Physicochemical and Sensory Attributes of Robusta Coffee as Influenced by Sorbitol Concentration and Roasting Time

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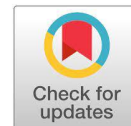
Abstract

Many studies have reported several methods to improve the quality of Robusta coffee such as fermentation, but it takes a relatively long time. In this study, a new processing method for Robusta coffee quality enhancement was investigated. Robusta coffee cherry was immersed using sorbitol solution under different concentrations (10%, 15%, and 20%), then the green bean coffee was roasted with several roasting duration (1, 3, and 5 minutes after coffee beans cracking) to determine the characteristic of coffee produced. Characteristics examined were chemical responses consisted of water content, pH, caffeine content, and anti-oxidant activity (IC_{50}); physical responses consisted of L* color attribute; and organoleptic responses consisted of color, aroma, taste, and aftertaste. Principal component analysis (PCA) was employed to examine the qualitative correlations between dependent variables. The results demonstrated that the concentration of sorbitol of 10% to 20% altered the organoleptic reaction but not the physical and chemical responses. The roasting time impacted the coffee's water content, pH, antioxidant activity (IC_{50}), color, flavor, and aftertaste, but not its caffeine content and aroma. The interaction between sorbitol concentration and roasting time influences the color, flavor, and aftertaste characteristics of coffee. This finding led to an improvement in the quality of Robusta coffee. Furthermore, PCA showed that IC_{50} value was positively correlated with pH value and was conversely correlated with water content and L*, and slightly correlated with caffeine. Sensory attributes had no correlation with variables of IC_{50}, caffeine and pH, and L*.

Keywords: sorbitol concentration; roasting time; postharvest processing; sensory properties

INTRODUCTION

Coffee (*Coffea* sp.) is one of the most popular beverages in Indonesia and the entire world. Coffee is a member of the family *Rubiaceae* and the genus Coffea. Generally, there are two species of coffee: Arabica coffee and Robusta coffee (Kristanti *et al.*, 2022). The International Coffee Organization (ICO) recognises four varieties of coffee: Arabica, Robusta, Liberica, and Excelsa (Afriliana, 2018). In Indonesia, the area of coffee plantations in 2019 climbed to 1.21 million hectares (DGE, 2020). The global production of coffee increased from 9.5 million tons (2018) to approximately 10.2 million tons (2019) (Adam *et al.*, 2020). Coffee provides health benefits that include lowering the risk of diabetes, boosting stamina, reducing headaches, and relieving bad breath (Bidel & Tuomilehto, 2013).

Robusta coffee contributes 36% of global coffee production, and it is cultivated mostly in Vietnam, West Africa, Indonesia, and the majority of Southeast Asia (Campuzano-Duque *et al.*, 2021). Coffee contains caffeine, phenols, alkaloids, flavonoids, saponins, chlorogenic acid, and trigonelline, among other active components. Robusta has a lower acidity level and has higher caffeine content than Arabica. Additionally, coffee contains carbs, proteins, lipids, and minerals. Robusta coffee contains alkaloids, flavonoids, saponins, tannins, caffeine, and phenols, among other chemical components (Utami & Nhestricia, 2019). Caffeine is one of the essential chemical components of coffee. Caffeine (1,3,7-trimethylxanthine) is an alkaloid that present in coffee beans, tea leaves, and cocoa beans (Heckman *et al.*, 2010). Caffeine contributes to the level of bitterness in coffee and has certain pharmacological effects (Savitri *et al.*, 2022). According to literature, physical and chemical features of coffee might change during the roasting process (Darmajana *et al.*, 2022; Hidayat *et al.*, 2021). Coffee changes occurred during roasting (Ortolá *et al.*, 1998), starting from the temperature of the coffee beans and extending to their physical and chemical composition (Bustos-Vanegas *et al.*, 2018). Appropriate heat-transfer and temperature are the two most important factors that influence the physical and chemical properties of roasted coffee beans (Bottazzi *et al.*, 2012; Chiang *et al.*, 2017; Hidayat *et al.*, 2021).

Many previous studies have reported several methods to improve the quality of coffee such as fermentation (Mulyara *et al.*, 2021; Wei *et al.*, 2015), but it takes a relatively long time. In this study, a new processing method was used to enhance the sensory characteristics of Robusta coffee with minimal processing time by using sorbitol immersion technique. The loss of physical and chemical features of Robusta coffee during roasting may be prevented by adding sorbitol prior to roasting.

