Biochemical Characteristics of Ground Robusta Coffee under Various Postharvest Technologies and Processing Parameters

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Abstract: The purpose of this study was to analyze the biochemical characteristics of ground Robusta coffee under various postharvest technologies and processing parameters and to find out the best treatment combination. The orthogonal array notation of Taguchi method used was L_9 (3^4) with four factors and three levels from postharvest (full wash, honey, and natural), temperature (150 ºC, 175 ºC, 200 ºC), roasting time (10 minutes, 12.5 minutes, and 15 minutes) and milling (80 mesh, 100 mesh, and 120 mesh). The tested biochemical characteristics were moisture, caffeine, chlorogenic acid, sucrose, and lipid contents. ANOVA for the mean and SNR values were performed to determine significant differences between treatments. The best conditions were carried out by Grey Relational Analysis, which furthermore tested with a confirmation test. The analysis results showed that the effectiveness of the treatment had significant differences from each treatment from parameters: moisture content, caffeine, chlorogenic acid, and lipid. The best conditions were the combination of postharvest technologies (full wash), temperature and roasting time (175°C and 12.5 minutes), and milling (100 mesh) with moisture content (3.21%), caffeine (0.81%), chlorogenic acid (8.1%), sucrose (2.58%), lipids (8.5%) and these results have been confirmed.

1 INTRODUCTION

Coffee is one of the mainstay plantation commodities for Indonesia's national income and foreign exchange. According to data from the International Coffee Organization (ICO) in 2019, Indonesia ranks fourth with a total production of 12 million bags of coffee weighing 60 kg. In Indonesia, the Sumatra Island is the largest coffee plantation area, specifically in Bengkulu province which ranks 6th as the largest coffee barn in Indonesia. Bengkulu coffee plantation produced 184,168 tons of coffee in 2018 (Directorate General of Estate Crops, 2018)

There are three postharvest technologies for red-picked Robusta coffee beans in Bandung Jaya, Kepahiang, Bengkulu: In the full wash, honey, and natural process. In the full wash process, the cherry coffee must be soaked in a soaking tub, and then only submerged cherry coffee is peeled off with a peeling machine. Afterward, it is soaked for twenty-four hours before dried in the drying house pulped coffee beans washed. The honey process is simpler. After the coffee cherries are peeled with a peeling machine, the coffee beans from the pulper machine are fermented in a sack for twenty-four hours, and then dried in the drying house. In the natural process, cherry coffee is not peeled in the peeling machine. After soaking in the tub, it is immediately carried out in the drying house.

Harvesting methods such as selective harvesting are better than strip harvesting. Postharvest processing affects all physical and roast quality attributes so that variations in the physical properties of roasting results due to different harvesting and postharvest processing methods affect the quality of ground coffee (Ameyu, 2016). Interaction of varieties and postharvest processing methods affect the biochemical yield of coffee beans (Kassaye et al., 2019), such as different processing for wet pulper, hand pulper, and eco pulper showing varying results in fatty acid concentrations (Richard et al., 2020). The wet method caused an increase in chlorogenic acid and trigonelline content and a slight loss of sucrose content compared to the dry method (Duarte et al., 2010)

Roasting and milling operations are important operations in ground coffee processing. Roasting is the key to the quality of ground coffee, when roasting

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occurs the process of forming the taste and aroma of the coffee beans. The aroma of coffee is intrinsically related to chemical compounds in the beans, which occur during the roasting process (Toledo et al., 2016). While the factors that influence the roasting process are the type and physio-organoleptic properties of the coffee beans, the ratio of temperature and roasting time, the degree of roasting, and the roasting method (Mulato, 2019). The roasting process causes changes in the chemical composition and biological activity of coffee: while natural phenolic compounds may be lost, other antioxidant compounds are formed such as the products of the Maillard reaction (Wang et al., 2011). Roasting involves high-temperature treatment which triggers non-enzymatic browning reactions, breakdown of polymers (proteins, lipid, carbohydrates), breakdown of polyphenols, and other chemical changes (Wei & Tanokura, 2015).

The milling process in coffee aims to reduce the particle size of coffee beans, this operation can also affect the quality of ground coffee (Yüksel et al., 2020). Like the fine texture of ground coffee, it also determines the taste and aroma of ground coffee (Bladyka, 2016).

