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Analysis and technical optimization of processing condition for better quality of robusta coffee production

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ABSTRACT

The wet processing of robusta coffee starts with harvesting coffee cherries, followed by sorting the cherries, pulping, fermentation, washing, drying, hard skin hulling, bean sorting, and packaging. Soaking fruit before pulping is an alternative for coffee farmers to delay the pulping process if time does not allow it. The fermentation process aims to remove mucus that is firmly attached to the hard skin. The addition of *L. casei* bacteria can accelerate the process but affect the final taste. This study aimed to optimize the duration of soaking and fermentation processes for obtaining coffee beans with a minimum number of unpeeled beans, minimum partially black bean value, maximum taste quality, and to identify volatile components that play a role in forming the best steeping aroma after the coffee beans are roasted, ground and brewed. Experiments and data analysis were carried out using the Response Surface Method design. The optimization results showed that 24 hours of soaking and 24 hours of fermentation were the optimum treatment based on the criteria for unpeeled beans response, partially black bean value, and total taste score with a desirability value of 0.721. The identified volatile compounds (43) include 9 aldehyde group compounds, 3 alcohols, 4 furans, 5 heterocyclic N, 6 ketones, 1 organic acid, 3 phenols, 10 pyrazines, and 2 thiols. The spicy and chocolaty aroma produced was also the highest among treatments, namely 8.98% and 7.74%. The treatment without soaking and fermentation had the highest percentages of caramelly and nutty areas, namely 23.14% and 21.35%, respectively.

Key words: Coffee beans; fermentation; soaking; technical optimization; volatile compound.

1 INTRODUCTION

Coffee is one of the most wildly consumed non-alcoholic beverages globally (Kim; Giovannucci, 2019; Poole, 2017; Torres-Collado et al., 2019), and coffee is considered an essential commodity in world trade. Thousands of bioactive compounds in coffee include caffeine, diterpenes, flavonoids, and cafestol (Jeszka-Skowron; Zgoła-Grześkowiak; Grześkowiak, 2015). Coffee processing influences the quality of coffee beverages. Wet coffee processing is a common method to transform coffee cherries into green coffee beans. The wet processing includes multiple steps: (1) harvested coffee cherries are mechanically squeezed to remove the skin and pulp, this step is known as pulping, (2) cherries are soaking and fermented in the water to remove mucilage (a carbohydrate-rich layer). The soaking and fermentation take 12–72 h (Brando; Brando, 2014). After fermentation, the beans are washed and dried. The final step is dehulling to produce green coffee beans (Wahyudi; Pujiyanto; Misnawi, 2016). The standard wet processing is a time-demanding and resource-intensive process. Coffee farmers may delay the pulping process due to the limited access to pulping equipment. An alternative method is to soak cherries before pulping. Soaking time influences the quality of the coffee taste. For example, soaking coffee cherries for more than 48-hours negatively affects the coffee taste and quality value compared to coffee beans soaked for 24-hours and cherries without soaking (Sa'diyah et al., 2019).

The fermentation process is one of the essential stages in producing coffee beans and largely determines the quality, production, and taste quality of coffee. Controlled fermentation positively impacts coffee's quality attributes (Pereira et al., 2016). Adding *Lactobacillus casei* as a starter that accelerates the fermentation (Yusianto; Widyotomo, 2013) and it may provide the best quality coffee. This may lead to an increase in economic benefits for coffee farmers (Pereira et al., 2016). Fermentation time up to 48 hours has a significant effect on the decrease in unpeeled beans and an increase in the quality of taste (mouthfeel). Based on the assessment of trained panelists, the treatment without soaking and fermentation have a dominant spicy and caramelly aroma, while 48-hours fermentation of coffee cherries produces the dominant aroma of caramelly, sour, and greenish. However, the volatile components that cause the dominant aroma have not been identified yet (Sa'diyah et al., 2019).

The optimum soaking and fermentation time cannot be estimated based on just the one-factor-at-a-time (single factor) approach because it is time-consuming, and the interaction between soaking and fermentation time may not be included in the determination of the coffee taste quality. Therefore, a study is needed to determine the optimum soaking and fermentation time to obtain a desirable coffee taste. A statistical optimization procedure, Response Surface Methodology (RSM), for consistency through the manuscripts used in this study (Haaland, 1989) to technically optimize the duration of soaking and fermentation processes to obtain coffee beans with a minimum number of unpeeled beans, minimum partially black bean value, maximum taste quality. RSM includes statistical techniques and is widely applied in the food industry to determine the effects of multiple processing variables and their interaction on response variables and to develop, improve, and optimize a process (Senanayake; Shahidi, 2002; Téllez-Luis et al., 2003). Using RSM can reduce the number of experimental trials to optimize the process in a timely manner (Giovanni, 2013).

The purpose of this study was to optimize the duration of soaking and fermentation processes for obtaining coffee beans with a minimum number of unpeeled beans, minimum partially black bean value, maximum taste quality, and to identify volatile components that play a role in forming the best steeping aroma after the coffee beans are roasted and ground.

2 MATERIAL AND METHODS

This research was conducted from August 2018 to January 2019 at the Experimental Field of the Coffee and Cocoa Research Center at Sumber Asih Sub-village, Harjokuncaran Village, Sumber Manjing Wetan District, Malang Regency, East Java. Meanwhile, coffee bean samples were analyzed at the Postharvest Laboratory of the Coffee and Cocoa Research Center in Jember, East Java.