Sorbitol is a polyol (sugar alcohol) that is used as a bulk sweetener in a variety of culinary products. The effect of sorbitol is smooth and pleasant. Sorbitol is non-carcinogenic and beneficial for diabetics (Gupta, 2018). Sorbitol has the advantage of retaining moisture in food products and not causing browning during high-temperature processing (Deis & Kearsley, 2012). Sorbitol, in addition to working as a humectant in the material, preserves the material's moisture stability and can protect the firmly bound components (Deis & Kearsley, 2012). The addition of sorbitol may alter the properties, especially sensory properties of unroasted coffee beans prior to roasting when the sugar content of the beans increases and influence all roasting-related processes. The reaction that produces aroma and flavor in Arabica and Robusta coffee is affected by pre-roasting treatment of green coffee beans (Liu *et al.*, 2019). Based on the literature, no previous research found regarding the pre-treatment of Robusta coffee cherry using sorbitol combined with several roasting time variations and its effect on the physicochemical and sensory attributes of coffee quality. Therefore, the purpose of this study was to explore relationship between sorbitol concentration and roasting time on the characteristics of Robusta coffee from the Subang District, Indonesia.

MATERIALS AND METHODS

Materials and Equipment

The raw materials used in this experiment were Robusta coffee (*Coffea canephora*) in the form of cherry coffee which harvested from Cilame Hamlet (6^0 42' 52.77'' S, 107^0 46' 19.65" 354 MAML), Mayang Village, Cisalak sub-district, Subang District, West Java, Indonesia. Samples used in this research were ripe Robusta coffee cherry. Samples coffee cherry was soaked in the water to

separate the good and bad cherries. The submerged cherries were collected, while the floated cherries were discarded.

Experimental Procedure

Robusta coffee cherry samples (5 kg per treatment) and sorbitol solution (5 L per treatment) with concentration of 10%, 15%, and 20% were prepared. Three hours were spent immersing coffee cherries in 10%, 15%, and 20% sorbitol solutions. The coffee cherries were then drained and dried in a cabinet dryer. The drying process was performed with temperature of 50 ^{0}C and 72 hours. Then the dried coffee was hulled to obtain green coffee beans. After that, the green beans were roasted and performed under three different levels based on the duration of the developing time (after bean cracking): 1 minute for the lightest level, 3 minutes for the medium level, and 5 minutes for the darkest level. The initial temperature when the coffee beans enter the roasting room was 180 ^{0}C. This value was based on the literature that had found the optimum roasting process (Dharmawan *et al*., 2018). The roasted coffee were ground to obtain coffee powder.

Color and Water Content Measurement

Color and water content measurement was performed in the form ground coffee. The color (brightness) of coffee powder was measured by CIE method using a colorimeter (NH310, China). Water content was analysed by gravimetric method (AOAC, 1995).

pH Measurement

The pH of coffee sample was measured by using a pH meter (SI Analytics Lab 865, Xylem Inc., USA). Prior to analysis, one gram of ground coffee sample was diluted using 10 mL of demineralized water at 90-95 ^{0}C.

Then the solution was allowed to cool to room temperature (30 ^{0}C). After that, the residue was separated from the liquid to get a coffee liquid sample that was ready for pH analysis. The liquid was placed in erlenmeyer, then the pH meter was calibrated using buffer standard solutions (pH 4.0 and 7.0). The probe was dipped into the coffee liquid until the pH meter displayed a stable value. The pH meter probe was rinsed with distilled water every time the sample changed. The measurement was performed in duplicate for each treatment replication.

Caffeine Measurement

The caffeine content of coffee was measured by using HPLC Infinity II 1260-AGILENT (Agilent Technologies, USA) according to DIN 20481 (Naegele, 2016). The type of column used was the Agilent ZORBAX Eclipse Plus C18, 4.5×150 mm column. The detector was set at 275 nm. The mobile phase used a combination of demineralized water and methanol with a ratio of 60:40. The mobile phase flow rate was 1 mL min^{-1}. Prior to analysis, a standard solution of 500 ppm caffeine was prepared by weighing 12.5 mg of caffeine (free of water) then dissolved in warm water in a 25 mL volumetric flask, then allowed to cool to room temperature. Standard series were made with concentrations of 0, 25, 50, 75, 100, 125, 150 ppm. Then, coffee powder (0.25 g) was input in 200 mL water at 90 ^{0}C and stirred for 20 minutes at 90 ^{0}C in a water bath. After removal from the water bath and cooling down to room temperature, a part of the liquid was filtrated through a cellulose syringe filter (Agilent Captiva Premium Syringe Filter, Regenerated Cellulose, 0.45 µm, 25 mm, p/n 5190-5111). The filtered extract from the decaffeinated product was used directly for injection and the extract from regular coffee after a 1:10 dilution.

