Evaluation of Fluidized-Bed and Drum Roaster Performance in Roasting of Robusta Green Bean

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Abstract. The roasting process is essential in producing ground coffee as it is where coffee's distinctive aroma and flavour are developed. There are two coffee roasters: drum and fluidized bed roasters, each with benefits and drawbacks. This study aimed to determine the effects of roasting machine type and roasting level on the characteristics of Robusta coffee. The experimental design used was a 2x3 factorial of a Randomized Block Design. The results indicated that the water content, ash content, caffeine content, total phenol content, bulk density, colour, coffee ground aroma, brewing colour, brewing aroma, bitterness, acidity, and sweetness were all affected by roasting level. The interaction between roaster type and roasting level affected the water content, total phenol content, bulk density, colour, ground coffee aroma, brewing aroma, bitterness, and acidity. The analysis of volatile compounds in ground roasted coffee by hot-air and drum roasters at light, medium, and dark levels revealed 40, 20, 18 and, 46, 48, 48 volatile compounds, respectively. As a conclusion it was found that the type of roasting machine and the degree of roasting have a strong influence on different characteristics of coffee powder, including moisture content, ash content, total phenol content, volatile compounds, bulk density, colour, and sensory qualities like aroma, bitterness, acidity, and sweetness. However, they didn't have a significant impact on the caffeine content. Keywords: Coffee Roasting, Robusta Coffee, Roasting Machine Type, Roasting Level, CoffeeCharacteristics
Keywords : Roasting Uniformity, Flawor Defelompment, Roasting Time, Energy Efficiency.

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1 Introduction

Coffee is a plantation commodity that is important in Indonesia's economic cycle. Indonesia is the third- largest coffee-producing country in the world. About 67% of domestic coffee production is exported, and the remainder is used for domestic needs [1]. In Indonesia, there are generally two types of coffee, i.e., Robusta and Arabica coffee. Robusta coffee is more accessible to care for than Arabica coffee. Robusta coffee is more rounded and smaller than Arabica coffee beans [2]. The processing of coffee beans can affect the chemical composition of coffee. Changes occur due to an oxidation process during roasting [3]. Roasting is an essential process in coffee bean processing. Roasting can determine the quality of roasted coffee. The roasting process is one of the factors that can affect the taste of coffee [4]. Roasting coffee beans causes chemical reactions that can develop the flavour and aroma of coffee with certain qualities [5,6]. Roasting occurs due to heat transfer from the heating surface into the material. The roasting process will increase the temperature of the ingredients; changes in material temperature cause changes in the mass contained in the material. An increase in the temperature of the material causes the water pressure to be higher than the vapour pressure of the air. This difference in vapour pressure can cause mass transfer, i.e., water vapour transfer into the air [7].

There are generally two coffee roasters: a drum roaster and a fluidized bed roster. Both roasting machines have advantages and disadvantages. A drum roaster will stir and roast the coffee in a drum and heat it directly. A fluidized bed roaster floats and roasts the green bean coffee [8]. The epidermis remains on the drum during the roasting process on a drum-type machine. The epidermis can mix with coffee oil to form a crust on the drum wall. The crust on the drum wall will give rise to the aroma of smoke in the subsequent roasting. The smell of smoke in coffee is usually not liked by consumers [9].