The materials used in this research are freshly harvested robusta coffee cherries, starter *Lactobacillus casei* $2.5 \cdot 10^7$ cfu ml $^{-1}$, water, and distilled water. The experimental apparatus used are a cherry pulper machine (CPF1000, Vina Natrhang, Vietnam), mechanical dryer (BEDCO-200, ICCRI, Indonesia) coffee huller machine (local made, ICCRI, Indonesia), roaster machine (type BRZ 2 Probat-Werke Emmercih-Rhein, USA), grinder machine (Latina 600N, Yang Chia Machine Works, Taiwan), digital scale with a capacity of 30 kg (Henherr type ACS-718, Fedito Bahtera Abadi Co., Indonesia), measuring cup capacity 1000 ml, beaker glass 500 ml and 250 ml, plastic net, and plastic containers with a capacity of 25 liters.

This research was conducted using the Response Surface Method (RSM) design to obtain the optimal response values of soaking time and fermentation time to get the best quality coffee beans. The stages in the RSM application consist of making a treatment design, response analysis, data analysis, and determining the optimum point (Montgomery, 2012).

The treatment design was carried out through the Design Expert 11 program to determine the independent and fixed variables. The independent variables consisted of soaking time as factor 1 (S) and fermentation as factor 2 (F) as seen in Table 1, while the dependent variables are the observing variables, consisted of unpeeled beans (%), partially black beans value, and total taste score.

Table 1: Determination of the independent variable and treatment codes.

Independent variable	Code	Range and level		
		−1	0	1
Soaking time (h)	S	0	12	24
Fermentation time (h)	F	24	36	48

2.1 Response Measurement and Development Relationship Model

Response analysis was carried out on the data collected from the research. The research stage begins with sorting red-yellow coffee cherries to full red (superior). After that, a batch of 10 kg for each treatment of cherries were soaked in water and placed in a plastic container until the container was completely submerged and left for several hours in accordance with the treatment. The zero hour soaking time means no soaking applied to the batch but it was directly fermented. The coffee cherries were drained and then peeled using a machine (pulper). The peeled coffee beans were then fermented in a plastic container with a volume of 25 liters, and 65 ml of *Lactobacillus casei* $2.5 \cdot 10^7$ cfu ml $^{-1}$ starter was added to the container. The coffee beans and starter mixture were stirred evenly, then closed tightly, and stored at ambient temperature to allow fermentation to occur. The treatments of soaking and fermentation were carried out for the duration listed in Table 1.

The fermented coffee beans were washed using running water until the beans were rough and then drained on a plastic net. The coffee beans were then dried until the moisture content was approximately 12% on a wet basis. The drying was conducted with combined methods, of sun-drying for about 12 hours and mechanical drying for about 8 hours with 60 °C drying temperature. The dried coffee beans hulls were then removed with a huller machine, and then roasted at a medium level. Grinding of roasted coffee beans was done with adjustments to produce a powder with a 1-3 mm particle size.

The measurement of coffee bean quality parameters was conducted for percentage of unpeeled beans and partially black bean value, where every bean with black color spot contributes to a half value of defect (no unit), while taste quality testing was carried out by three trained coffee tester panelists (Purnamayanti; Gunadnya; Ardi, 2017). The test method refers to the (Specialty Coffee Association of America -SCA, 2015), while the quality of taste-tested includes fragrance, flavor, after-taste, salt/acidity, bitterness, sweetness, balance, clean cup, uniform cup, body, overall, and total scores. The taste attribute scale and terms used were: 6.00 to less than 7.00 is good; 7.00 to less than 8.00 is very good; 8.00 to less than 9.00 is excellent; 9.00 to less than 10.00 is outstanding, and 10 is perfect.

Data analysis and determination of the optimum point were carried out by entering response data in the Design Expert 11 program (Stat-Ease, Inc., USA) used for a series of processing. In the first step, the program provides suggestions for the selection of polynomial models according to the response data conditions. A polynomial model consists of mean, linear, 2FI, quadratic, and cubic. In the second step, the model that best describes the response data was selected for analysis of variance (ANOVA). The model was said to be significant if it had a "prob bigger than f" and the value is less than 0.05. In the third step, the data is tested for lack of fit to find out whether the model can describe the distribution of the data well or otherwise. The expected lack of fit value is not significant or more than 0.05. In the fourth step, testing the coefficient of determination includes the predicted-squared and adjusted R-squared, where the smaller the difference between the two, the better the model. In the fifth step as the final step, the adeq-precision value was calculated, which is expected to be greater than four. The polynomial model obtained can be displayed in mathematical equations and three-dimensional plot graphs and contours.

2.2 Optimization of Soaking and Fermentation Time

The responses obtained were analyzed to determine the optimum process conditions. The determination of the optimum conditions was carried out by adjusting the established criteria. The criteria set are goals and importance, each of which has its own scale. The goal scale consists of target, in range, maximize, and minimize, while the importance scale is a value that ranges from 1-5. The higher the importance value indicates that the response is really desired to reach the optimum. The resulting optimum condition is a combination of the duration of the soaking and fermentation process based on the output of Design Expert 11 software. High desirability values indicated the optimum for soaking and fermentation treatment duration. The desirability value is a value that indicates that the program is able to fulfill the target based on the established criteria. The scale ranges from 0-1, where the closer the value is to 1, the more the program is able to produce the optimum product according to the predetermined goals and importance criteria (Montgomery, 2012). The relationship between the response (y) and the dependent variable (x) is shown in Equation (1) below:

$$y = f\left(x_1, x_2\right) + \varepsilon \quad (1)$$

where y is response variable, x_1, x_2, ..., x_k are dependent variables, and ε is error.

