Sensory Evaluation of Robusta Coffee under Various Postharvest and Processing

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ABSTRACT
The sensory quality of food products including coffee determines the level of consumer acceptance. This study ancover the differences in consumer acceptance and determines the best postharvest and processing treatments of ground and brewed Robusta coffee. The Taguchi orthogonal array L9 (34) with four factors and three levels: postharvest (full wash, honey, natural), roasting temperature (150, 175 and 200ºC), roasting time (10, 12.5 and 15 minutes), and milling (80, 100 and 120 mesh), was used in the study. The acceptance was assessed on five hedonic scales by 36 trained panelists. One-way ANOVA and DMRT were performed the significant differences in panelist acceptance under various postharvest and processing treatments. At the same time, zero-one integer programming was used to determine the best treatment combination. The best acceptance results were further tested through a confirmation test. Postharvest and processing treatments significantly influenced ($p<0.05$) most of the sensory qualities of the samples, such as color and aroma of brewed samples as well as taste, bitterness, viscosity, and overall of the brewed samples. The best combination of the postharvest and processing treatments for the sample was postharves honey, temperature and roasting time of 175ºC for 15 minutes, and a sieve size of 80 mesh, all attributes confirmed as well as attribute in a favorable acceptance level in score (3.58) and less-favorable in score (3.22). Various of postharvest and processing treatments influence sensory quality of ground and brewed so effect of consumer acceptance.

Keywords: *Consumer acceptance, Postharvest, Processing, Robusta coffee, Zero one.*

1. INTRODUCTION

Quality is the main criterion that can help producers win the global coffee market. Quality can be expressed by physical composition, organoleptic and biochemical [1]. The stages of the coffee processing may determine the quality of the beans, ground and brews produced [2]. The most commonly recognized methods of coffee beans processing are the dry and the wet methods. In addition to wet and dry processings, semi-wet processing method is currently known [3]. There are three methods to process red-picked robusta coffee beans in Bandung Jaya Village, Kepahiang district, Bengkulu province, namely the full wash, honey, and natural process. Different methods can have an impact on sensory qualities such as improving the taste and aroma of the coffee [4]. Roasting and grinding operations are important operations in ground coffee processing. Roasting is the key to the quality of ground coffee, when roasting occurs the process of forming taste and aroma in coffee beans [5]. The colour produced from coffee grounds is also affected during the roasting process [6]. The grinding process in coffee aims to reduce the particle size of the coffee beans, this operation can also affect the quality of ground coffee [7]. Particle size, contact time, and type of coffee affect the physicochemical and sensory properties of coffee [8].

Table 1. Factors and level chose in robusta coffee processing

No	Factor	Level 1	Level 2	Level 3
1	Postharvest (A)	Full wash	Honey process	Natural process
2	Roasting temperature (B)	150ºC	175 ºC	200 ºC
3	Roasting time (C)	10 minutes	12.5 minutes	15 minutes
4	Milling (D)	80 mesh	100 mesh	120 mesh

Sensory evaluation is widely used to assess quality in the food industry and other agricultural products. Hedonic testing is a test in organoleptic sensory evaluation that is used to determine the magnitude of the difference in quality by giving a score to certain properties of a product [9]. The results of sensory testing have been analyzed statistically, and the test results obtained only show the difference in the effect of each treatment. We need a data analysis that can help to make a final decision to get the best product in general. Zero one is a technique for selecting the best alternative by making comparisons between alternatives based on the criteria and weight of each alternative. This comparison process is carried out against each existing criterion and each alternative is compared one by one. So that the zero one method can be used as a priority analysis in decision making. Zero-one can be used to determine the best formula from several alternatives for several criteria in decision making [10].

Based on these considerations, it is necessary to determine the differences in consumer acceptance and to determine the best variants of postharvest and processing treatments for ground robusta coffee and its brew from sensory evaluation. The research design used was the Taguchi design, which its design can be an effective lower cost product design [11].

