine the optimum roasting temperature of Agung banana peel (Utami *et al.*, 2017).

To date, the utilization of banana peel waste still has low economic value. One previous study made starch from banana peels (Hadisoewignyo *et al*., 2017). This study used banana peels as an ingredient that works as a source of antioxidants and antidepressants. Banana peel is made into powder and roasted. The roasting process can affect the air content, color, and antioxidant activity of the ingredients, it is necessary to determine the optimal conditions of the roasting process. This study aimed to optimize the conditions for roasting agung banana peels with high antioxidant activity.

2. Materials and methods

2.1 Materials

The raw material used is Agung banana peel from Lumajang, East Java, Indonesia. The chemicals used were of analytical grade, including DPPH reagent pa (Merck), methanol pa (Merck), and distilled water. The equipment used is a roaster, chopper, oven, analytical balance, spectrophotometer (UV-Vis Thermo Scientific, Genesys 10S UV), magnetic stirrer, colorimeter Linshang LS171, Ohaus moisture analyzer MB25, vortex Dlab MX-S, micropipette, and glassware.

2.2 Optimization of banana peel powder processing with factorial design

The roasting process was optimized using the factorial design method with two factors and two levels. The factors used are the temperature of the roaster and the roasting time. The temperature levels were 180°C and 200°C and the roasting time was 15 mins and 20 mins. Water content, powder color, and antioxidant activity (IC_{50}) were the observed responses to obtain the optimum process. The optimum condition was analyzed using Design Expert software ver 10.0.1.

Banana peels are washed, chopped (1×1 cm), dried, ground and sieved with 80 mesh. Banana peel powder is roasted at a roasting temperature of 180 and 200°C for 15 and 20 mins, as mentioned in Table 3.

2.3. Moisture content analysis

The moisture content of the banana powder was determined after the roasting process using a moisture balance analyzer.

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2.4 Color analysis

The color of roasted banana peel powder was measured using a colorimeter. L*, a*, b* values obtained represent three dimentions:1. L* represents the light-dark spectrum with a range from 0 to 100 d(black to white), 2. a* value represents the green-re spectrum with a range from -60 to +60 (green to red), 3. b* value represents the blue-yellow spectrum with a range from -60 to +60 (blue to yellow). The L*, a*, and b* values were then converted into $\Delta \boldsymbol{E}^*_{\boldsymbol{ab}}$ Values using equation 1.

$$\Delta \boldsymbol{E}^*_{\boldsymbol{ab}} = \sqrt{(\boldsymbol{L}^*_2 - \boldsymbol{L}^*_1)^2 + (\boldsymbol{a}^*_2 - \boldsymbol{a}^*_1)^2 + (\boldsymbol{b}^*_2 - \boldsymbol{b}^*_2)^2} \quad (1)$$

L*a*b* Color Difference Compare with Local Coffee Product

2.5 DPPH radical scavenging activity

The DPPH radical scavenging activity (DPPH-RSA) test was carried out using the Burda and Oleszek (2001) method. A weight of 12.5 mg of the sample was dissolved in 25 mL of methanol. Then 1 mL of the solution was pipetted, and 2 mL of 0.1 mM DPPH solution was added. Then it was incubated in a dark room for 30 mins at room temperature, and then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength (λ) of 517 nm. Antioxidant activity as a free radical scavenger was expressed as IC_{50} (μg/mL), which indicates the sample's concentration that can inhibit free radicals by 50%.

3. Results and discussion

3.1 Characteristics of banana peel powder and roasted banana peel powder

The characteristics of banana peel powder and roasted banana peel powder (Figure 1) were determined by several parameters, as shown in Table 1. Banana peels contain high amounts of minerals, especially sodium, potassium, calcium, magnesium, iron and zinc. In addition, there are also several vitamins, including vitamin C and beta-carotene, in a reasonably high amount. Dietary and insoluble dietary fiber is available in relatively high quantities in roasted and non-roasted banana peel powder. The insoluble dietary fiber in banana peels was high enough to benefit the body, especially the digestive system. In addition, heavy metal contamination is determined for roasted and non-roasted banana peel powder. The content of lead, cadmium, copper, tin, and mercury does not exceed the required provisions.

The test on microbial contamination (Table 2) showed that the total plate count and the number of yeast molds were lower in the roasted banana peel powder. That was related to the use of high temperatures in the roasting process.