An earlier published study compared roasting methods on the aroma, sensory quality, and volatile and non- volatile compounds of Robusta coffee [10] stated that fluidized-bed roasting resulted in higher levels of desirable aroma compounds, such as pyrazines and furans, and lower levels of undesirable compounds, such as aldehydes and ketones. The sensory analysis also showed that the fluidized-bed roasted coffee had a better overall quality and higher acceptability than the drum-roasted coffee. A study on the effects of roasting conditions [11] revealed that fluidized-bed roasting at higher temperatures led to higher levels of desirable flavour compounds, antioxidant activity, and a better sensory profile. However, drum roasting at lower temperatures resulted in a more uniform colour and a smoother taste. A study on the effects of fluidized bed roasting on Robusta coffee's physicochemical and sensory properties [12] found that fluidized- bed roasting resulted in a more uniform colour than drum roasting. The sensory analysis also showed that the fluidized-bed roasted coffee had a better overall quality, a more intense aroma, and a less bitter taste than the drum-roasted coffee. Other studies [13] reported that fluidized-bed roasting resulted in a higher product yield and a better sensory quality, with a smoother and less bitter taste. They also observed that fluidized-bed roasting produced a more uniform colour and consistent roast degree than drum roasting. These studies suggest that fluidized-bed roasting may have a better sensory profile, a higher product yield, and a more uniform roasting than drum roasting. However, the optimal roasting conditions may depend on the specific coffee variety and desired flavour profile thus further research is needed to understand the differences between the two methods completely. Therefore, this study aimed to determine the effects of small- scale roasting machine type and roasting level on the characteristics of Robusta coffee originating from Subang.

2 Methods

2.1 Materials preparation

Green Robusta coffee beans that were naturally processed served as the experiment's raw ingredients, originated from Subang, 6°45'10.74" S, 10°741'22.59" E, at an elevation of 943 MAMSL, West Java. The chemicals needed for analysis in the study consisted of distilled water (H2O), and 50% Folin-Ciocalteu, consisted of 6% Na2CO3, methanol (CH3OH), gallic acid (C7H6O5), chloroform (CHCl3), CaCO3, 2% tetramethyl pyrazine (C8H12N2) and standard caffeine (C8H10N4O2).

2.2 Equipment

Utilized equipment used in this study consisted of a drum roaster, fluidized bed roaster, coffee grinder, basins, winches, digital scales, cups, spoons, Hg-thermometers (Yenaco, 0-150 °C), and sealer (Omega Teknik). In contrast, the equipment used for chemical analysis is an analytical balance, spatula, porcelain dish, oven (Memmert UM500), furnace, desiccator, beaker, funnel, stir bar, filter paper (Whatman), aluminium foil, Erlenmeyer, separating funnel, rotary evaporator (Iwaki CLU-S21), measuring flask, test tube, UV-Vis spectrophotometer (Shimadzu UV 1900), measuring cup, vial, GC-MS (Shimazu QP-2010 ultra), SPME, measuring pipette, vortex mixer, chromameter (3nh colourimeter SN-3050947), and moisture analyzer (wile brand).

2.3 Roaster Description

A group of researchers from the Agricultural Mechanisation and Postharvest Equipment National Research and Innovation Agency of Indonesia's Research Centre for Appropriate Technology created a drum and fluidized bed roaster. The drum and fluidized bed roaster utilised for this study is shown in Figure 1. Each of them has a capacity of 1 kg per batch, and the specification of both equipment is presented in Table 1.

(a)

(b)

Fig. 1. (a) Drum roaster, (b) Fluidized bed roaster

Table 1. The specification of drum roaster and fluidized coffee roaster

Parameters	Fluidized roaster	Drum roaster
Overall dimension	982 × 500 × 1390 mm	840 × 480 × 770 mm

Chaff and dust collector	Ø 60 × 110 mm	76 × 46 mm
Blower	ø2 inches, 220V, 50 Hz, 600-watt, 16000 rpm	ø2 inches, 220 V, 50 Hz, 25-watt, 3600 rpm
Motor	-	25 watts
Burner	Jet burner	Ceramic heater
Fuel Consumption	LPG (450 gr/hr)	LPG (270 gr/hr)
Temperature sensors	K Type, Ranging Temperature 0-700 ºC	K Type, Ranging Temperature 0-700ºC
Roasting capacity	500 g	500 g