If the response and treatment have linear relationship, then the function equation approach uses a first-order model, as shown in Equation (2). But if the relationship is quadratic, then the function approach uses a second-order model, as shown in Equation (3).

$$y = \beta o + \sum_{i=1}^{k} \beta i\, Xi \quad (2)$$

$$y = \beta o + \sum_{i=1}^{k} \beta o\, Xi + \sum_{i=1}^{k} \beta ii\, Xi^2 + \sum_{1=1,\, j=2}^{k-1,k} \beta i, j\, Xi\, Xj + \varepsilon \quad (3)$$

where y is response observed (score of unpeeled beans, partially black beans, and total taste score), βo is intercept, βi is linear coefficient, βii is a quadratic coefficient, βij is interaction coefficient of treatment, Xi treatment code for ith factor (duration of soaking), Xj is treatment code for jth factor (duration of fermentation), and k is a number of treatment factors in the experiment.

2.3 Identification of Volatile Compound

Analysis of volatile compounds was carried out using GC-MS (QP 2010S Shimadzu, Japan). Samples of roasted coffee beans were ground into a coffee powder with a particle size of 1-3 mm. Five grams of coffee powder was weighed, then put in a 22 mL SPME (solid-phase microextraction) vial. After that, the sample was heated in a water bath at 60 °C for 30 minutes and there was a change in the appearance of the vial tube space.

The flavor components contained in the vial are sucked using SPME fiber DVB/CAR/PDMS (Divinybenzen/polydimethylsiloxane), then injected into GC-MS (modification of López-Galilea et al., 2006; Nielsen, 2016). The carrier gas in this analysis was helium at a flow rate of 1 mL min $^{-1}$. The detector used was the Mass Spectrophotometry type with the injector mode using splitless with a split speed of 50 mL min $^{-1}$ and the injector temperature can reach 250 °C. The initial injection temperature was 40 °C with an increased rate of 5 °C min $^{-1}$ until the temperature reached 250 °C and the final temperature was held for five minutes.

3 RESULTS

3.1 Response Measurement and Development of Relationship Model

Based on the design of the Response Surface Method (RSM) applied in this experiment, the response to the duration of soaking and fermentation processes were measured to obtain conditions with an optimal response. The measurement results had the following ranges; the percentage of unpeeled beans were between 6.00 and 20.00%, the value of partially black beans was between 22.50 and 100.00, and the total taste score was between 80.17 and 84.08. More detailed measurement results are shown in Table 2 which shows the recapitulation for the results of measurements on the responses of 13 treatment combinations.

A mathematical model is needed to describe the relationship between the parameters of soaking and fermentation duration time on some quality parameters. Table 3 shows constant values to build mathematical models that can describe the relationship between the parameters of soaking and fermentation duration time on unpeeled beans (%) and the value of partially black beans which is quadratic while the total taste score is 2FI (2-factor interaction) model.

3.2 Optimization of Soaking and Fermentation Time

The effect of soaking and fermentation time on unpeeled beans, partially black beans, and total taste scores were shown in the form of a response equation which was a function of soaking time and fermentation time. Table 4 shows that the length of soaking time can significantly reduce the unpeeled beans, while the length of the fermentation time is not significant for the partially black beans value.

The response obtained from the Design Expert 11 program is shown in Figure 1 in the form of a three-dimensional graph and a contour plot of the relationship between soaking and fermentation time factors on the response of unpeeled beans.

The visualization in Figure 2 shows that the longer the soaking time and the fermentation time the value of partially black beans increases. Partially black beans showed high values when the soaking time was between 6-21 hours and the fermentation time was 30-48 hours.

The relationship between soaking and fermentation time on total taste score can be seen in Figure 3.

3.3 Identification of Volatile Compound

Based on SPME GC-MS analysis on coffee beans from S0F0 treatment (no soaking and no fermentation), S0F2 treatment (no soaking and 48 hours fermentation), and S1F1 (24 hours soaking and 24 hours fermentation), 9 groups of volatile components were detected. The nine groups include aldehydes, alcohols, furans, heterocyclic, ketones, organic acids, phenols, pyrazines, and thiols. The highest peaks in the S0F0 chromatogram were components of 2-furanmethanol at a retention time of 20.09 minutes, 5-methyl-2-furancarboxaldehyde at a retention time of 17.95 minutes, furfural at a retention time of 15.23 minutes, acetate 2-furanmethanol at a retention time of 17.07 minutes, and 5-dimethylpyrazine at a retention time of 11.72 minutes. The components of the compounds 2-furanmethanol, 5-methyl-2-furancarboxaldehyde, furfural, acetate 2-furanmethanol, at S0F2 and S1F1 were identified at the same retention time. The results of the identification of volatile compounds are presented in Table 5.

Table 2: Response measurement results.