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The presence of high carbohydrate content in banana peel powder and the heat during processing allows the formation of acrylamide, which is formed through various reactions, one of which is the Millard reaction (reaction between amino acids and reducing sugars). In the roasting process, the temperature used was 200^{o}C, where high temperatures can increase the formation of acrylamide, so the acrylamide content is higher in roasted banana peel powder (0.475 µg/g).

The presence of tryptophan in banana peels can relieve symptoms of depression and mood disorders. Tryptophan turns into serotonin when it breaks down, which can improve mood. The presence of tryptophan in banana peels can be used as an antidepressant. The tryptophan content in unroasted banana peel powder was higher than that of roasted banana peel powder, 0.1% and 0.01% (w/w), respectively. The roasting process can reduce the tryptophan content because tryptophan is unstable at high temperatures.

3.2 Moisture content and color determination

The moisture content of the roasted banana peel was determined using a moisture content analyzer (Table 4). The moisture content is lowest in the fourth roasting condition (200^{o}C, 20 mins). Controlling moisture content was essential for optimal process control, maintaining high product quality, and compliance with regulations (Wernecke and Wernecke, 2014). Although roasting can kill microbe's toxins and deactivate enzymes, the process can affect the nutrition status. A roasting process can influence color, aroma, taste and antioxidant properties (Sruthi *et al.*, 2021).

The brownish color resembling ground coffee is achieved with 200 degrees of roasting (Table 4, Figure 2). The visual appearance of the color could be an indicator of the roasting degrees and play as an indicator to stop the roasting process. During roasting, some important reactions are the Maillard reaction which induces aroma, the caramelization that creates the color, and pyrolysis, which creates a signature aroma and taste (Tarigan *et al.*, 2022). Maillard reaction has melanoidins as the end product with reducing properties, absorbing oxygen, and metal chelating capacity. Color can be an index of the antioxidant properties of food (Pokorný and Schmidt, 2003).

3.2 Antioxidant activity

The scavenging activity of roasted banana peel powder was higher in high temperatures and more prolonged during the duration of roasting (Table 4). This result was in agreement with a previous study, which reported a lower IC_{50} value with a longer drying time for banana peel (Mentari *et al.*, 2019). Some compounds with antioxidant properties can get lost during roasting, but new compounds with antioxidant activity were created during the Maillard reaction. Maillard reaction is also responsible for forming volatile compounds that contribute to the aroma of the food (Diaz-de-Cerio *et al.*, 2019).

Some antioxidant molecules are formed during the roasting process, such as phenylalanine and heterocyclic compounds (Poncet *et al.*, 2021). Phenolic compounds were considered one of the quality markers of the roasting process (Diaz-de-Cerio *et al.* 2019). Although enzymatic or chemical oxidation of polyphenols can reduce the antioxidant capacity, higher antioxidant activity is shown by partially oxidized polyphenols (Pokorný and Schmidt, 2003). A previous study reported that the maximum antioxidant activity was in medium-roasted coffee and dark-roasted coffee has a lower antioxidant value (Nicoli *et al.*, 1997; del Castillo *et al.*, 2002). Other studies reported the highest antioxidant capacity in lightly roasted coffee (Duarte *et al.*, 2005).

3.3 Optimization of the roasting condition using factorial design

Roasting temperature and time will significantly affect several parameters of the roasted powder, such as the resulting color and antioxidant content. The roasting conditions must be optimal per the standard criteria to produce the roasted powder. Therefore, optimizing the roasting process will provide optimal conditions to make the desired roasted powder. Optimization is carried out using a factorial design with two factors and two levels. The temperature and time of the roasting optimization condition were analyzed using the factorial design method using the software Design Expert ver 10.0.1. Polynomial equations (Table 5) were built based on the moisture content, color similarity and IC_{50} value. Y is the response, and X is the value of the level of concentration. Roasting time and temperature influenced color similarity, moisture content and IC_{50} value. A longer roasting time resulted in lower moisture content.

Based on the polynomial equation, it can be seen that the interaction between temperature and roasting time dominantly affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The color change of the roasted powder depends on the length of the roasting time. The longer the roasting time, the darker color will appear, in this case, giving a darker brown color. The contour plot of moisture content, color similarity and IC_{50} have been established based on polynomial equations (Figure 3).