2. MATERIAL AND METHOD

2.1. The Taguchi experiment design

Determination of factors and levels was carried out based on literature studies, discussions with coffee experts and academics. In this study, four-factors with three levels were used, as presented in Table 1.

The choice of a standard orthogonal matrix is done by determining the degrees of freedom. The degree of freedom is the level of each factor minus one, because there are 4 factors each with 3 levels, the total degrees of freedom are 8 (eight). The chosen Orthogonal matrix is a matrix that has a degree of freedom value equal to or greater than the value of the experimental degree, so in this study using the L_9 (3^4) matrix, 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).

Table 2. Orthogonal Matrix L_9 (3^4)

Experiments 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

2.2. Implementation of the Taguchi experiment

The processing treatment was carried out based on a combination of factors and levels in the Taguchi method shown in Table 2. 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 the roasted coffee for 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).

2.3. Sensory evaluation

Sensory evaluation was carried out on ground coffee and brew coffee samples using the five scale hedonic test, ranging from (dislike very much, dislike slightly, like slightly, like moderately, and like very much) [13]. Sensory testing was carried out at two Rumah Kopi in Bandung Jaya Village and Kepahiang both of them were production centers and gathering places for the coffee lover community. According to [12], the panelist commitment, motivation, and knowledge, significantly influences panelists' success in conducting sensory analysis. A total of 36 panelists with the criteria of having a great interest in coffee, accustomed to drinking coffee twice a day, and having a sufficent knowledge of coffee, were asked to fill in the sensory attribute scores listed on the questionnaire. Ground coffee color, aroma, and fineness, and brew color, aroma, taste, bitterness, acidity, sweetness, viscosity, and overall acceptance were used as the sensory attributes. Samples of ground coffee were presented in plastic jars with same sample weight. Sensory evaluation of brewed sample was also carried out. The ratio of coffee ground to water (w/v) was (8.25 g: 150 ml). During the evaluation, the panelists were ensured to drink water before starting the next samples assessment.

2.4. Data analysis

2.4.1. Determination of acceptance difference

Data analysis was performed using one-way ANOVA using IBM SPSS Statistics 22. The difference between the means of each treatment was followed by the posthoc DMRT test. P-value or significance less than 0.05 ($p<0.05$) was considered to have a statistically significant difference.

2.4.2. The Best Treatment Determination

The determination was carried out using the zero one integer programming analysis. With multi-inputs and -outputs in the experiment, it was necessary to make a multi-criteria decision. We performed a ranking analysis to determine the priority order of the treatments. A ranking analysis is a method used in engineering to examine more deeply an alternative presented both qualitatively and quantitatively. Ranking analysis can be done using the Zero-one method [14]. Zero one decision-making stages: Determining the percentage of criteria values by calculating the criteria ranking divided by the total of criteria rankings and then multiplying by 100. Making a diagonal matrix, the principle of this method is to determine the relativity of a criterion "more important" or less important to other criteria. The more important criteria are given a value of 1 (one), while the less important values are given a value of 0 (zero), the criteria that are compared with the criteria themselves will be marked with a cross (X). Doing a comparison reference then finally obtained an index for each criterion. Furthermore, making an evaluation matrix, in this section an assessment of the alternatives displayed will be carried out, the assessment is carried out by considering the established criteria and then choosing the best alternative based on the largest total value.

2.5. Confirmation step

The purpose of the confirmation test is to validate the best treatment obtained from data analysis using zero-one. Confirmation was done by comparing the actual value with the predicted interval so that the upper and lower limits can be found. The treatment is said to be confirmed if the actual value is at the predicted value interval.

3. RESULT AND DISCUSSION

3.1. The average attribute value of each treatment and its significance

Panelists used in this hedonic test were trained panelists consisting of 36 people. Regarding the organoleptic or sensory testing instructions, the minimum number of trained panelist in one test is six people and for untrained panelists is 30 people [15]. Table 3 showed the results of the sensory evaluation of each attribute. There were significant differences in the attributes of ground coffee color, brewed coffee color, the aroma of brewed, the taste of brewed, the bitterness of brewed, viscosity,and the overall acceptance among treatments ($p<0.05$), it means factor and level of various postharvest and processing treatments gave a significant difference for the panelist's preferences that attributes. The treatment did not significantly different to attributes ground aroma, and fineness, as well as brewed acidity, and sweetness ($p>0.05$).