2.4 Experimental procedure

The Robusta green bean presented as an example has undergone natural processing. The sample of green coffee beans originated in Subang. Five hundred (500) grams of unroasted coffee beans were prepared and placed on a roaster. Two types of roasting machines were used, namely drum and fluidized bed. The speed rotation of the drum roaster was 75 rpm, while the airflow rate of the fluidized bed roaster was five m/sec. The roasting process was carried out sequentially using a drum (a1) and a fluidized bed roaster (a2). The green bean coffee samples were added to the roaster when the temperature reached 180 °C. Three development times were applied to achieve three distinct roasting levels. In the light (b1), medium (b2), and dark (b3) roast levels, respective development times of 1, 3, and 5 minutes were applied to the roasting process. The roasting for each level of the roast was repeated four times. After being roasted for three days, the coffee was subsequently ground. The coffee was ground to a fineness of 80 mesh in preparation for further examination.

2.5 Physical, chemical, and sensory analysis

Physical, chemical, and organoleptic response analysis comprised the resultant product analysis. The physical analysis includes colour and bulk density; The chemical analysis looks at things like the amount of moisture, ash, total phenol, caffeine, and volatile chemicals; and the organic response analysis has aroma, flavour, and bulk density. A colourimeter (3nh SN-3050947) is used to identify colour differences. The method used was CIELAB. The colour attributes that are measured are lightness (L*), red/green (a*), and yellow/blue (b*). Bulk density is calculated to determine the weight-to-volume ratio of the material, using a gravimetric method.

Moisture and ash content were analysed with the Gravimetric Method [14]; caffeine content and total phenol was analysed with UV-Vis spectrophotometry [4,15]. Analysis of volatile substances in coffee grounds was carried out using Gas Chromatography-Mass Spectrophotometry [16]. Thirty untrained coffee- drinking panellists evaluated the hedonic quality of cupped-brewed ground coffee products. Panellists consisted of Research Center of Appropriate Technology employees and uncertified bartenders, aged between 30-60 years. The hedonic quality test was adapted based on SCAA [17] (Specialty Coffee Association of America). Tested responses included the aroma of coffee grounds, the brew's colour, the brewed coffee's aroma, and the bitter, acidic, and sweet tastes.

2.6 Statistical analysis

The roasting chamber conditions were evaluated using paired t-tests. On the other hand, the roasting results were analysed using ANOVA to look for statistically significant differences

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between the means of each treatment group. Tukey's HSD test was used to identify statistically significant differences between groups with a 95% confidence interval.

3 Result and discussion

3.1 Roaster performance

Regarding the setup of the roasting chamber, the findings of the evaluation suggested that the temperature distribution in the fluidized bed roaster was more uniform than that in the drum roaster; This was evident from the lower standard deviation values obtained from the measurements in the fluidized bed roaster as compared to those obtained from the drum roaster, except for the dark roast level. The average temperatures for the drum roaster's light, medium, and dark roast levels were 176.42±32.11oC, 178.17±36.73 oC, and 187.85±38.39 oC, respectively. In contrast, the average temperatures for the same roast levels in the fluidized bed roaster were 178.27±23.25 oC, 191.91±23.80 oC, and 191.62±38.94 oC, respectively. The time required for cracking in the fluidized bed roaster was shorter than that of the drum roaster. Figure 2 shows the performance of the drum and fluidized bed roaster at various roasting levels.