In Figure 4, the yellow area on the superimposed contour plot depicts the optimum area. The optimum condition chosen was 200^{o}C for 20 mins of roasting temperature. The optimum condition will result in moisture content of 2.00%, color similarity of 11.80 and IC_{50} of 1979.2 (ppm). The previous hedonic test study showed that panelists prefer a darker color, a more pungent aroma and a bitter coffee analog from the banana peel (Hasbullah *et al.*, 2021). Hence, it is probable that panelists will also prefer this optimum condition of the Agung banana peel coffee analog.

4. Conclusion

Roasted banana peel can be considered a food raw material that has antioxidant and antidepressant activity. The optimum conditions selected based on the factorial design were 200°C; 20 mins. The presence of tryptophan in banana peel powder can be used as an antidepressant compound. It is recommended that further study should be carried out on a hedonic test for the taste and aroma of Agung banana peel coffee analog.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

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Table 1. Characteristics of non-roasted and roasted banana peel powder

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Water content (%)	4.42	2.38
Ash content (%)	10.24	10.59
Acid insoluble ash (%)	0.07	0.09
Protein (%)	6.98	7.12
Fat (%)	3.37	3.04
Carbohydrate (%)	74.99	76.87
Sugar content (%)	3.48	1.83
Reducing sugar (%)	0.90	0.73
Dietary fiber (%)	28.39	30.07
Insoluble dietary fiber (%)	27.40	28.01
Amylose (%)	14.89	15.51
Amylopectin (%)	27.46	25.77
pH	6.74	6.58
Density (g/mL)	0.7308	0.6903
Caffeine (mg/Kg)	<1.20	<1.20
Sodium (mg/Kg)	1099	1066
Potassium (mg/Kg)	113585	135073
Calcium (mg/Kg)	973	1174
Magnesium (mg/Kg)	1420	1544
Iron (mg/Kg)	30.09	34.80
Zinc (mg/Kg)	20.69	22.18
Vitamin A (IU/100 g)	<0.50	<0.50
Betacarotene	76.5	60.7
Vitamin B1 (mg/Kg)	< 0.25	< 0.25
Vitamin B2 (mg/Kg)	<0.25	<0.25
Vitamin B6 (mg/Kg)	<0.20	<0.20
Vitamin C (mg/Kg)	75.5	69.3
Vitamin D (μg/100g)	11.3	3.69

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Vitamin E (mg/100g)	3.88	6.20
Folic acid (mg/Kg)	<0.25	<0.25
Tryptophan (%)	0.1	0.01
Acrylamide (μg/g)	0.127	0.475

Table 2. Microbial contamination on non-roasted and roasted banana peel powder

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Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Total plate count (colony/g)	7.2×10^{-6}	3.0×10^{-4}
Escherichia coli (APM/g)	<3	<3
Staphylococcus aureus (colony/g)*	0	0
Bacillus cereus (colony/g)**	0	0
Pseudomonas aeruginosa (colony/g)*	0	0
Salmonella sp. (/25g)	Negative	Negative
Mold (colony/g)	7	<10
Yeast (colony/g)	17	<10

Table 3. Factorial design for the roasting condition

Factors		Selected levels	
		-1	+1
A	Roasting temperature (°C)	180	200
B	Roasting time (min)	15	20

Table 4. Color space, moisture content after roasted, and antioxidant activity after roasting

Roasting Condition	Color Similarity	Moisture Content After Roasted (%)	IC_{50} (ppm)
180°C, 15 mins	13.47 ± 4.41	1.96 ± 0.06	2450 ± 919.24

200°C, 20 mins	12.32 ± 3.91	3.00 ± 0.68	2250 ± 495.98
200°C, 15 mins	11.18 ± 3.82	1.99 ± 1.03	2050 ± 354.55
200°C, 20 mins	11.81 ± 0.49	1.93 ± 0.18	1950 ± 70.71

Table 5. Polynomial equation

Response	Polynomial Equation
Moisture Content after roasted (%)	$Y = 2.22 - 0.26(X_a) + 0.25(X_b) - 0.28 (X_a)(X_b)$
Color Similarity	$Y = 12.20 - 0.70(X_a) - 0.13(X_b) + 0.44 (X_a)(X_b)$
IC_{50} (ppm)	$Y = 2175 - 175(X_a) - 75(X_b) + 25 (X_a)(X_b)$