Color is the first sensory that can be seen directly by panelists. Determination of the quality of food ingredients generally depends on the color it has, a color that does not deviate from the color that should give the impression of a separate assessment by the panelists [16]. The role of color is very important, because generally consumers will get the first impression whether they like or dislike a food product from the color. In Table 3, ground color of treatment 5 had the highest score. In brewed coffee, the color score that had the highest score on treatment 4. The interaction of temperature and roasting time results in color differences, roasting time produces a higher color value on ground and brew coffee [17]. The interaction of temperature and time in the roasting process causes the sugar caramelization process in coffee beans which causes color changes.

The aroma-forming compounds in coffee that come from volatile components are sulfur components, pyrazines, pyridines, pyrroles, the furran group, the aldehydes, ketones group, and the phenol group. The distinctive aroma of coffee will be formed during the roasting process and appears during the brewed process [18]. In table 3, ground aroma of treatment 9 had the highest score. In brewed coffee, the aroma score that had the highest score on treatment 5. Roasted coffee

Table 3. Average scores of sensory attributes of Robusta coffee

		Treatments								
Form	Attributes	1	2	3	4	5	6	7	8	9
Ground	Color (*)	2.61 ±0.80 ^{a}	3.17±0.81^{ab}	3.17±0.91^{ab}	3.41±0.73^{b}	3.53±0.81^{b}	3.28±0.97^{b}	3.06±1.01^{ab}	3.36±0.79^{b}	3.47±0.94^{b}
	Aroma	2.83±0.94^{a}	3.00±0.89^{a}	2.92±0.87^{a}	3.28±0.91^{a}	3.28±0.91^{a}	3.11±0.92^{a}	2.86±0.93^{a}	3.28±0.81^{a}	3.39±0.90^{a}
	Fineness	3.28±0.85^{a}	3.53±0.74^{a}	3.44±0.73^{a}	3.47±0.61^{a}	3.53±0.65^{a}	3.70±0.67^{a}	3.50±0.88^{a}	3.56±0.77^{a}	3.47±0.81^{a}
Brewed	Color (*)	2.75±0.91^{a}	3.19±0.86 ^{ab}	3.39±0.73^{b}	3.67±0.67^{b}	3.58±0.73^{b}	3.64±0.68^{b}	3.42±0.84^{b}	3.47±0.65^{b}	3.42±0.69^{b}
	Aroma (*)	2.56±0.87^{a}	2.94±0.86^{ab}	3.19±0.85^{bc}	3.31±0.78^{bc}	3.58±0.91^{c}	3.42±0.87^{bc}	3.25±0.77^{bc}	3.47±0.65^{bc}	3.44±0.81^{bc}
	Taste (*)	2.56±0.81^{a}	3.11±0.82^{ab}	3.14±0.96^{ab}	3.33±0.93^{b}	3.36±0.83^{b}	3.44±0.91^{b}	3.11±0.92^{ab}	3.25±0.69^{b}	3.58±0.60^{b}
	Bitterness (*)	2.58±0.87^{a}	3.03±0.91^{ab}	3.19±1.04^{ab}	3.25±0.81^{b}	3.53±0.84^{b}	3.39±0.87^{b}	3.08±0.77^{ab}	3.36±0.64^{b}	3.47±0.74^{b}
	Acidity	2.50±0.88^{a}	2.67±0.83^{a}	2.81±0.82^{a}	2.94±0.95^{a}	3.03±1.03^{a}	3.11±1.01^{a}	2.86±0.93^{a}	3.06±0.89^{a}	2.94±0.89^{a}
	Sweetness	2.75±0.87^{a}	2.86±0.87^{a}	2.94±0.89^{a}	2.89±0.88^{a}	3.08±0.91^{a}	3.17±0.94^{a}	2.86±0.79^{a}	2.97±0.69^{a}	2.94±0.82^{a}
	Viscosity (*)	2.58±0.81^{a}	2.94±0.83^{ab}	3.06±0.86^{abc}	3.28±0.78^{bc}	3.50±0.77^{bc}	3.53±0.74^{c}	3.08±0.84^{abc}	3.17±0.65^{bc}	3.28±0.61^{bc}
	Overall acceptance (*)	2.94±0.71^{a}	3.22±0.68^{ab}	3.44±0.69^{b}	3.47±0.61^{b}	3.52±0.74^{b}	3.58±0.65^{b}	3.33±0.67^{ab}	3.38±0.59^{ab}	3.50±0.61^{b}