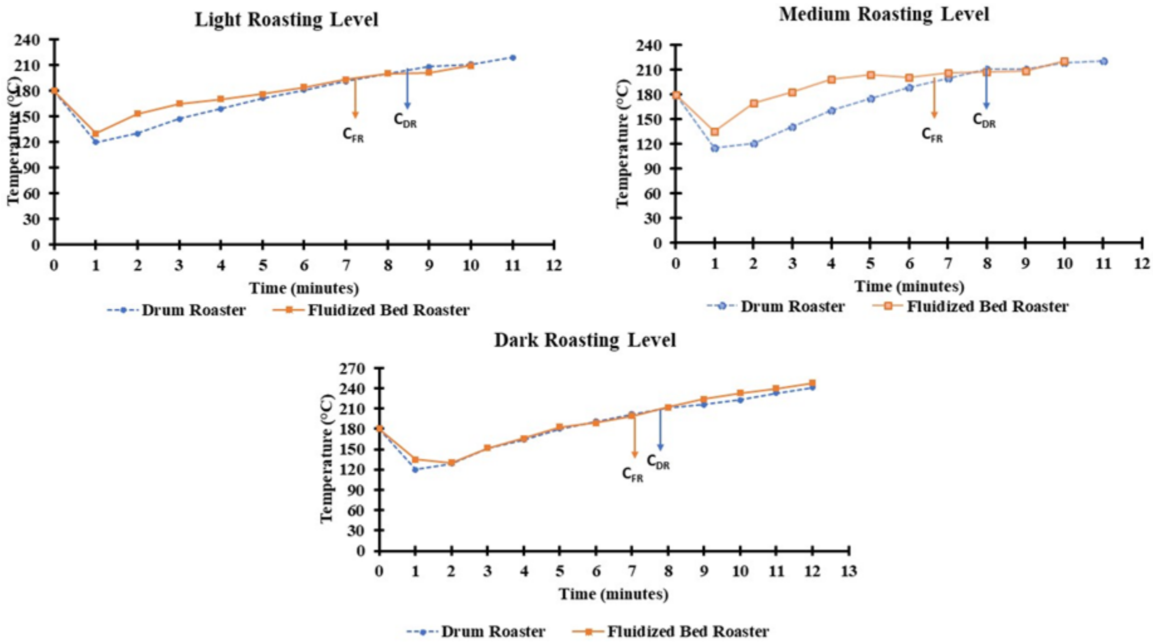

Fig. 2. Performance of drum and fluidized bed roaster at a various roasting level

As presented in Table 2, the results of the paired sample test between the drum and fluidized bed roasters indicate no significant difference ($p > 0.05$) in the light roasting level. However, there were significant differences ($p < 0.05$) in the medium and dark roasting levels. At the light roasting level, there may be no significant differences between the fluidized bed roaster and drum roaster because the coffee beans are roasted for a shorter period and at lower temperatures; This means that the differences in the heating mechanisms and airflow between the two types of roasters may have little impact on the final product at this roasting level. However, at the medium and dark roasting levels, the coffee beans are roasted more extended and at higher temperatures, which can result in more significant differences between fluidized bed and drum roasters. The drum roaster may heat the coffee beans less uniformly, resulting in more variation in the degree of roasting. In contrast, the fluidized bed roaster may provide more even heating, resulting in a more consistent roast. These differences in roasting can result in significant differences in flavour, aroma, and overall quality of the final product. This finding is consistent with several recent studies [3,11,18].

Table 2. Paired sample test of drum and fluidized bed roaster at various roasting levels

Pair	Paired difference					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error mean	95% Confidence Interval of the Difference				
				Upper	Lower			
LDR-LFR	-5.7273	8.9676	2.7038	-11.7518	0.2973	-2.118	10	0.06
MDR-MFR	-17.5455	18.9703	5.7198	-30.2899	-4.801	-3.068	10	0.012
DDR-DFR	-3.7692	5.2465	1.4551	-6.9397	-0.5988	-2.59	12	0.024

The calculation results found that the power required by the drum roaster during the light, medium, and dark roasting levels was 128.37, 113.00, and 104.48 watts, respectively. In contrast, the power required by the fluidized bed roaster was 173.25, 197.90, and 193.96 watts, respectively. On average, the energy needed by the fluidized bed roaster was higher than that of the drum roaster, with a factor of 1.5 times higher.

The power required by the fluidized bed roaster was higher than that of the drum roaster due to the differences in the roasting process. In the fluidized bed roaster, the coffee beans are suspended and agitated in a stream of hot air, requiring more energy to maintain the temperature and keep the beans in motion. Meanwhile, in the drum roaster, the beans are heated by direct contact with the drum, which requires less energy to maintain the temperature. Additionally, the drum roaster has a smaller surface area in connection with the coffee beans, contributing to the lower power requirement. This study finding is consistent with several previous studies conducted by researchers [12,19].