Statistical methods have been developed and used in various fields, one of which is optimization. The statistical method commonly applied for optimization is Taguchi. The Taguchi method is off-line quality control which means preventive quality control that ensures the product design or process before it reaches production at the shop floor level. The Taguchi method is expected to improve the quality of products and processes while minimizing costs and resources. The method is aimed to make the product robust against noise (Sidi & Wahyudi, 2013). Taguchi method is used to analyze the experimental finding to achieve one or more of the following three objectives: (1) to determine trends in the influence of factors and interactions being studied, (2) to identify important factors and their relative influence on outcome variability, (3) to determine the best or optimum conditions for a product or process (Roy, 2010).

Based on these considerations, it is necessary to study the relationship between postharvest technologies and processing parameters towards the biochemical characteristics in premium, red-picked Robusta coffee. This study aimed to analyze differences in biochemical characteristics consisting of moisture, caffeine, chlorogenic acid, sucrose, and lipid content of premium red pick Robusta coffee based on postharvest technologies (full wash, honey, and natural) and processing parameters (roasting and milling) of coffee in Bandung Jaya, Kepahiang, Bengkulu. The Taguchi experiment was used in this research and to find out the best conditions from ground Robusta coffee used Grey Relational Analysis.

2 METHODS (AND MATERIALS)

The method used in this research was the experimental method which began with a literature study, established problem formulations and boundaries, determined parameters, performed the tests, analyzed data, discussed test results, and drawn the conclusions.

2.1 Taguchi Experimental Design

Experimental design involves evaluating the ability of two or more factors (parameters) to influence the average or variability of the combined results for a specific product or process characteristics. Several steps proposed by Taguchi to conduct experiments systematically include the following: problem formulation, experimental objectives, identification of independent and dependent factors, determination of each factor level, identification of interactions between control factors, selection of orthogonal arrays, experimental preparation, experiments execution, analysis of data results with ANOVA, interpretation of results, and confirmation (Sidi and Wahyudi, 2013).

2.1.1 Determination of Each Factor's Level (Roy, 2010)

Determination of factors and levels is carried out based on the results of literature studies, discussions with coffee experts, and academics. In this study, four-factor variables were selected at three levels presented in Table 1.

Table 1: Factors and level treatment selected in processing ground Robusta coffee.

No	Factor	Level 1	Level 2	Level 3
1	Postharvest technologies	Full wash	Honey	Natural
2	Temperature of roasting	150ºC	175 ºC	200 ºC
3	Time of roasting	10.0 minutes	12.5 minutes	15.0 minutes
4	Milling	80 mesh	100 mesh	120 mesh

2.1.2 Selection of Orthogonal Matrix (Roy, 2010)

An orthogonal matrix is a matrix of rows and columns. Columns reflect the factors that can be altered during an experiment. The row is a combination of experiment levels and influence (Sidi & Wahyudi, 2013). The orthogonal matrix used was a standard matrix for experiments with a number of 3 levels: L_9 (3^4), L_{27} (3^{13}) and L_{81} (3^{40}). The chosen orthogonal matrix is one with a degree of freedom equal to or greater than the experimental degree, as in this study with a matrix L_9 (3^4) where L denotes: Latin square design, 9 denotes the number of rows or experiments, 3 denotes the number of levels, and 4 denotes the number of columns or factors. Table 2 showed the orthogonal matrix L_9 (3^4) which had 4 factors and 3 levels.

Table 2: Orthogonal Matrix L_9 (3^4).

Experiment number	Experimental factors			
	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

The factors and levels that have been compiled when combined follow the orthogonal array matrix used, they can be presented in Table 3.

Table 3: The full interpretation of Taguchi's orthogonal array.