Code	Treatment		Response		
	Soaking (h)	Fermentation (h)	Unpeeled beans (%)	Partially black beans (-)	Total taste score
A	0.00	24.00	11.00	22.50	80.17
B	24.00	24.00	14.00	52.00	81.83
C	0.00	48.00	8.00	42.50	84.08
D	24.00	48.00	13.00	57.00	82.67
E	0.00	36.00	17.00	47.50	81.50
F	28.97	36.00	9.00	57.00	83.58
G	12.00	19.03	9.00	67.00	82.92
H	12.00	52.97	6.00	88.00	83.33
I1	12.00	36.00	13.00	61.50	83.92
I2	12.00	36.00	20.00	100.00	83.17
I3	12.00	36.00	18.00	71.50	84.00
I4	12.00	36.00	9.00	74.50	82.17
I5	12.00	36.00	18.00	60.50	82.33

Table 3: Analysis results of the mathematical model response.

Parameter	Mathematical model	Model significance	Lack of fit	Adjusted R^2 model	Predicted R^2 model	Adequated precision
Unpeeled beans (%)	*Quadratic*	<0.05*	0.06	0.83	0.41	11.59
Partially black beans value	*Quadratic*	0.23	0.38	0.25	-0.91	3.87
Total taste score	*2FI*	0.12	0.37	0.29	-0.54	5.39

Note: *significant at P<0.05.

Table 4: Significance factors for response.

Factor	Unpeeled beans (%)	Partially black beans	Total taste score
S	−1.00*	4.21	0.23
F	0.43	2.58	0.12
SF	−0.01	−0.03	−0.01
S^2	0.03*	−0.11*	
F^2	−0.01	−0.02	

Note: S=soaking time (h), F=fermentation time (h); *significant at p<0.05.

4 DISCUSSION

4.1 Response of Treatment and Relationship of Mathematical Model

The responses measured consisted of the percentage of unpleed beans, the value of partially black beans, and the total taste score. The mathematical model of the relationship between treatments and response was used to see the effect of treatments in the form of soaking and fermentation duration

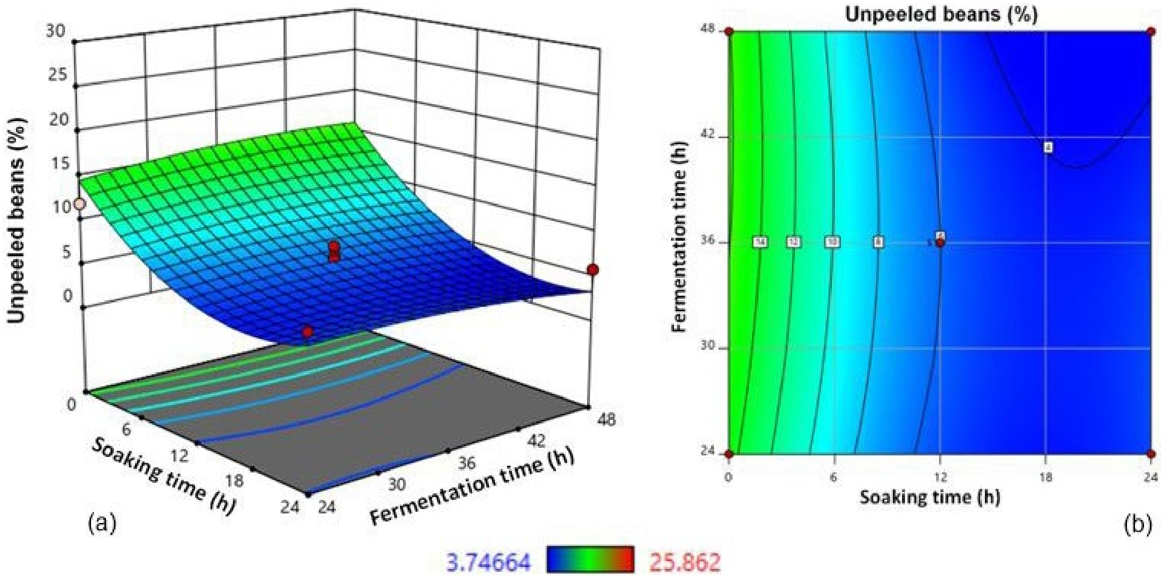

Figure 1: The relationship between the combination of soaking and fermentation time to the response of the unpeeled beans in (a) three-dimensional surface, and (b) contour plot.