3.2 Physical responses

The study found that the type of roasting machine, the level of roasting, and their interaction significantly affected the lightness colour of the coffee beans. The lighter the roasting level, the lighter the colour, and vice versa. The colour is affected by a chemical process called the Maillard reaction, which creates melanoidins that give the beans their brown colour. The degree of roast determines the extent of the Maillard reaction and the level of melanoidin formation, ultimately affecting the colour of the roasted beans. The study's findings were consistent with previous research [2,8] showing that lighter roasts have a lighter colour, while darker roasts have a darker colour, but the exact shade can vary depending on several factors. Figure 3 shows the post hoc test results of the different influence of Roaster Type and Roasting level on the lightness and bulk density of roasted coffee.

The study found that the type of roasting machine, the level of roasting, and their interaction significantly affected the bulk density of Robusta coffee powder. Light roasting resulted in higher density compared to medium and dark roasting levels. The interaction between the type of roasting machine and the roasting level also significantly affected bulk density in all treatments. The Tukey post hoc test results showed which treatments varied greatly from one another. The bulk density of coffee is influenced by the roasting level because during the roasting process, the coffee beans undergo changes in their physical and chemical properties, including changes in their size, shape, and mass. These changes can affect the density of the coffee beans and, consequently, the bulk density of the roasted coffee. During roasting, the moisture content of the beans is reduced, causing them to expand and increase in size. This expansion can lead to a decrease in the bulk density of the beans. Additionally, as the beans are roasted, they undergo thermal degradation, resulting in the loss of mass and the formation of gases, which can also contribute to a decrease in bulk density.

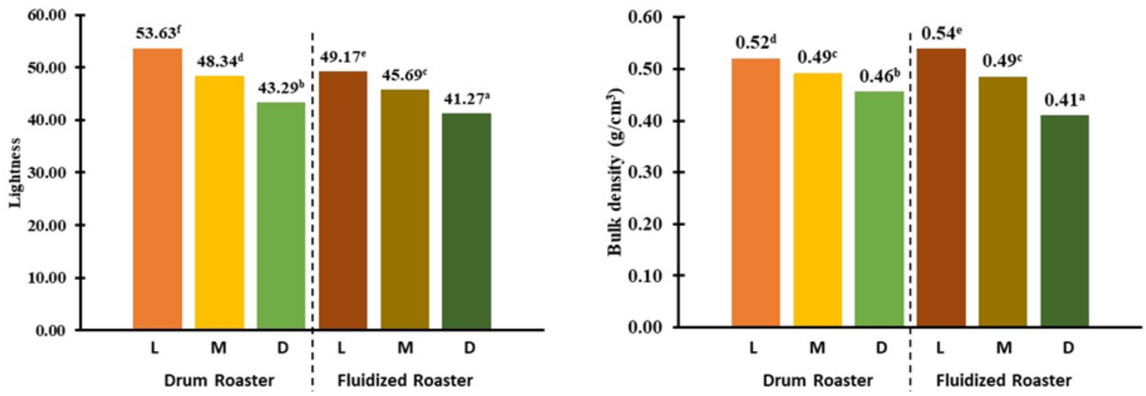

Fig. 3. The influence of roaster type and level on the lightness colour attribute and bulk density. Note: Means with different letter in the same column are significantly different at 95% confidence level

The degree of roast also affects the bulk density of the coffee. Generally, lighter roasts have a higher bulk density than darker roasts, as the lighter roasts undergo less thermal degradation and expansion. Darker roasts, on the other hand, have a lower bulk density due to the loss of mass and the increased expansion of the beans. The results of the study showed similarities with that conducted by previous researchers [2]. Coffee's bulk density is a crucial factor that can influence its quality and consistency. In order to achieve the desired bulk density and produce a high-quality product, it is essential to carefully monitor and control the roasting process.