Experiment number	Experimental factors			
	Postharvest technologies	Temperature of roasting	Time of roasting	Milling
1	Full wash	150ºC	10.0 minutes	80 mesh
2	Full wash	175ºC	12.5 minutes	100 mesh
3	Full wash	200ºC	15.0 minutes	120 mesh
4	Honey	150ºC	12.5 minutes	120 mesh
5	Honey	175ºC	15.0 minutes	80 mesh
6	Honey	200ºC	10.0 minutes	100 mesh
7	Natural	150ºC	15.0 minutes	100 mesh
8	Natural	175ºC	10.0 minutes	120 mesh
9	Natural	200ºC	12.5 minutes	80 mesh

2.1.3 The Stage of Carrying Out the Taguchi Experiment

The processing treatment was carried out based on a combination of factors and levels in the Taguchi method with the experimental design shown in Table 3. The green coffee bean samples was prepared for each treatment so that the total ingredients used were 27 kg (9 kg green bean full wash, 9 kg green bean honey, and 9 kg natural green bean). Before the roasting process, 1 kg of the bean sample was weighed in triplicate one treatment. The sample was roasted with the temperature and roasting time according to the combination of factors and levels. After the roasting process was complete, the coffee was cooled and put into a labeled plastic. After cooling (8-24 hours), the sample was grounded using a grinder machine in the coffee processing plant. Milling was carried out with a variety of mesh, namely: 80, 100 and 120 mesh (Table 1).

The quality of ground coffee resulted from the experiments was evaluated its biochemical characteristics. The characters included moisture, caffeine, chlorogenic acid, sucrose, and lipid content. Determination of moisture content used the oven method. The sample was dried in an oven set to 100 ℃ - 102 ℃ until the sample has a constant weight. Caffeine content was determined using the Balley-Andrew method. The chlorogenic acid concentration was measured using an HPLC instrument. The sucrose content was calculated as the difference between reducing sugar and the total sugar. The sugar reduction was determined based on the Nelson Somogyi method. Meanwhile, the lipid content was measured using the Soxhlet method, the principle of Soxhlet method was the separation of the components contain in the substance by filtering for carried out several times using a certain solvent so that the desired component was obtained.

2.2 Data Analysis

2.2.1 Determine Effectiveness Treatments with S/N (Signal to Noise) and ANOVA

The Taguchi method is used to design experiments based on the orthogonal arrays to obtain the maximum amount of information with minimum experiments. Moreover, it can also analyze the experimental data based on the signal-noise ratio. The signal-noise ratio (S/N) is the ratio of the mean standard deviation which serves as an objective function for the optimization process The biochemical quality characteristics discussed in this study are moisture content, caffeine, chlorogenic acid, sucrose, and lipid in ground coffee. The quality characteristics of the ratios used for each parameter are described as follows:

1. Moisture content (smaller the better) which means the smaller in moisture content value on the test results, the better the nature of the ground coffee produced, this determination refers to where the maximum moisture content in coffee is 7% (The National Standardization Agency of Indonesia, 2004), the moisture content is related to the shelf life to prevent discoloration, mold and the appearance of other microorganisms, so that if the content is high, the product is easily contaminated by microorganisms (Novita et al., 2010).
2. Caffeine is determined (large the better), based on states that caffeine in coffee it also as an index of organoleptic quality and used as a consideration to determine the mixing formula for a recipe of ground coffee mixture (Marsilani et al., 2020). The main role of caffeine in the body is to increase psychomotor work so that the body remains awake and provides a psychological effect in the form of increased energy (Thomas et al., 2016).
3. Chlorogenic acid is determined (larger the better) with the consideration that chlorogenic acid is beneficial for human health, namely as an antioxidant, antiviral, hepatoprotective, and plays a role in antispasmodic activities, high chlorogenic acid in coffee can be used as a source of therapy or drug manufacture (Farhaty & Muchtaridi, 2014)
4. Sucrose is determined (larger the better) because sucrose plays a role in influencing the test and aroma of coffee so it is expected that its presence is always high in coffee (Borem et al., 2016)
5. Lipids is determined (smaller the better) because lipids in coffee affect the taste of coffee grounds, an increase in free fatty acids during storage will cause rancidity in coffee grounds so that it affect to the taste, causing a decrease in the quality of ground coffee (Hayati et al., 2012).

A mathematical model for the signal to noise ratio (S/N) (Jeffrey et al., 2011):

For Smaller the better

$$SNR = -10 \log \left(\frac{1}{n} \sum_{i}^{1} - yi^2 \right) \quad (1)$$

For Larger the better

$$SNR = 10 \log \left(\frac{1}{n} \sum_{i=1}^{n} \frac{1}{y1^2} \right) \quad (2)$$

where y_i is a quality measurement; and n is the total of the measurements.