Note: The attributes with (*) were significantly different at ($p<0.05$) and the numbers followed by the same letter in each row were not significantly different at ($p>0.05$)

aroma is formed from the Maillard reaction or non-enzymatic browning reaction, free amino acid degradation, trigonelin degradation, sugar degradation and degradation of phenolic compounds. The distinctive aroma of coffee will slowly appear after the roasted beans are cooled. The longer the roasting, the more volatile compounds that evaporate so that it will affect the aroma of ground coffee [17].

The milling process in coffee processing aims to reduce the particle size of the coffee beans so that their physical properties change. In table 3, the highest score for panelists' preference for ground coffee fineness was treatment 6. The finer the grind, the smaller the particle size, the greater the surface area and therefore additional contact between coffee grounds and water. The grind size and shape thus is correlated with pore space of the coffee bed. The coffee grind has also been found to influence the rate of caffeine extraction [19]

The taste of food and beverages is the most critical factor for consumers. The taste of brewed coffee depends on the size of the coffee grinder, the ingredients added, and the amount of water used in the brew. Some

Table 4. .Evaluation Matrix

Criteria	1	2	3	4	5	6	7	8	9	10	11	Total
Weight	9.16	8.81	9.93	9.63	9.20	9.11	9.11	8.17	8.34	8.96	9.58	100
1	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	
2	6.94	8.34	15.28	2.78	2.78	4.17	2.78	2.78	4.17	2.78	2.78	5.13
	63.64	73.52	151.66	26.74	25.54	37.95	25.30	22.70	34.77	24.89	26.61	
3	6.94	5.56	2.78	5.56	5.56	8.33	8.33	5.56	12.50	5.56	11.11	7.03
	63.64	49.01	27.57	53.48	51.08	75.89	75.89	45.41	104.30	49.79	106.44	
4	16.67	18.54	6.94	22.22	11.11	13.89	11.11	9.72	8.33	15.28	13.89	13.48
	152.73	163.38	68.94	213.94	102.17	126.49	101.19	79.47	69.53	136.92	133.06	
5	22.22	15.75	15.28	16.67	22.22	16.67	22.22	16.67	19.44	19.44	19.44	18.72
	203.64	138.79	151.66	160.45	204.34	151.78	202.38	136.23	162.24	174.26	186.28	
6	11.11	11.12	22.22	19.44	13.89	19.44	16.67	22.22	22.22	22.22	22.22	18.43
	101.82	98.03	220.60	187.20	127.71	177.08	151.78	181.63	185.42	199.15	212.89	
7	2.78	2.78	11.11	9.72	8.33	4.17	5.56	11.11	4.17	8.33	5.56	6.73
	25.45	24.51	110.30	93.60	76.63	37.95	50.59	90.82	34.77	74.68	53.22	
8	13.89	15.66	19.44	13.89	19.44	11.11	13.89	19.44	16.67	11.11	8.33	14.76
	127.27	138.06	193.02	133.71	178.80	101.19	126.49	158.93	139.06	99.58	79.83	
9	19.44	22.24	6.94	9.72	16.67	22.22	19.44	12.50	12.50	15.28	16.67	15.73
	178.18	196.06	68.94	93.60	153.25	202.38	177.08	102.17	104.30	136.92	159.67	