3.3 Chemical responses

The post hoc test analysis findings are shown in Table 3 that the type of coffee roasting machine, roasting level, and their interaction significantly affected the water content of Robusta coffee. According to the analysis's findings, the fluidized bed roaster yielded coffee beans with a lower moisture content than the drum roaster. Furthermore, an increase in the roasting level leads to a decrease in moisture content in the roasted beans. There are several reasons why a fluidized bed roaster may produce coffee beans with less water content compared to a drum roaster i.e., heat transfer, air flow and roasting temperature.

Table 3. Results of chemical analysis of roasted coffee under different treatment

Roaster type	Roasting levels	Water content (%)	Ash (%)	Caffein e (%)	Total phenolic (%)
Drum Roaster	Light	2.57^{e}	4.63^{a}	1.88^{a}	4.19^{d}
	Medium	1.64^{c}	4.53^{a}	1.86^{a}	3.83^{c}
	Dark	1.24^{a}	4.76^{cd}	2.02^{b}	3.59^{b}
Fluidized Roaster	Light	2.13^{d}	4.59^{ab}	1.87^{a}	4.09^{d}
	Medium	1.40^{b}	4.69^{bc}	1.90^{a}	3.65^{c}
	Dark	1.34^{ab}	5.00^{d}	2.00^{b}	2.93^{a}

Note: Means with different letter in the same column are significantly different at 95% confidence level

Transfer and shorter roasting times. This can reduce the amount of water lost during roasting compared to a drum roaster, which uses indirect heat and may require longer roasting times. In a fluidized bed roaster, the hot air flows through the coffee beans, which can help to evaporate moisture and remove it from the roasting environment. This can lead to lower water content in the roasted beans compared to a drum roaster, where the beans are stationary, and the airflow is less direct. A fluidized bed roaster can achieve higher roasting temperatures compared to a drum roaster, which can help to evaporate moisture more quickly and efficiently as also reported by previous study [8]. This can result in lower water content in the roasted beans. An increase in the roasting process leads to a reduction in moisture content [3]. This is due to the fact that as the roasting time is prolonged, the material is exposed to heat for a longer period, resulting in a greater amount of water vaporization from the material. This is in accordance with the findings of the research conducted by Schenker, et al. [20].

In terms of ash content, the analysis of variance showed that the roasting types and the roasting level had a significant effect on the ash content, whereas the interaction had no significant effect on the ash content. Roaster types and level can affect the ash content of coffee beans due to the chemical changes that occur during the roasting process. Ash content is a measure of the total mineral content of a substance, including the inorganic compounds that are left behind after the organic material is burned off. In coffee beans, the ash content includes minerals such as potassium, sodium, calcium, and magnesium.

Different types of roasting machines can generate different levels of heat and airflow during the roasting process, which can affect the rate and extent of chemical reactions that occur within the beans. For example, drum roasters typically operate at a slower rate and with less airflow than fluid bed roasters, which can lead to differences in the chemical composition of the coffee beans. The roasting level can also affect the ash content of coffee beans. As the beans are roasted, the organic material within them is broken down and burned off, leaving behind the inorganic ash content. The longer and hotter the beans are roasted, the more organic material is burned off, which can result in a higher ash content.

The results of this study indicated that the ash content produced by fluidized bed roasters was not significantly different from that of drum roasters. Furthermore, as the roasting level increases, the ash content also tends to increase, in line with the findings of [21]. Generally, the ash content of coffee beans is an important parameter that can affect the flavour and quality of the final product. Therefore, it is important for roasters to carefully monitor and control the roasting process to achieve the desired ash content and ensure a high-quality product.