ANOVA in Taguchi to detect differences in the mean performance of the test groups of parts. ANOVA can analyze the total variance into factor variance so that it can be seen the effect of each factor on the total variance. The use of ANOVA in the Taguchi method is used as a statistical method to interpret experimental data in the calculation of the process as follows (Jeffrey et al., 2011):

1. Calculating the total sum of squares (Sstotal), with the following formula :

$$\text{Ss total} = \sum y^2 \quad (3)$$

Where y is the data for every replication.

2. Calculating the Sum of squares due to mean (Ssmean)

$$Ssmean = n.\underline{y}2 \quad (4)$$

Where n is total all replication.

3. Calculating the sum of square due to factors SS_A, SS_B, etc), example factor A:

SSA=[$(\underline{A1})^2 xn1$] +[$(\underline{A1})^2 xn2$]+…+ =[$(\underline{Ai})^2 xn1$]-$ssmean$ (5)

4. Calculating the sum of square total (SST

SST= $(Sstotal - Ssmean)$ (6)

5. Calculating the sum of squares due to error (SSe)

$$SSe = SStotal - SSmean - SS_A\text{-}SS_B\text{-}SSn \quad (7)$$

6. The degrees of freedom factor (DF)

$$DF = (number\ of\ levels - 1) \quad (8)$$

7. The degrees of freedom factor total (DF total)

$$DF\ total = (number\ of\ experiment - 1) \quad (9)$$

8. Calculating mean sum of squares (MS)

$$MS = \frac{SS}{DF} \quad (10)$$

Where MS is mean Square, DF is degrees of freedom

9. Calculating of (F-Ratio)

$$F\ ratio = \frac{Ms\ on\ each\ factor}{Ms\ error} \quad (11)$$

10. Calculating the pure sum of square (SS') for each factor

SS'= $(SS\ factor - (v\ factor\ xMS\ error$ (12)

11. Calculating % Ratio of each factor, example factor A:

$$\%\ Ratio\ A = \frac{SSA\prime}{SST} \quad (13)$$

2.2.2 Determination of The Best Treatment

To overcome the multi-response problem in the Taguchi method, Grey Relational Analysis (GRA) was performed to obtain the best treatment with several analysis steps below (Jeffrey et al., 2011):

1. Calculating the normalization of SNR value for each response to reduce the effect of using different units and reduce variability, the equation is as follows:

$$X_i^*(j) = \frac{x_i(j) - x_i(j)}{max\, x_i(j) - min x_i(j)} \quad (14)$$

(for signal to noise larger the better)

$$X_i^*(j) = \frac{x_i(j) - x_i(j)}{max\, x_i(j) - min x_i(j)} \quad (15)$$

(For signal to noise small the better)

where xi(j) is the measurement of the quality characteristics

2. Calculating the delta and gamma values (grey relational coefficient) for each response. After the deviation sequence value was obtained, put into the formula to calculate the Grey Relational Coefficient value. Distance measure $\Delta_{oi}(j)$ was performed which was the absolute value of the difference between x_0^* and x_i^* on j point.

$$\Delta_{oi}(j) = |x_0^*(j) - x_0^*(j)| \quad (16)$$

Note:
$x_0^*(j)$ = 1 (highest value of SNR was inversed as (1)
calculating grey relational coefficient $\gamma_{0i}(j)$, with following equation:

$$\gamma_{0i}(j) = \frac{\Delta_{+} \lambda\Delta max}{\Delta 0i\ (j) + \lambda\Delta max} \quad (17)$$

Note:
Δ_{min} = minimum value of $\Delta_{0i}(j)$
Δ_{min} = maximum value of $\Delta_{0i}(j)$
λ = coefficient range between 0 and 1 (value λ determined by the decision-maker as he expected, generally λ = 0,5)

3. Calculating grey relational grade which resulted from the average of the grey relational coefficient from the whole response

$$\gamma_i = \frac{1}{n}\sum_{k-1}^{n} \xi(k) \quad (18)$$

4. After obtaining the Grey Relational Grade value for each experiment, the highest value was determined from the response of each factor at each level.