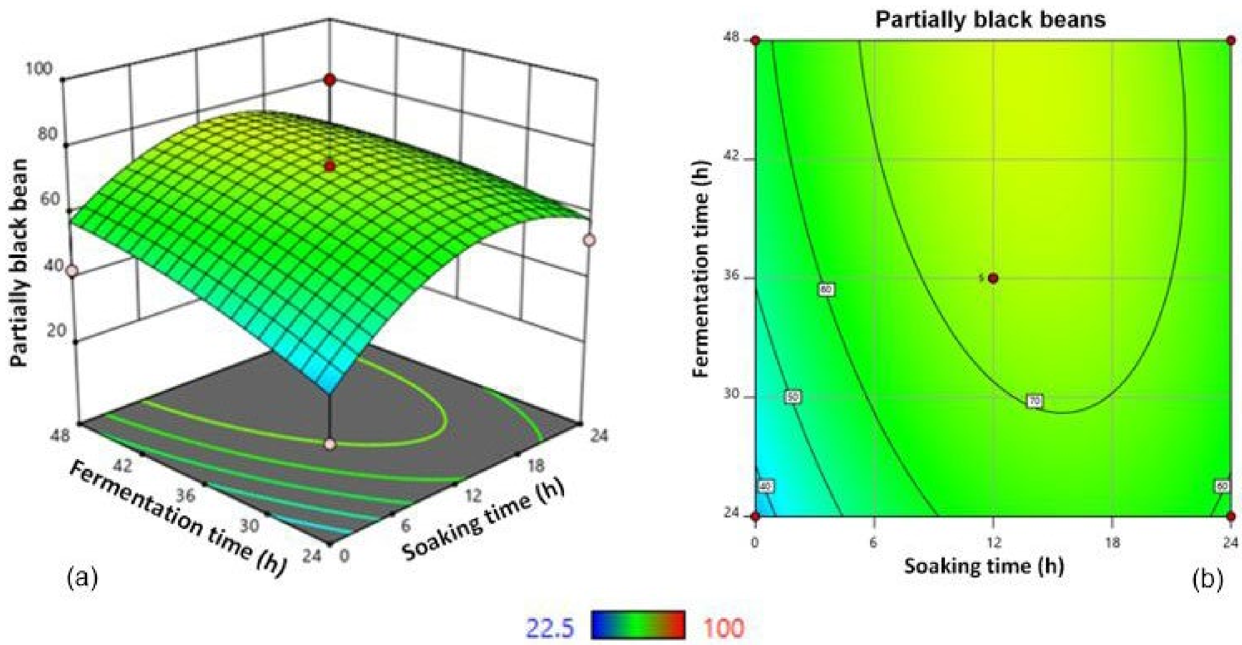

Figure 2: The relationship between the combination of soaking and fermentation time to the response of the partially black beans in (a) three-dimensional surface, and (b) contour plot.

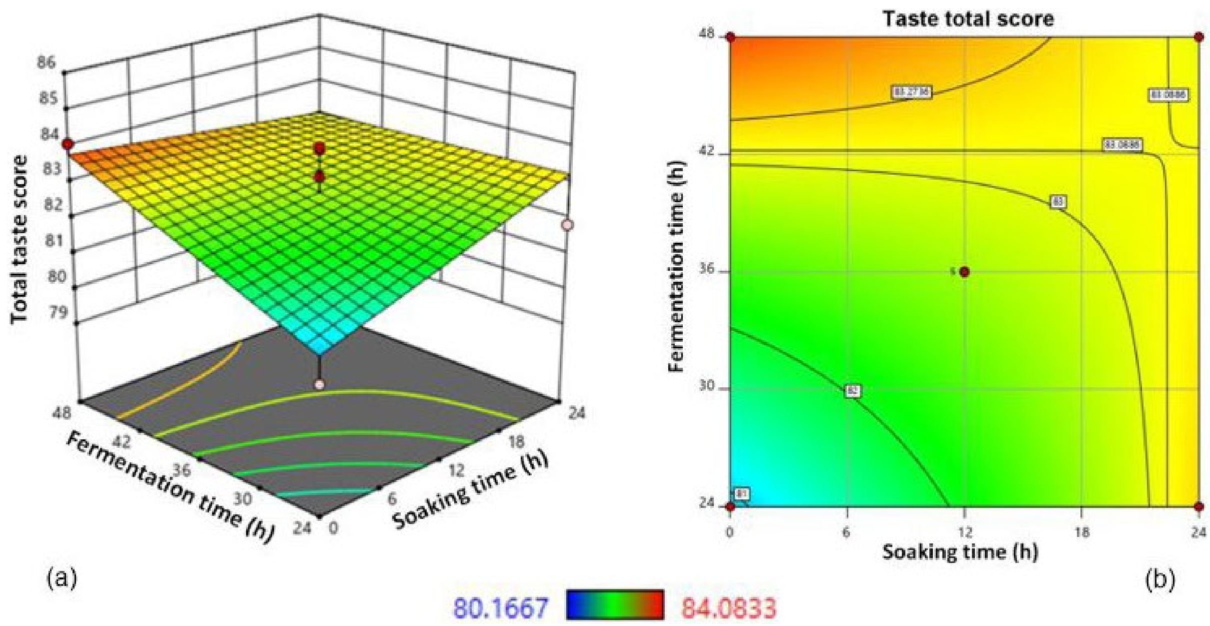

Figure 3: The relationship between the combination of soaking and fermentation time to the response of the total taste score in (a) three-dimensional surface, and (b) contour plot.

time on the response which included unpeeled beans (%), partially black beans value, and total taste score.

The significance value for the response model of the unpeeled beans showed the suitability of the data distribution with the model (P<0.05) and the lack of fit test of all responses was not significant (P>0.05). This shows that the model is appropriate, but if viewed based on the coefficient of determination, namely the difference between the predicted R-squared (0.41) and the adjusted R-squared (0.83) which is more than 0.20, it can be said that the model is not suitable for describing the distribution of data. However, it can be said that the model for the unpeeled bean response has good precision (adequate precision bigger than 4.0).

The partially black beans value parameter model suggested by the software is quadratic where the model shows an insignificant value (P>0.05). However, the lack of fit test still showed insignificant results (P>0.05). Therefore, the model was still suitable for describing the data distribution. The predicted R-squared value is negative so the model is not suitable to describe the data distribution because the difference with the adjusted R-squared is greater than 0.20. When viewed from the adequated precision value, the value is smaller than 4.0; therefore, the model lacks of good precision adequacy value.

The suggested model by the software for the total taste score parameter is the 2FI relationship model with an insignificant value. Based on the results of the lack of fit test, an insignificant value was obtained so that the model described the distribution of the data well. The predicted R-squared value shows negative so that the model is not suitable to describe the data distribution. However, when viewed from adequate precision, the value is more than 4.0 so it has a good precision adequacy value.