Xa: level value for temperature, Xb: level value for time

Figure 1.Roasted banana peel powder

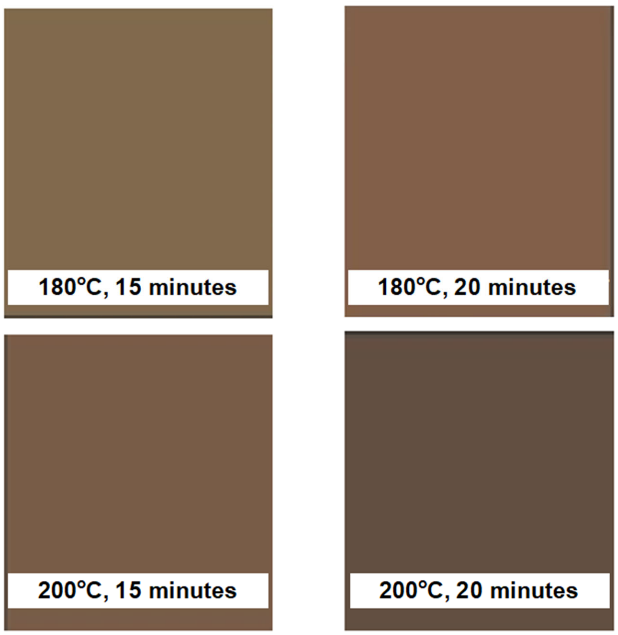
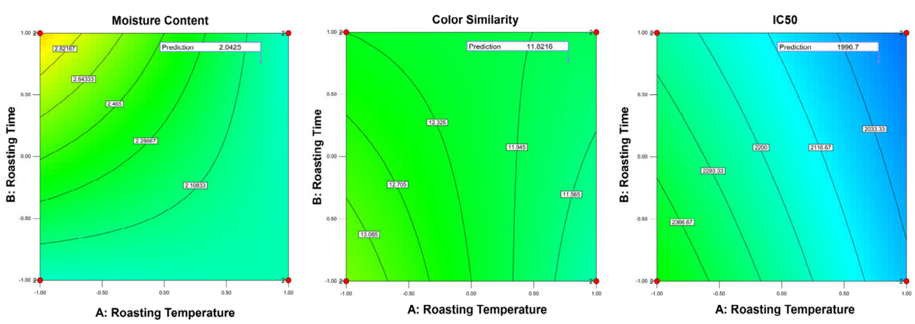


Figure 2. Color of banana peel after roasting



(A) (B) (C)

Figure 3. Contour plot of moisture content (A), color similarity (B), and IC_{50} (C) of roasting conditions (roasting time and roasting temperature)

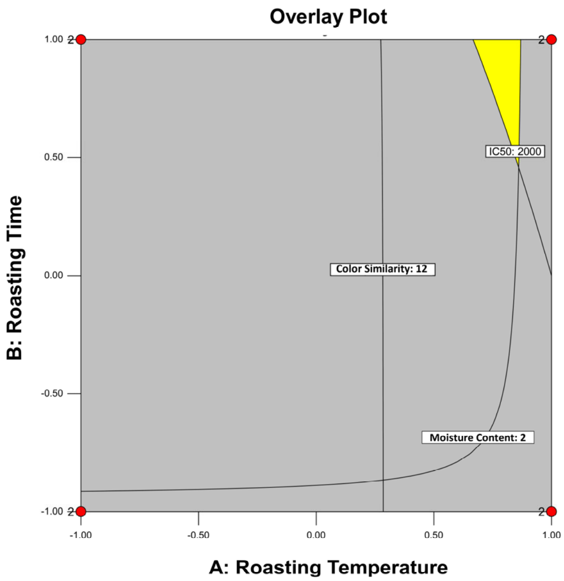


Figure 4. Superimposed contour plot

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Dear Dr Lannie,

Please refer to the attachment for the galley proof of your manuscript FR-2022-462 entitled 'Factorial experimental design for optimizing the roasting condition of banana peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity'. Please check the content of the galley proof. If there are any mistakes on the typesetting, please comment and highlight them in the PDF itself and revert to us within five (5) days of receipt. Change or addition of data/results is strictly prohibited. Please note that you are allowed one (1) revision of the galley proof. If the galley proof is fine, please approve the galley proof.