Referring to the caffeine content, roasting level significantly affected the caffeine content of Robusta coffee. However, the roasting type and the interaction had no significant effect on the caffeine content of Robusta coffee. The increase in caffeine content only occurred from medium to dark level, while from light to medium is relatively stable. Based on several recent research, it was reported that there is no clear trend between roasting level and caffeine content [4,22,23]. However, there is some evidence to suggest that excessively high roasting levels can lead to the degradation of caffeine and a subsequent decrease in its content. Increasing roasting level can result in an increase in caffeine content up to a certain point, after which the caffeine content may start to decrease [24].

In terms of total phenolic content, roasting types, level of roasting, and their interaction had a significant effect on the total phenolic content of roasted Robusta coffee. Phenolic compounds are naturally occurring antioxidants that contribute to the flavour, aroma, and health benefits of coffee. During the roasting process, these compounds undergo changes that can affect their overall concentration and composition.

Different types of roasting machines can generate different levels of heat and airflow during the roasting process, which can affect the rate and extent of chemical reactions that occur within the beans. For example, drum roasters typically operate at a slower rate and with less airflow than fluid bed roasters, which may result in variations in the chemical make-up of the coffee beans and the total phenolic content. The roasting level can also affect the total phenolic content of coffee beans. As the beans are roasted, the phenolic compounds undergo various chemical reactions, including degradation and polymerization, which can affect their concentration and composition.

The research results indicated that the total phenolic of roasted coffee bean produced by the drum roaster was higher than that of the fluidized bed roaster, which is consistent with the study conducted by Baggentos et al. [3]. Furthermore, an increase in roasting level has an impact on the decrease in total phenolic of roasted coffee bean and this is in line with previous research [22]. Generally, lighter roasts have a higher total phenolic content than darker roasts because the longer and hotter the beans are roasted, the more phenolic compounds are broken down and degraded.

3.4 Volatile compounds

Based on the analysis results of the coffee samples, it is evident that coffee roasted with a Drum roaster produces more volatile components than coffee roasted with a Fluidized bed roaster. Specifically, coffee roasted with a Drum roaster at light, medium, and dark levels produced 46, 48, and 48 volatile compounds, respectively. On the other hand, coffee roasted with a Fluidized bed roaster produced 40, 20, and 18 volatile compounds, respectively. This result is in line with the findings of a study conducted by Bolka and Emire [25], where the drum roaster was discovered produced the highest levels of beneficial chemicals and the least amount of acrylamide production.

The way coffee is roasted can affect the chemicals in it that make it taste and smell different. Roasting can create or break down different compounds, including volatile ones that affect the aroma. The length and intensity of the roasting process can also change the number and types of volatile compounds in the coffee. Two different methods of roasting, drum roasting and fluidized bed roasting, can produce different volatile compounds. Drum roasting allows for a longer and slower roasting time, leading to more complex reactions and a wider range of volatile compounds. Fluidized bed roasting, on the other hand, provides faster and more consistent heat, which may not create as many diverse volatile compounds. The level of roasting also affects the number of volatile compounds produced, with darker roasts producing more. This is why coffee roasted in a drum roaster at a dark level of roasting has a smoky aroma, while coffee roasted in a fluidized bed roaster does not.

3.5 Sensory responses

Table 4 showed the analysis' findings of organoleptic responses of coffee. Results showed that the factors of coffee roasting machine type, roasting level, and their interplay have a significant effect on the aroma attribute of Robusta ground coffee in the sensory evaluation. Different coffee roasting machines and roasting levels can affect the smell of Robusta ground coffee by changing the chemical reactions that happen during roasting. Each machine can cause different reactions to happen at different rates, and different levels of roasting can create different smells. The way the machine and roasting level work together can also impact the smell of the coffee. By controlling these factors during roasting, it is possible to create the desired aroma for Robusta ground coffee.