2.2.3 Confirm Test

The confirmatory experiment is designed to ensure that the variables and levels chosen provide the expected results. The confirmation test results are declared valid or accepted if the confirmation test's confidence interval falls within the optimal value interval and rejected if the confidence interval is not within the optimal value interval. The confidence interval was calculated using equations (Jeffrey et al., 2011).

Optimal Condition (Taguchi Experiment)

a. Optimal Condition

$$\mu prediction = \bar{y}ijkoptimal - \bar{y} \quad (19)$$

Note:
$\underline{yijk}$ optimal = The sum of the average value of the optimal level

b. Calculation of Confidence Interval

$$Clmean = \pm\sqrt{F \propto; v1; v2xMSe1\, x \frac{1}{neff}} \quad (20)$$

$$neff = \frac{Number\ of\ x\ experiment\ repetition}{Number\ of\ DF\ used\ for\ average\ value}$$

Note:
Cl = confidence interval
$F\propto;v1;v2$ = F-ratio value from table
$\propto$ = Risk, confidence level = 1 – risk
$v1$ = Degree of freedom for the numerator
$v2$ = Degree of freedom for the denominator
MSe= Mean polled error sum of squares

Confirmatory Experiment

a. Calculation of Mean Value

$$\mu = \frac{1}{n}\sum_{i=1yi}^{n} \quad (21)$$

b. Calculation of confident interval

$$Clmean = \pm\sqrt{F \propto; v1; v2xMSe1\, x \left(\frac{1}{neff} + \frac{1}{r}\right)} \quad (22)$$

Note: r = The number of observations used to calculate the mean

3 RESULT AND DISCUSSION

3.1 Effectiveness of Treatment on Biochemical Characteristics

3.1.1 Moisture Content

ANOVA calculations use equations 3 to 13. In moisture content result presented in Table 4:

Table 4: ANOVA calculation of moisture content mean from ground coffee.

Source	F Ratio	% ratio	F -Table
Postharvest technologies	2619.28	49.12	4.256
Temperature of roasting	881.0	16.51	4.256
Time of roasting	199.51	3.72	4.256
Milling	1626.19	30.49	4.256
Residual Error	1	0.16	4.256
Total		100	

According to ANOVA in Table 4, calculation average of moisture content, all factors have an F-ratio value ≥ F-Table which means that they have a significant influence on the characteristics of the moisture content. Postharvest technology factor is the most influential factor on moisture content with the largest contribution of 49.12%. Post-harvest handling is an activity that includes all treatments from harvesting to the production of green coffee beans (Mayrowani, 2013). One of the causes to decrease in moisture content is post-harvest handling and drying of coffee beans (Novita et al., 2010). Full wash, honey and natural processes which have different processing stages affect the moisture content of the coffee beans, this also affects the moisture content of the ground coffee produced because the moisture content of the initial coffee beans used is different. In addition, the mill size factor also contributes greatly to the moisture content of ground coffee, the size of the mesh affects the resulting texture, the larger the mesh size, the smoother the resulting material (Yulia et al., 2018). The larger of the mesh size (the smaller the particle size of the ground coffee), the higher the absorbance intensity.

3.1.2 Caffeine

Table 4 shown the result of ANOVA calculations in caffeine content.

Table 5: ANOVA calculation of caffeine mean from ground coffee.

Source	F Ratio	% Ratio	F-Table
Postharvest technologies	75.50	22.04	4.256
Temperature of roasting	219.07	64.52	4.256
Time of roasting	26.00	7.40	4.256
Milling	12.93	3.53	4.256
Residual Error	1	2.51	4.256
Total		100	

According to ANOVA calculation in Table 5, calculation average of caffeine**,** all factors have an F-ratio value ≥ F-Table which means that they have a significant influence on the characteristics of the caffeine. Roasting temperature factor is the most influential factor on caffeine content with the largest contribution of 64.52%. Roasting time and higher roasting temperature increased caffeine content due to the breakdown of liquids and acids (Agustina et al., 2019). Higher roasting temperature intensified the caffeine content in the ingredients, as the amount of liquid and acidic substances decreased, the amount of non-liquid content such as caffeine, minerals, and lipids increased (Wijayanti & Anggia, 2020).