of the constituent components in stimulating the taste of coffee are caffeine, chlorogenic acid, sucrose, and trigonellin. Caffeine is a compound that is responsible for the bitterness of beverages, chlorogenic acid is a compound that is responsible for acidity in coffee drinks, Trigonellin is a precursor to various classes of volatiles and also contributes to the formation of flavor products [1]. In table 3, highest score for the panelists' preference for the taste was treatment 9. The roasting process results in the loss of compounds due to degradation. Carbohydrates are degraded to form sucrose and simple sugars that produce a sweet taste. Alkaloids, namely caffeine, undergoes sublimation to form caffeine [17]. The result of the Maillard and Strecker reaction during roasting causes an increase in bitterness, this is due to the release of caffeic acid and the formation of lactones and other phenolic compounds that affect the flavor and aroma of coffee [20].

Roasting is an essential process for developing organoleptic properties, color impressions, aroma, taste, bitterness, and a preference for brewed coffee. Combining physical and organoleptic properties in the brewed of the coffee grounds will determine the level of preference for the panelists. As a percentage, the roasting process has an effect of 30% on the contribution of aroma and taste. The taste and bitterness are considerably influenced by the temperature and the duration of roasting [21]. In table 3 the highest score for the panelists' preference for bitterness was treatment 5. The higher the temperature and the roasting time, the compounds will heat up faster, so the atoms will move harder and will break the chemical bonds, this causes the coffee to taste bitter and has no taste when roasted at high temperatures [17]. Temperature degradation during roasting in chlorogenic acid will produce phenolic substances that contribute to the bitterness of brewing coffee.

Acidity in coffee is a vital attribute because a certain level of coffee indicates the flavor variance in coffee [22]. Acidity is formed from the non-volatile components in coffee. In table 3 the highest score for the panelists' preference for the acidity of brewed coffee was treatment 6.

The sweetness produced in the coffee brew comes from the carbohydrate content that reaches more than 50% by weight of the coffee beans [23]. This compound triggers the Maillard reaction, and the result of this reaction became one of the factors that make up the taste of the coffee. One of the carbohydrate derivative compounds that affect the flavor of the coffee was sucrose. In table 3 the highest score for the panelists' preference for the sweetness of brewed coffee was treatment 6.

The body is the internal character of coffee; the taste of oil (oiliness) and slipperiness is a description of the oil content, while the thickness describes the fiber or protein content in coffee [24]. In Table 3, the highest score for the panelists' preference for the viscosity of brewed coffee was treatment 6.

Overall acceptance is a hedonic assessment to determine the panelist's preferred response to the overall acceptance of each robusta coffee formula studied. Overall acceptance is the accumulation of all sensory test parameters that have been carried out by panelists such as color, aroma,taste, bitterness, and viscosity. In Table 3, the highest score for the panelists' preference for robusta coffee acceptance was treatment 6. Thus the overall acceptability varied considerably from intensity between dislike slightly, like slightly, and like moderately. Coffee roasted at lower time and temperature was found to be dull in color and not attractive having score of dislike. On the other hand, coffee roasted at high temperature and time was darker in color. However, those coffee beans roasted at medium temperature and time were shiny brown in color and more liked by the sensory panel.

3.2. Determination of the best treatment

Determination of the best treatment using zero-one integer programming technique. Based on the data obtained on the criteria (attributes) of acceptance through a Likert scale preference level questionnaire, data processing will be carried out. The evaluation matrix calculates the total value for each alternative and chooses the alternative with the largest total value. The assessment of each treatment is obtained from the multiplication of the performance criteria index with the weight of the criteria. The evaluation matrix is presented in Table 4. The evaluation matrix in Table 4 has the largest total value of 18.72%, namely alternative 5 so that the best treatment for consumer acceptance is the combination of postharvest honey, roasting temperature 175ºC, roasting time 15 minutes, and 80 mesh.