Table 4. Results of the analysis of organoleptic responses of coffee

Roaster type	Roasting levels	Aroma-ground coffee[1)]	Colour[2)]	Aroma-brewed coffee[1)]	Bitterness[3)]	Acidity[4)]	Sweetness[5)]
Drum Roaster	Light	2.67[a]	2.37[a]	2.53[a]	2.93[a]	2.77[a]	2.57[b]
	Medium	3.17[c]	3.79[c]	3.17[b]	3.69[c]	3.07[c]	2.63[b]
	Dark	3.78[d]	5.29[e]	4.19[c]	4.68[e]	2.87[ab]	2.18[a]
Fluidized Roaster	Light	3.04[b]	3.30[b]	3.12[b]	3.50[b]	3.27[d]	2.63[b]
	Medium	3.86[d]	4.59[d]	4.08[c]	4.33[d]	3.40[e]	2.67[b]
	Dark	4.26[e]	5.64[f]	4.60[d]	5.16[f]	2.91[b]	2.07[a]

Note: Means with different letter in the same column are significantly different at 95% confidence level. [1)] Very weak (1) - Very strong (6); [2)] Slightly yellow (1) – Black (6); [3)] Not very bitter (1) – Very bitter (6); [4)] Not very sour (1) – Very sour; 5) Not very sweet (1) – Very sweet (6).

For colour attribute, coffee roaster machine, the roasting level, and their interaction had a significant effect on the colour attribute of the brewed powder of Robusta coffee. Different roasting machines can create different amounts of heat and airflow during roasting, which affects chemical reactions like the Maillard reaction that develop colour and flavour. The level of roasting also affects the colour of the coffee, with darker roasts creating a darker colour and lighter roasts producing a lighter colour.

Regarding the aroma of brewed coffee, results showed that the type of roasting machine, level of roasting, and their interaction can affect the aroma of brewed Robusta coffee. The chemical reactions during roasting are influenced by the machine and level of roasting, which can impact the aroma of the coffee. Different levels of roasting produce different aroma compounds, with lighter roasts having fruity or floral notes and darker roasts having smoky or roasted notes. The type of roasting machine and the level of roasting can interact to affect the aroma of the coffee, as some machines work better for certain roasting levels. The roasting process can also produce volatile organic compounds that contribute to the coffee's aroma.

For bitterness, it was influenced by the type of roasting type, the roasting level, and their interaction. The bitterness of coffee depends on chemical changes that occur during roasting. The breakdown of chlorogenic acids, which contribute to bitterness, can be affected by the heat and airflow from different roasting machines. Darker roasts taste more bitter than lighter roasts because chlorogenic acids break down into other bitter compounds during roasting. The bitterness of coffee can also be influenced by the interaction between the roasting machine type and roasting level, as some machines are better suited for certain levels of roasting, which can affect the heat and airflow that the coffee beans are exposed to during roasting.

Acidity was also found affected by roasting type, roasting level, and their interaction. Roasting can cause chemical changes that affect the acidity of coffee, and this is influenced by the temperature, duration, method, and type of roasting machine. Therefore, the choice of roasting machine and level can affect the acidity of the resulting coffee.

Regarding the sweetness, it was found that the factor of roasting machine type and roasting level influenced the sweet taste attribute, while their interaction had no significant effect on the sweetness attribute. The individual effects of roasting machine type and roasting level may dominate the combined effect of the two factors on sweetness, resulting in no significant interaction effect. Coffee sweetness may also depend on coffee bean origin, processing, and brewing method.

4 Conclusions

Based on the results of the study, it can be concluded that both the type of roasting machine and the degree of roasting had a substantial effect on various attributes of coffee powder, such as moisture content, ash content, total phenol content, volatile compounds, physical response of bulk density, colour analysis, and organoleptic attributes of aroma, bitterness, acidity, and sweetness. However, the roasting machine type or the roasting degree did not significantly affect the caffeine content. The interaction between the type of roasting machine and the degree of roasting also significantly affected various attributes of coffee powder. Therefore, the selection of the roasting machine and degree of roastedness must be carefully considered to achieve desired coffee quality. Overall, the fluidized roaster provides a faster roasting time, but the volatile components tend to be less, more bitter and darker in colour.

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