3.1.3 Chlorogenic Acid

The results of the ANOVA calculations in chlorogenic acid are presented in Table 6:

Table 6: ANOVA calculation of chlorogenic acid mean from ground coffee.

Source	F Ratio	% Ratio	F-Table
Postharvest technologies	370.23	60.17	4.256
Temperature of roasting	105.69	17.06	4.256
Time of roasting	15.73	2.40	4.256
Milling	117.51	18.99	4.256
Residual Error	1	1.39	4.256
Total		100	

In Table 6, it is known that all factors have an F-ratio value ≥ F-Table, it means that the factors have a significant effect on the characteristics of chlorogenic acid. Postharvest technologies factor is the most influential factor on the levels of chlorogenic acid with the largest contribution of 60.17%. The differences in the stages of processing coffee in full wash, honey and natural processes in this study have an effect on the content of chlorogenic acid. This is appropriate where the biochemistry of coffee is significantly influenced by the processing process, such as the wet processing method causing an increase in the content of chlorogenic acid (Duarte et al., 2010).

3.1.4 Sucrose

The results of the ANOVA calculations of sucrose are presented in Table 7.

Table 7: ANOVA calculation of sucrose mean from ground coffee.

Source	F Ratio	% Ratio	F-Table
Postharvest technologies	1.62	5.71	4.256
Temperature of roasting	2.08	9.93	4.256
Time of roasting	2.28	11.73	4.256
Milling	0.41	-5.44	4.256
Residual Error	1	78.07	4.256
Total		100	

F-ratio value ≤ F-Table which means that it does not have a significant effect on the characteristics of sucrose. Roasting time factor donating a percentage ratio of 11.73% and a roasting temperature of 9.93%. Roasting time and roasting temperature cause a decrease in the content of sucrose, amino acids, proteins, and polysaccharides (Williamso & Hatzakis, 2019), because roasting causes the evaporation of some substances in the coffee beans.

3.1.5 Lipid

The results of the ANOVA calculations of lipid are presented in Table 8.

Table 8: ANOVA calculation of lipid mean from ground coffee.

Source	F Ratio	% Ratio	F Table
Postharvest technologies	4580.48	37.34	4.256
Temperature of roasting	2435.06	19.85	4.256
Time of roasting	4642.02	37.85	4.256
Milling	600.66	4.89	4.256
Residual Error	1	0.07	4.256
Total		100	

Table 8 shows the F ratio value ≥ F-Table, this means that all factors have a significant effect on the lipid of ground coffee. The roasting time factor is the most influential factor on lipid content with the largest contribution of 37.85%. Differences in the coffee process result in distinct tastes, owing primarily to differences in the chemical composition it contains. Wet-processed coffee beans contain higher levels of amino acids, fats, and ash, and contain less protein and caffeine than dry-processed coffee. Conducted a study and demonstrated that roasting had a significant impact on coffee and on the lipid composition of coffee beans (Williamson & Hatzakis, 2019).

3.2 Determination of the Best Treatment

There were 5 types of response variables in this study, each with a different set of quality characteristics (moisture content “small the better, caffeine “large the better”, chlorogenic acid “large the better”, sucrose “large the better”, and lipid “small the better).

Table 9: SNR value for each response.

Experiment	Moisture content	Caffeine	Chloro-genic acid	Sucrose	Lipid
I	-12.95	-3.54	15.32	-6.07	-20.76
II	-13.06	-2.21	17.45	-3.69	-21.59
III	-12.72	-1.67	13.84	-14.89	-21.06
IV	-11.93	-2.62	9.11	-10.62	-20.83
V	-10.38	-1.83	8.95	-20.00	-20.96
VI	-11.85	-1.57	7.77	-13.55	-18.85
VII	-13.94	-3.04	16.93	-13.36	-21.30
VIII	-13.14	-2.73	12.79	-20.00	-21.03
IX	-11.54	-2.33	9.98	-20.00	-21.27

The calculation of the SNR value for the five responses was calculated with equation (1) and equation (2). The result presented in Table 9: After calculating the SNR, then the normalization of the SNR was performed under equations (14) and (15). The normality data of SNR is presented in Table 10.