3.3. Confirmation test

The purpose of the confirmation test is to reaffirmed the conclusions obtained from data analysis using a zero one on determining the best treatment. Confirmation was done by comparing the actual value with the prediction so that the upper and lower limits can be found. In this study, the actual value was the best attribute score and the predictive value was the best treatment score (postharvest honey, temperature 175ºC, roasting time 15 minutes, and 80 mesh). The comparison table for the comparison of the best treatment attribute scores and the best attribute scores was presented in Table 5.

Comparison of the upper and lower limits between the best treatment score and the best attribute score is confirmed because the actual value is in the predicted value interval. Based on Table 5, if an average calculation is carried out on a score that has a value greater than (3.5), namely in the attributes: ground and brewed color, ground fineness, the aroma of brewed, the taste of brewed, the bitterness of brewed, the viscosity of brewed and overall acceptance, the value is 3.58. It can be interpreted that the panelists' acceptance level of these attributes at the best treatment (postharvest honey, temperature 175ºC, roasting time 15 minutes, and 80 mesh) was like moderately. Whereas for the best attribute score which has a value less than (3.5), namely in the attributes: ground aroma, acidity, and sweetness, if the average calculation is carried out, the value is 3.2 which means that the panelist acceptance level of these attributes at the best treatment (postharvest honey, roasting temperature 175ºC, roasting time 15 minutes, and 80 mesh) was like slightly.

The correlation between biochemical components and sensory attributes shows that biochemical content acts as an indicator of sensory attributes [25]. There is an interaction of varieties and processing methods on coffee biochemistry, dry processing increases sucrose content [26]. Sucrose plays an important role in influencing the taste and aroma of coffee [27], honey processing is dry processing so that the postharvest honey taste is better because the sucrose contained in it is better, this causes a good acceptance rate for postharvest honey products. The volatile concentration of coffee is also influenced by the roasting level factor [28], there is a roasting process that will change the level of moisture content and acidity as well as the development of aroma and taste of coffee which depends on temperature and roasting time [29].

The higher the roasting temperature and time the more susceptible it is to damage and grinding which can result in higher extraction of bitter substances. A medium roast is better at preserving the original coffee beans because a darker roast burns some of the natural coffee oils and causes a stronger flavor. Medium roasting allows for a better taste, dark roasted beans can be too fine when ground resulting in increased surface area during brewed. Thus the extraction rate is high and results in a bitter, strong taste, due to over-extraction. On the other hand, too coarse ground coffee produces a soft coffee taste [30]. The effect of milling with an evaluation score shows that coarse grinding gives a better score because it is characterized by a strong sweet taste, fruity taste, moderate acidity and bitterness and a soft body [31]. This is in line with this study where the level of consumer acceptance of the combination of postharvest honey, roasting temperature of 175°C, roasting time of 15 minutes, and 80 mesh had a better acceptance rate because the combination of factors and levels of this combination resulted in ground color and brewed, grond fineness, brewed aroma, brewed taste, steeping bitterness, steeping viscosity, and overall acceptance at the level of liking.

4. CONCLUSION

The sensory attributes of ground coffee color, brewed color, brewed aroma, brewed taste, bitterness, viscosity, and overall acceptance had a significant effect on panelist acceptance with a significant value ($P<0.05$), but did not significantly affect the sensory attributes of the aroma of ground coffee, fineness, acidity, and sweetness. The best treatment is determined with zero-one, resulting in a combination treatment level postharvest honey, roasting temperature 175ºC, roasting time 15 minutes, and 80 mesh with acceptance level like moderately (3.58) on the color of the ground and brewed, brewed aroma, brewed taste, brewed bitterness, ground fineness, brewed viscosity, and overall acceptance, while ground aroma, brewed acidity, brewed sweetness with like slightly acceptance (3.22) and all attributes confirmed. Various of postharvest and processing treatments influence sensory quality of ground and coffee brewed so effect of consumer acceptance.

ACKNOWLEDGMENTS

This research project is supported by the Final Project Recognition (RTA) 2020 of Directorate Research Universitas Gadjah Mada

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