4.2 Optimization of Soaking and Fermentation Time

Meanwhile, the increase in the quadratic interaction of soaking time could significantly increase the unpeeled beans. Soaking and fermentation time did not significantly increase the total taste score, while the interaction of soaking and fermentation time decreased the total taste score.

The mathematical model predicted the percentage of unpeeled beans (UB), the value of partially black beans (PB), and the total taste score (TS) in the form of equations are shown in Equations (4), (5), and (6).

$$UB = -1S + 0.43F - 0.01SF + 0.03S^2 - 0.01F^2 \quad (4)$$

$$PB = 4.21S + 0.258F - 0.03SF - 0.11S^2 - 0.02F^2 \quad (5)$$

$$TS = 0.23S + 0.12F - 0.01SF \quad (6)$$

where S is soaking time (h) and F is fermentation time (h).

From Figure 1, it can be seen that within the range of soaking times (0 to 24 h) and fermentation times (24 to 48 h), the longer the soaking time, the lower the percentage of unpeeled beans. This is because at the time of soaking an imbibition stage occurs which causes the absorption of water in the cell wall and macromolecules such as proteins and polysaccharides. During the imbibition stage, the beans expand rapidly, and the skin and pulp that covers the beans become softer. The expansion of colloidal particles produces great pressure. The soaking process also triggered the germination because the outer shell becomes soft and easily splits (Pancaningtyas; Santoso; Sudarsianto, 2014; Warle et al., 2015).

Table 5: Relevant and precious data for processing planning to achieve certain sensory goals.

Aromatic compounds	Retention time (min)	Area (%)			Description of aroma
		S0F0	S0F2	S1F1	
Aldehyde					
Hexanal	5.75	-	0.08	0.11	Grassy, green oily
1-hydroxy-2-propoanone	11.08	-	2.20	2.05	Caramel
2-Methylbutanal	12.97	-	0.65	0.03	*Chocolate like, fruity, malty*
Nonanal	13.46	-	0.28	-	Citrus like
Furfural	15.24	6.37	7.02	4.85	Sweet, woody, almond
5-Methyl-2-furancarboxaldehyde	17.95	8.03	8.24	8.04	Caramel
3-Methyl-1-butanol	20.06	4.03	0.60	3.08	Earthy, pungent
Propanal	30.29	0.27	0.03	-	Caramel, sweet
Butanal	28.88	0.27	0.27	0.23	Caramel, chocolate
Total *aldehyde*		18.97	19.37	18.39	
Alcohol					
1-octen-3-ol	7.02	0.18	-	0.30	*Mushroom, earthy, herbaceous green*
2-Furanmethanol	20.09	11.96	2.37	11.28	Caramel, burnt, smoky
Maltol	26.53	0.82	0.65	0.57	Caramel
Total *alcohol*		12.96	3.02	12.15	
Furan					
2-[(methylthio) methyl]-furan	15.80	-	0.24	0.24	Smoke-roast
2-Acethyl-5-methylfuran	18.91	-	0.14	0.19	Strong, nutty, cocoa like, toasted, bready
2-(2-furanylmethyl)-5-methylfuran	20.39	0.27	0.12	0.17	Earthy, mushroom
Total *furan*		0.27	0.49	0.60	
Heterocyclic N					
Pyrrole	16.51	0.40	0.42	0.36	Nutty, hay-like, herbaceous
Pyridine	8.18	3.12	2.70	2.15	Astringent, bitter, roasted, burnt
2-Formyl-1-methylpyrrole	19.03	1.82	0.35	1.13	Nutty, roasted
1-furfurylpyrrole	23.63	-	1.33	-	Hay-like, mushroom-like, green
Total *Heterocyclic N*		5.34	4.80	3.64	
Ketone					
2,3-Butanedione	3.90	0.08	0.12	0.05	Buttery, sweet, caramel-like, chessy
2,3-Pentadione	5.33	1.02	0.79	0.12	Buttery, oily, sweet, caramel-like, oily buttery
1-hydroxy-2-butanone	12.97	0.62	-	0.56	Sweet
1-(1H-pyrrole-2-yl)-ethanone	26.62	1.18	-	1.05	Nutty, musty
1H-pyrrole-2-carboxaldehyde	27.65	0.11	-	0.87	Smoky, spicy
Furaneol	27.91	0.69	0.67	0.64	Sweet, caramel
Total *ketone*		3.69	1.59	3.29	
Organic acid					
Acetic acid	14.76	3.71	3.88	3.29	Pungent,vinegar, sour
Phenol		0.43	0.47	-	Phenolic, plastic, rubber, smoky
2-Methoxyphenol	24.31	0.84	1.06	0.92	Phenolic, roasted
4-Ethyl-2-methoxyphenol	27.74	0.36	-	0.42	Spicy
2-Methoxy-4-vinylphenol	30.67	4.22	4.65	4.41	Spicy, peanut, winelike, or clove and curry

Continue...

Table 5: Continuation.