Before performing the analysis using Grey Relational Grade, first calculate the delta value and gamma value of each response according to equation (16), equation (17), and equation (18). Deviation sequence (Delta) is presented in Table 11, meanwhile the Grey Relational Coefficient and Grey Relational Grade are presented in Table 12.

After obtaining the Grey Relational Grade value for each experiment, the best treatment was calculated as the response of each factor at each level that produced the highest value (Table 13).

In table 13, the best treatment was obtained from combination of the factors of A1B2C2D2 levels (full wash postharvest technologies, roasting temperature 175 ºC, roasting time 12.5 minutes, and milling 100 mesh).

After obtaining the Grey Relational Grade value for each experiment, the best treatment was calculated as the response of each factor at each level that produced the highest value (Table 13).

Table 10: Normality of data.

Experiment	Normality of data								
	Factor				Moisture content	Caffeine	Chlorogenic acid	Sucrose	Lipid
	A	B	C	D					
I	1	1	1	1	0.720	0.000	0.779	0.854	0.698
II	1	2	2	2	0.753	0.672	1.000	1.000	1.000
III	1	3	3	3	0.656	0.947	0.627	0.313	0.805
IV	2	1	2	3	0.435	0.470	0.138	0.575	0.723
V	2	2	3	1	0.000	0.867	0.122	0.000	0.771
VI	2	3	1	2	0.413	1.000	0.000	0.395	0.000
VII	3	1	3	2	1.000	0.257	0.946	0.407	0.894
VIII	3	2	1	3	0.774	0.410	0.519	0.000	0.795
IX	3	3	2	1	0.324	0.613	0.229	0.000	0.884

Table 11: Deviation sequence (Delta).

Experiment	Deviation sequence (Delta)								
	Factor				Moisture content	caffeine	Chlorogenic acid	Sucrose	Lipid
	A	B	C	D					
I	1	1	1	1	0.280	1.000	0.221	0.146	0.302
II	1	2	2	2	0.247	0.328	0.000	0.000	0.000
III	1	3	3	3	0.344	0.053	0.373	0.687	0.195
IV	2	1	2	3	0.565	0.530	0.862	0.425	0.277
V	2	2	3	1	1.000	0.133	0.878	1.000	0.229
VI	2	3	1	2	0.587	0.000	1.000	0.605	1.000
VII	3	1	3	2	0.000	0.743	0.054	0.593	0.106
VIII	3	2	1	3	0.226	0.590	0.481	1.000	0.205
IX	3	3	2	1	0.676	0.387	0.771	1.000	0.116

Table 12: Grey Relational Coefficient and Grey Relational Grade.

Experimen t	Grey Relational Coefficient									Grey Relational Grade
	Factor				Moisture content	Caffeine	Chlorogenic acid	Sucrose	Lipid	
	A	B	C	D						
I	1	1	1	1	0.641	0.333	0.694	0.775	0.623	0.613
II	1	2	2	2	0.669	0.604	1.000	1.000	1.000	0.855
III	1	3	3	3	0.592	0.904	0.572	0.421	0.720	0.642
IV	2	1	2	3	0.469	0.485	0.367	0.541	0.643	0.501
V	2	2	3	1	0.333	0.790	0.363	0.333	0.686	0.501
VI	2	3	1	2	0.460	1.000	0.333	0.453	0.333	0.516
VII	3	1	3	2	1.000	0.402	0.903	0.458	0.825	0.717
VIII	3	2	1	3	0.689	0.459	0.510	0.333	0.709	0.540
IX	3	3	2	1	0.425	0.564	0.393	0.333	0.812	0.506

Table 13: The response of each factor at each level.

Level	Factor			
	A	B	C	D
1	0.703	0.611	0.556	0.540
2	0.506	0.632	0.621	0.696
3	0.588	0.554	0.620	0.561
Delta	0.197	0.077	0.064	0.156
Rank	1	3	4	2

In table 13, the best treatment was obtained from combination of the factors of A1B2C2D2 levels (full wash postharvest technologies, roasting temperature 175 ºC, roasting time 12.5 minutes, and milling 100 mesh).

3.3 Confirm Test

Confirmation is done by comparing the actual value

Table 14: Comparison experiment result confident intervals.