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FOOD RESEARCH

RESEARCH PAPER

Factorial experimental design for optimizing the roasting condition of banana peel (*Musa paradisiaca* var Semeru): characteristics and antioxidant activity

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1. Introduction

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roasting temperature of Agung banana peel (Utami *et al.*, 2017).

To date, the utilization of banana peel waste still has low economic value. One previous study made starch from banana peels (Hadisoewignyo *et al.*, 2017). This study used banana peels as an ingredient that works as a source of antioxidants and antidepressants. Banana peel is made into powder and roasted. The roasting process can affect the air content, color, and antioxidant activity of the ingredients, it is necessary to determine the optimal conditions of the roasting process. This study aimed to optimize the conditions for roasting agung banana peels with high antioxidant activity.

2. Materials and methods

2.1 Materials

The raw material used is Agung banana peel from Lumajang, East Java, Indonesia. The chemicals used were of analytical grade, including DPPH reagent pa (Merck), methanol pa (Merck), and distilled water. The equipment used is a roaster, chopper, oven, analytical balance, spectrophotometer (UV-Vis Thermo Scientific, Genesys 10S UV), magnetic stirrer, colorimeter Linshang LS171, Ohaus moisture analyzer MB25, vortex Dlab MX-S, micropipette, and glassware.

2.2 Characteristics of banana peel powder and roasted banana peel powder

The characteristics of banana peel powder and roasted banana peel powder were carried out at the Center of Agro-Based Industry, Ministry of Industry of the Republic of Indonesia, including microbiological testing.

2.3 Optimization of banana peel powder processing with factorial design

The roasting process was optimized using the factorial design method with two factors and two levels. The factors used are the temperature of the roaster and the roasting time. The temperature levels were 180°C and 200°C and the roasting time was 15 mins and 20 mins. Water content, powder color, and antioxidant activity (IC_{50}) were the observed responses to obtain the optimum process. The optimum condition was analyzed using Design Expert software ver 10.0.1.

Banana peels are washed, chopped (1×1 cm), dried, ground and sieved with 80 mesh. Banana peel powder is roasted at a roasting temperature of 180 and 200°C for 15 and 20 mins, as mentioned in Table 1.

Table 1. Factorial design for the roasting condition.

	Factors	Selected levels -1	Selected levels +1
A	Roasting temperature (°C)	180	200
B	Roasting time (min)	15	20

2.4. Moisture content analysis

The moisture content of the banana powder was determined after the roasting process using a moisture balance analyzer.

2.5 Color analysis

The color of roasted banana peel powder was measured using a colorimeter. L*, a*, b* values obtained represent three dimentions:1. L* represents the light-dark spectrum with a range from 0 to 100 d(black to white), 2. a* value represents the green-re spectrum with a range from -60 to +60 (green to red), 3. b* value represents the blue-yellow spectrum with a range from -60 to +60 (blue to yellow). The L*, a*, and b* values were then converted into ΔE^*_{ab} values using equation 1.

$$\Delta E^*_{ab} = \sqrt{(L^*_2 - L^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_2)^2} \quad (1)$$

L*a*b* Color Difference Compare with Local Coffee Product

2.6 DPPH radical scavenging activity

The DPPH radical scavenging activity (DPPH-RSA) test was carried out using the Burda and Oleszek (2001) method. A weight of 12.5 mg of the sample was dissolved in 25 mL of methanol. Then 1 mL of the solution was pipetted, and 2 mL of 0.1 mM DPPH solution was added. Then it was incubated in a dark room for 30 mins at room temperature, and then the absorbance was measured using a UV-Vis spectrophotometer at a wavelength (λ) of 517 nm. Antioxidant activity as a free radical scavenger was expressed as IC_{50} (μg/mL), which indicates the sample's concentration that can inhibit free radicals by 50%.

3. Results and discussion

3.1 Characteristics of banana peel powder and roasted banana peel powder

The characteristics of banana peel powder and roasted banana peel powder (Figure 1) were determined by several parameters, as shown in Table 2. Banana peels contain high amounts of minerals, especially sodium, potassium, calcium, magnesium, iron and zinc. In addition, there are also several vitamins, including vitamin C and beta-carotene, in a reasonably high amount. Dietary and insoluble dietary fiber is available in relatively high quantities in roasted and non-roasted banana peel powder. The insoluble dietary fiber in banana peels was high enough to benefit the body, especially the digestive system. In addition, heavy metal

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contamination is determined for roasted and non-roasted banana peel powder. The content of lead, cadmium, copper, tin, and mercury does not exceed the required provisions.