Aromatic compounds	Retention time (min)	Area (%)			Description of aroma
		S0F0	S0F2	S1F1	
Total *phenol*		9.56	10.07	5.75	
Pyrazine					
Methylpyrazine	10.25	3.79	3.23	4.20	Nutty, roasted, sweet, chocolaty
2,5-Dimethylpyrazine	11.72	4.51	4.73	4.53	Nutty, roasted, grassy, corn
2,6-Dimethylpyrazine	11.90	3.43	2.69	3.28	Chocolate, cocoa, nutty, sweet, fried, spicy, potato like
2,3-Dimethylpyrazine	12.34	1.16	1.39	-	Raw, nutty, green pepper
Ethylpyrazine	12.03	2.29	-	-	Nutty, roasted, woody, musty
2-Ethyl-6-methylpyrazine	13.35	2.32	4.08	3.76	*Flowery, fruity, roasted, hazelnut*
2-Ethyl-3-methylpyrazine	13.50	0.48	2.38	2.16	Peanut like, roasty
Trimethyl pyrazine	13.86	2.62	2.98	2.81	Nutty, roasted
3-Ethyl-2,5-dimethylpyrazine	14.59	0.75	0.81	0.72	Earthy, roasted
2-Ethyl-3,5-dimethylpyrazine	14.92	3.57	2.93	2.79	Earthy, roasted
Total *pyrazine*		24.93	25.22	12.24	
Thiol					
2-Furfurilthiol	14.47	0.05	0.19	0.02	Sulfur, roasty
2-Methyl-3-furanthiol	26.09	0.15	0.18	0.14	Nutty, sulfur like, roasty
Total *Thiol*		0.20	0.37	0.16	

Source: Caporaso et al. (2018); Chin, Eyres and Marriot (2011); Dulsat, Quintanilla-casas and Vichi (2016); Bressanello et al. *(*2017); Hurtado-benavides and Sánchez-camargo (2016); Iamanaka et al. (2014); Liu et al. (2019); Sunarharum, Williams and Smyth, (2014); Toci and Boldrin (2018).

For the quadratic interaction model, the soaking treatment could significantly reduce the partially black beans (Table 4). The presence of black beans is partly related to over fermentation during the wet processing of coffee beans. Black beans contain a small amount of 5-CQA (5-caffeoylquinic acid), more or less around 0.6% (db). The 5-CQA and 5-FQA (5-feruloylquinic acid) compounds undergo isomerization during fermentation and the possibility of hydrolysis of 5-CQA compounds in the fermentation process causes the occurrence of partially black bean defects, and the aging process which causes the occurrence of black beans (Farah; Donangelo, 2006).

Total taste score increased due to the length of fermentation time and soaking time but decreased not significantly for interaction of the two factors. The total taste score shows a high value between the soaking time of 0-15 hours and the fermentation time of 42-48 hours. During soaking process, the coffee cherries spontaneously fermented, meaning that partially fermentation started because the rind contained 20.8% fiber, 10.7% crude protein, 8.8% minerals, 49.2% nitrogen, 12.0% organic acids, caffeine, trigonelin, and 1.8% tannin which were good substrates for microbes naturally since in the field it is found in coffee cherries (Sarinana; Trinidad, 2017). Fermentation tends to improve flavor because during fermentation microbial bacteria involved produced metabolites that have an impact on volatile compounds formed during the roasting process.

Optimization aims to obtain optimum conditions by analyzing the response of the treatment of soaking and fermentation time in accordance with the established criteria. The criteria set include goals and importance, with the goal being the desired optimum value target. Goals consist of range, minimum, maximum, and target. Importance is a scale for factors and responses, ranging from 1 (+) to 5 (+++++). The more important the factor or response, the greater the importance value. The criteria for the determined factors and responses can be seen in Table 6.

In Table 6, the factors of soaking and fermentation time are set in range as goal and the value of three as importance. The resulting dry coffee beans are expected to contain a minimum value of unpeeled beans. The unpeeled bean response criteria were given a goal of minimizing and five for importance value (+++++) because the significant model could describe the influence of factors on the response. The partially black beans were given a minimized goal because it is expected that the coffee beans contain no partially black beans which are defective beans. Partially black beans are given four important values (++++) because the model does not significantly describe the influence of factors on partially black beans. The total taste was given a goal of maximize because it is expected that coffee beans have a high taste value and the importance is given four (++++) because the model does not significantly describe the influence of factors on taste responses.

Determination of factor and response criteria resulted in predictions of the optimum point of soaking and fermentation time in coffee processing shows in Table 7, where the 24-hours soaking and 24-hours fermentation has the highest desirability so that they have the potential to be selected as optimum conditions. The predicted response resulting from the highest optimum conditions showed that the unpeeled beans was 5.23% (minimum), partially black beans was 58.28 (minimum), and the total taste score was 83.25 (maximum).

4.3 Identification of Volatile Compound

Coffee cherries treated with S0F0 and S1F1 showed the highest peaks of the alcohol compound groups, 2-furanmethanol was the largest component of this group. The S0F2 treatment had the highest component of the aldehyde group compared to other treatments. The aldehyde and ketone group compounds are the result of the degradation of carbohydrates or sugars and then undergo oxidation (Shibamoto, 2015). Alcoholic compounds are metabolites resulting from sugar metabolism during fermentation. Furans are a group of compounds derived from the caramelization of sugar components during roasting, fat oxidation, and thiamin degradation. S0F2 and S1F1 treatments had a higher amount of compound group. The class of heterocyclic compounds, pyridine, and pyrrole are the result of the Maillard reaction between amino acids and sugars. Pyridine is formed due to the degradation of trigonelline. The phenol group of compounds comes from the degradation of phenolic acids (such as quinic, ferulic, and caffeic acid) which are degraded by heat during roasting. The thiol group of compounds comes from the Maillard reaction and the degradation of glutathione (Bressanello et al., 2017).