Response	Taguchi experiment		Confirmatory experiment		Note
	Prediction	Optimization	Prediction	Optimization	
Moisture content	3.37	3.37±0.2745	3.21	3.21±0.3783	Confirmed
Caffeine	0.84	0.84±0.0249	0.81	0.81±0.0343	Confirmed
Chlorogenic acid	7.19	7.19±1.0444	8.1	8.1±1.4395	Confirmed
Sucrose	0.75	0.75±0.3494	2.58	2.58±0.4815	Confirmed
Lipid	9.56	9.56±0.5599	8.5	8.5±0.7717	Confirmed

with the prediction interval so that the upper and lower limits can be known. The treatment is said to be confirmed if the actual value is in the predicted value interval. The confidence interval was calculated using equations (19) to (22). Table 14 comparison experiment result in confidents intervals. The decision on whether the optimal condition can be accepted or not is to compare the mean value of the prediction on Taguchi and the results of the confirmation experiment with each level of confidence. If the confidence interval of the confirmation experiment is within the confidence interval of the Taguchi experiment, then the decision is accepted and confirmed even though not all are vulnerable. In Table 14, biochemical characteristic in confirmatory experiment is confirmed because the result better than Taguchi experiments.

The best combination of factors and levels in this study was the treatment with full wash postharvest technology, temperature 175ºC, roasting time 12.5 minutes and milling 100 mesh, with moisture content values (3.21%), caffeine (0.81%), chlorogenic acid (8.1%), sucrose (2.58%), and lipid (8.5%). Research related to the effect of postharvest handling on chlorogenic acid and caffeine content shows that in wet processing is greater than that of semi-wet and dry processing (Kassaye et al., 2019). Similarly with this study, to get a good chlorogenic acid and caffeine, proper postharvest technology was the full wash method.

The interaction between temperature and roasting time has a significant effect on parameters, such as moisture content, ash content, caffeine content, antioxidant activity, yield (Saloko et al., 2019). At different temperatures, the moisture content tends to fluctuate, the longer the roasting time, the higher the evaporated water. A roasting temperature of 190ºC and a time of 10 minutes is the best combination of treatments, if the temperature and roasting time exceed it will cause a decrease in the quality of the ash and caffeine content (Thomas et al., 2016). Similarly with this study the combination of postharvest technology full wash, temperature 175ºC, time 12.5 minutes, and milling 100 mesh, interact with each other to produce the best moisture and caffeine content.

Chlorogenic acid will be degraded higher with a long time and high temperature. The temperature of 225ºC for 19 minutes chlorogenic acid degraded up to 85% (Diviš et al., 2019). The roasting process produces melanoidin and aroma compounds while reducing other important ingredients such as sucrose, protein, amino acids, fatty acids, chlorogenic acids, and polysaccharides. Only caffeine is relatively stable during roasting because it is stable to heat (Wang & Lim, 2015). Controlling the temperature and roasting time at 175ºC and 12.5 minutes in this study caused biochemical parameters such as caffeine, chlorogenic acid, sucrose, and lipid to be in the best position.

Roasting conditions such as roasting degree affect the antioxidants in coffee. During roasting, low water activity and high temperature support the development of the Maillard reaction, so that phenolic compounds also participate in this reaction which become part of melanoidin, can maintain or increase antioxidant compounds, but with increasing roasting activity will cause greater damage than phenolic compounds. So that coffee that comes from light roasting shows a greater antioxidant capacity (Vignoli et al., 2014). The combination of treatment with full wash postharvest technology, roasting temperature of 175C, time of 12.5 minutes, and milling 100 mesh, this find out light roasting product so caused the best in biochemical characteristic.

4 CONCLUSIONS

The effectiveness of treatment has a significant difference from each treatment for the parameters of moisture, caffeine, chlorogenic acid, and lipid content because value F-Ratio ≥ F-Table, but not significantly different for the mean on the sucrose parameter.

The best treatment was the combination of full wash postharvest technologies, roasting temperature 175 ºC, roasting time 12.5 minutes, and milling mesh 100 which resulted in moisture content (3.21%), caffeine (0.81%), chlorogenic acid (8.1%), sucrose (2.58%), and lipid (8.5%). All these results were confirmed through a confirmatory experiment.

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