Figure 1.Roasted banana peel powder.

Table 2. Characteristics of non-roasted and roasted banana peel powder.

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Water content (%)	4.42	2.38
Ash content (%)	10.24	10.59
Acid insoluble ash (%)	0.07	0.09
Protein (%)	6.98	7.12
Fat (%)	3.37	3.04
Carbohydrate (%)	74.99	76.87
Sugar content (%)	3.48	1.83
Reducing sugar (%)	0.90	0.73
Dietary fiber (%)	28.39	30.07
Insoluble dietary fiber (%)	27.40	28.01
Amylose (%)	14.89	15.51
Amylopectin (%)	27.46	25.77
pH	6.74	6.58
Density (g/mL)	0.7308	0.6903
Caffeine (mg/Kg)	<1.20	<1.20
Sodium (mg/Kg)	1099	1066
Potassium (mg/Kg)	113585	135073
Calcium (mg/Kg)	973	1174
Magnesium (mg/Kg)	1420	1544
Iron (mg/Kg)	30.09	34.80
Zinc (mg/Kg)	20.69	22.18
Vitamin A (IU/100 g)	<0.50	<0.50
Betacarotene	76.5	60.7
Vitamin B1 (mg/Kg)	< 0.25	< 0.25
Vitamin B2 (mg/Kg)	<0.25	<0.25
Vitamin B6 (mg/Kg)	<0.20	<0.20
Vitamin C (mg/Kg)	75.5	69.3
Vitamin D (mg/100g)	11.3	3.69
Vitamin E (mg/100g)	3.88	6.20
Folic acid (mg/Kg)	<0.25	<0.25
Tryptophan (%)	0.1	0.01
Acrylamide (mg/g)	0.127	0.475

The test on microbial contamination (Table 3) showed that the total plate count and the number of yeast molds were lower in the roasted banana peel powder. That was related to the use of high temperatures in the roasting process.

The presence of high carbohydrate content in banana peel powder and the heat during processing allows the formation of acrylamide, which is formed through various reactions, one of which is the Millard reaction (reaction between amino acids and reducing sugars). In the roasting process, the temperature used was 200°C, where high temperatures can increase the formation of acrylamide, so the acrylamide content is higher in roasted banana peel powder (0.475 µg/g).

Table 3. Microbial contamination on non-roasted and roasted banana peel powder.

Parameter	Banana Peel Powder	Roasted Banana Peel Powder
Total plate count (CFU/g)	7.2×10^{-6}	3.0×10^{-4}
Escherichia coli (CFU/g)	<3	<3
Staphylococcus aureus (CFU/g)*	0	0
Bacillus cereus (CFU/g)**	0	0
Pseudomonas aeruginosa (CFU/g)*	0	0
Salmonella sp. (per 25 g)	Negative	Negative
Mold (CFU/g)	7	<10
Yeast (CFU/g)	17	<10

The presence of tryptophan in banana peels can relieve symptoms of depression and mood disorders. Tryptophan turns into serotonin when it breaks down, which can improve mood. The presence of tryptophan in banana peels can be used as an antidepressant. The tryptophan content in unroasted banana peel powder was higher than that of roasted banana peel powder, 0.1% and 0.01% (w/w), respectively. The roasting process can reduce the tryptophan content because tryptophan is unstable at high temperatures.

3.2 Moisture content and color determination

The moisture content of the roasted banana peel was determined using a moisture content analyzer (Table 4). The moisture content is lowest in the fourth roasting condition (200°C, 20 mins). Controlling moisture content was essential for optimal process control, maintaining high product quality, and compliance with regulations (Wernecke and Wernecke, 2014). Although roasting can kill microbe's toxins and deactivate enzymes, the process can affect the nutrition status. A roasting process can influence color, aroma, taste and antioxidant properties (Sruthi *et al.*, 2021).

The brownish color resembling ground coffee is achieved with 200 degrees of roasting (Table 4, Figure 2). The visual appearance of the color could be an indicator of the roasting degrees and play as an indicator to stop the roasting process. During roasting, some important reactions are the Maillard reaction which induces aroma, the caramelization that creates the color,

Table 4. Color space, moisture content after roasted, and antioxidant activity after roasting.