Based on the special taste described by the trained panelists, the dominant S0F0 treatment has a spicy aroma. The results of the identification of volatile compounds in Table 5 show that S0F0 has a spicy aroma area percentage of 8.12%. S0F2 has a lower percentage of spicy aroma area, namely 7.34% and that for S1F1 is 8.98%. The volatile compounds that cause the spicy aroma are 1H-pyrrole-2-carboxaldehyde, 4-Ethyl-2-methoxyphenol, 2-Methoxy-4-vinylphenol, and 2,6-Dimethylpyrazine. The treatments that had the highest percentage of caramelly area respectively based on Table 5 were S0F0 (23.14%), S1F1 (22.98%), and S0F2 (15.34%). Based on the description of the trained panelists, the S0F0 and S1F1 treatments had a higher caramelly aroma intensity than S0F2. The higher the fermentation time, the lower the caramelly aroma. The components that give rise to the caramelly aroma are 1-hydroxy-2-propoanone, 5-methyl-2-furancarboxaldehyde, propanal, butanal, 2-Furanmethanol, maltol, 2,3-pentadione, and furaneol (Dippong et al., 2022).

S0F0, S0F2, and S1F1 have the same intensity of chocolaty based on the descriptions of trained panelists. The percentage of chocolaty area test results for volatile compounds were 7.49%, 6.84%, and 7.74%, respectively. The components that give rise to the chocolaty aroma are 2-methylbutanal,

Table 6: Factor criteria and responses for determination of optimum conditions.

Factor/response	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Soaking time (h)	in range	0	24	1	1	3
Fermentation time (h)	in range	24	48	1	1	3
Unpeeled beans (%)	minimize	3.75	25.86	1	1	5
Partially black beans	minimize	22.50	100.00	1	1	4
Total taste score	maximize	80.17	84.08	1	1	4

Table 7: Prediction of optimum condition.

No	Soaking (h)	Fermentation (h)	Unpeeled beans (%)	Partially black beans	Taste total score	Desirability
1	24.00	24.00	5.23	58.28	83.25	0.721
2	24.00	24.11	5.24	58.37	83.25	0.720
3	23.70	24.00	5.12	58.81	83.22	0.717
4	23.47	24.00	5.44	59.18	83.20	0.713
5	24.00	48.00	3.31	64.45	83.04	0.678
6	1.95	48.00	13.70	62.94	83.72	0.626
7	2.04	48.00	13.59	63.17	83.72	0.626
8	1.78	48.00	13.90	62.51	83.73	0.626
9	2.22	48.00	13.39	63.60	83.71	0.626
10	1.18	48.00	14.61	60.93	83.75	0.625

butanal, methylpyrazine, and 2,6-dimethylpyrazine. The nutty aroma in S0F0, S0F2, and S1F1 described by trained panelists have the same intensity which mean the same strength. The percentage of nutty aroma area is 21.35%, 16.11%, and 17.69%, respectively. Nutty aroma components come from 2-Acethyl-5-methylfuran, pyrrole, 2-Formyl-1-methylpyrrole, 1-(1H-pyrrole-2-yl)-ethanone, methylpyrazine, 2,5-dimethylpyrazine, ethylpyrazine, trimethylpyrazine, and 2-methyl-3-furanthiol (Dippong et al., 2022).

In addition, the panelists described the S0F2 treatment with a greenish aroma. Based on Table 5, only S0F2 was noted as having greenish compounds. The area percentage associated with this was 1.33%. The component that gives rise to a greenish aroma is 1-furfylpyrrole which belongs to the heterocyclic N group (Sa'diyah et al., 2019). S0F2 has a more acidic flavor according to the panelists and has a high acetic acid component compared to S0F0 and S1F1.

5 CONCLUSIONS

The results of optimization of coffee cherries processing showed that 24 hours of soaking and 24 hours of fermentation were the optimum treatment based on the criteria for unpeeled beans response, partially black bean value, and a total taste score was the excellence of the product a bigger factor that the cost of production with a desirability value of 0.721. The identified volatile compounds (43) include 9 aldehyde group compounds, 3 alcohols, 4 furans, 5 heterocyclic N, 6 ketones, 1 organic acid, 3 phenols, 10 pyrazines, and 2 thiols.

The 24-hours soaking and 24-hours fermentation treatments produced the highest spicy and the most elevated chocolaty aromas, namely 8.98% and 7.74%, respectively. The volatile compounds that cause the spicy aroma are 1H-pyrrole-2-carboxaldehyde, 4-Ethyl-2-methoxyphenol, 2-Methoxy-4-vinylphenol, and 2,6-Dimethylpyrazine. The components that give rise to the chocolaty aroma are 2-methylbutanal, butanal, methylpyrazine, and 2,6-dimethylpyrazine. The treatments without soaking and fermentation had the highest percentages of caramelly and nutty areas, namely 23.14% and 21.35%, respectively. The components that give rise to the caramelly aroma are 1-hydroxy-2-propoanone, 5-methyl-2-furancarboxaldehyde, propanal, butanal, 2-Furanmethanol, maltol, 2,3-pentadione, and furaneol.

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7 AUTHOR'S CONTRIBUTION

KS wrote the manuscript and performed the experiment, UA supervised the experiment and co-work the manuscript, and SS review and approved the final version of the work, UA conducted all statistical analyses.

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