Roasting condition	Color Similarity	Moisture Content After Roasted (%)	IC_{50} (ppm)
180°C, 15 mins	13.47±4.41	1.96±0.06	2450±919.24
180°C, 20 mins	12.32±3.91	3.00±0.68	2250±495.98
200°C, 15 mins	11.18±3.82	1.99±1.03	2050±354.55
200°C, 20 mins	11.81±0.49	1.93±0.18	1950±70.71

and pyrolysis, which creates a signature aroma and taste (Tarigan *et al.*, 2022). Maillard reaction has melanoidins as the end product with reducing properties, absorbing oxygen, and metal chelating capacity. Color can be an index of the antioxidant properties of food (Pokorný and Schmidt, 2003).

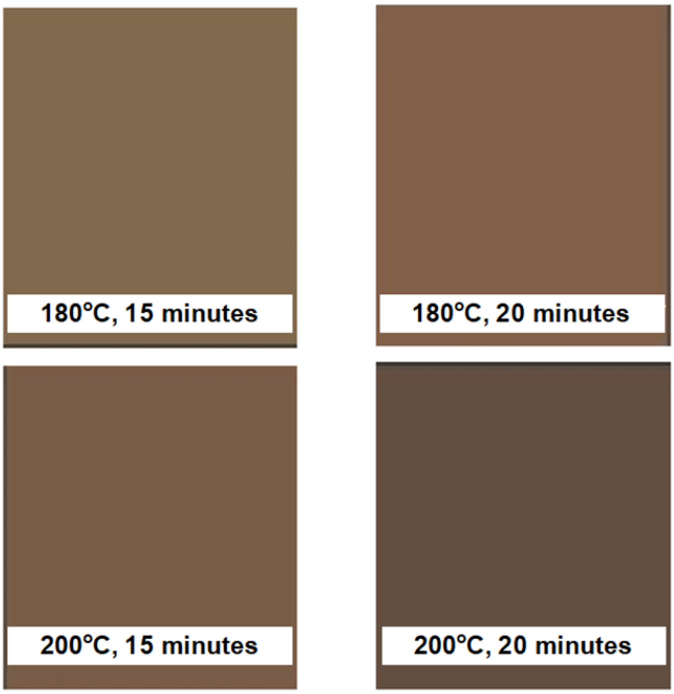

Figure 2. Color of banana peel after roasting.

3.2 Antioxidant activity

The scavenging activity of roasted banana peel powder was higher in high temperatures and more prolonged during the duration of roasting (Table 4). This result was in agreement with a previous study, which reported a lower IC_{50} value with a longer drying time for banana peel (Mentari *et al.*, 2019). Some compounds with antioxidant properties can get lost during roasting, but new compounds with antioxidant activity were created during the Maillard reaction. Maillard reaction is also responsible for forming volatile compounds that contribute to the aroma of the food (Diaz-de-Cerio *et al.*, 2019).

Some antioxidant molecules are formed during the roasting process, such as phenylalanine and heterocyclic compounds (Poncet *et al.*, 2021). Phenolic compounds were considered one of the quality markers of the roasting process (Diaz-de-Cerio *et al.,* 2019). Although enzymatic or chemical oxidation of polyphenols can reduce the antioxidant capacity, higher antioxidant activity is shown by partially oxidized polyphenols (Pokorný and Schmidt, 2003). A previous study reported that the maximum antioxidant activity was in medium-roasted coffee and dark-roasted coffee has a lower antioxidant value (Nicoli *et al.*, 1997; del Castillo *et al.*, 2002). Other studies reported the highest antioxidant capacity in lightly roasted coffee (Duarte *et al.*, 2005).

3.3 Optimization of the roasting condition using factorial design

Roasting temperature and time will significantly affect several parameters of the roasted powder, such as the resulting color and antioxidant content. The roasting conditions must be optimal per the standard criteria to produce the roasted powder. Therefore, optimizing the roasting process will provide optimal conditions to make the desired roasted powder. Optimization is carried out using a factorial design with two factors and two levels. The temperature and time of the roasting optimization condition were analyzed using the factorial design method using the software Design Expert ver. 10.0.1. Polynomial equations (Table 5) were built based on the moisture content, color similarity and IC_{50} value. Y is the response, and X is the value of the level of concentration. Roasting time and temperature influenced color similarity, moisture content and IC_{50} value. A longer roasting time resulted in lower moisture content.

Based on the polynomial equation, it can be seen that the interaction between temperature and roasting time dominantly affects the moisture content and color similarity, while the roasting time dominantly affects IC_{50}. The color change of the roasted powder depends on the length of the roasting time. The longer the roasting time, the darker color will appear, in this case, giving a darker brown color. The contour plot of moisture

Table 5. Polynomial equation

Response	Polynomial Equation
Moisture Content after roasted (%)	$Y = 2.22 – 0.26(X_a) + 0.25(X_b) – 0.28 (X_a)(X_b)$
Color Similarity	$Y = 12.20 – 0.70(X_a) – 0.13(X_b) + 0.44 (X_a)(X_b)$
IC_{50} (ppm)	$Y = 2175 - 175(X_a) - 75(X_b) + 25 (X_a)(X_b)$

X_a: level value for temperature, X_b: level value for time

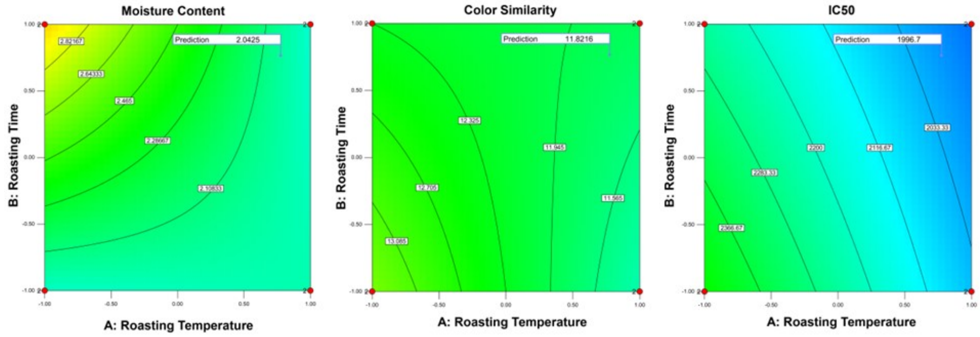

Figure 3. Contour plot of moisture content (A), color similarity (B), and IC_{50} (C) of roasting conditions (roasting time and roasting temperature).

content, color similarity and IC_{50} have been established based on polynomial equations (Figure 3).

In Figure 4, the yellow area on the superimposed contour plot depicts the optimum area. The optimum condition chosen was 200°C for 20 mins of roasting temperature. The optimum condition will result in moisture content of 2.00%, color similarity of 11.80 and IC_{50} of 1979.2 ppm. The previous hedonic test study showed that panelists prefer a darker color, a more pungent aroma and a bitter coffee analog from the banana peel (Hasbullah *et al.*, 2021). Hence, it is probable that panelists will also prefer this optimum condition of the Agung banana peel coffee analog.

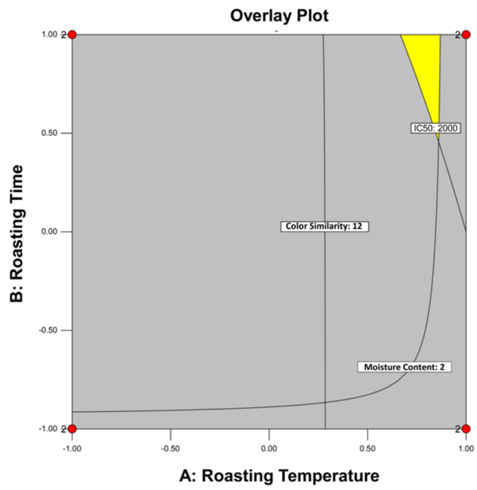

Figure 4. The superimposed contour plot of roasting condition.

4. Conclusion

Roasted banana peel can be considered a food raw material that has antioxidant and antidepressant activity. The optimum conditions selected based on the factorial design were 200°C; 20 mins. The presence of tryptophan in banana peel powder can be used as an antidepressant compound. It is recommended that further study should be carried out on a hedonic test for the taste and aroma of Agung banana peel coffee analog.

Conflict of interest

The authors declare no conflict of interest.

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