Antioxidant Activity Measurement (IC$_{50}$)

The antioxidant activity was determined using the 1,1-diphenyl-2-picrylhydrazy (DPPH) method (Sigma-Aldrich, Germany) according to Molyneux (2004). The preparation of coffee extract was carried out using the maceration method by soaking 2 g of coffee powder with 20 mL of ethanol as a solvent. Soaking was carried out for approximately one day at room temperature and stored in a place protected from sunlight. Then filtered through filter paper and the solvent was evaporated in a water bath at a temperature of 50 ^{0}C to obtain a coffee extract. Variations of the test solution were made by first making a 1000 ppm solution by dissolving 5 mg of coffee extract and then adding 5 mL of ethanol. Each was put into a 10 mL volumetric flask, then dissolved with ethanol until it reached the mark. The standard series was made with concentrations of 5, 10, 15, 25, 30 ppm. Then 4 mL of ethanol and 1 mL of 1 mM DPPH solution was added, diluted and homogenized. The absorbance samples were measured with a UV-Vis Spectrophotometer (Shimadzu 1900, Japan) at λ 517 nm. The radical scavenging activity was calculated according to the following equation:

$$RSA = \frac{Ac - At}{Ac} \times 100 \quad \text{.................... (1)}$$

where: *RSA* – radical scavenging activity (%); *Ac* – absorbance of control; *At* – absorbance of test sample.

The IC$_{50}$ value is defined as the amount of the sample to scavenge 50% of the DPPH radicals. It was calculated from percentage of radical scavenging activity results by plotting the graph of DPPH free radical scavenging activity versus concentration of the sample (Kuyu *et al.*, 2018).

Organoleptic Tests

In each treatment, 8.25 g of ground coffee with a size of 20 mesh was added with 150 mL water at a temperature of 90 ^{0}C. Then, the coffee was allowed to stand for 4 minutes. The foam on the surface of the solution was cleaned using a spoon. After the temperature reaches 70-73 ^{0}C, the coffee was ready for organoleptic analysis by the panelists. Organoleptic test of coffee was assessed using the hedonic method (preferred test). Organoleptic responses consisted of color, aroma, taste, and aftertaste. All samples were evaluated by 30 panelists (barista). There were 9 samples that were evaluated by the panelists and were given a score in the range of 1 to 6 points (1 = really disliked, 2 = disliked, 3 = somewhat disliked, 4 = somewhat liked, 5 = liked, 6 = really liked). The mean value of each hedonic parameter was reported as panelist acceptability.

Statistical Analysis

The experimental design was fully random with three replications. For each analysis, measurements were done in triplicate. Variance analysis was performed on the data using SPSS software version 25 (IBM Corp., USA). Duncan's multiple range tests (DMRT) as employed using *FactoMineR* package (Lê *et al.*, 2008) in open-source platform (R-statistical software) to evaluate the correlation between dependent variables measured from all treatments. Prior to PCA, the data was pre-processed using normalisation with the range between 0 and 1.

RESULTS AND DISCUSSION

Physicochemical Responses

The influence of sorbitol concentration and roasting time on the color of Robusta coffee powder is presented in Figure 1. The color intensity of coffee grounds was determined by the L* value of the colorimeter, which shows the level of brightness. The greater

the L* value, the lighter the coffee's color. Analysis of variance (ANOVA) on the Robusta coffee color test revealed that the concentration of sorbitol solution and interaction between sorbitol concentration and developing time had no significant effect (P>0.05) on the color of Robusta coffee, however roasting time had a significant effect.

The Duncan post-hoc test revealed substantial variations between the 1 minute, 3 minutes, and 5 minutes roasting development time periods. This discrepancy indicates that the L* color value decreases with increasing roasting time (developing time). The darker the coffee color, the lower the L* value (Mwithiga & Jindal, 2003). The degree of roasting affects the color of the coffee powder, which is one of the quality elements in coffee. According to Saloko et al. (2019), the roasting tempera-ture and duration determine the coffee's color. A lengthy roasting time results in a darker coffee powder and alters the color of the coffee extract. The darker the desired coffee, the higher the temperature and the longer the roasting time needed. The Maillard reaction, which results in the formation of a carbonyl group (reduction group) and an amino group, is responsible for the darker color of coffee (Kumar et al., 2017). The Maillard process is a non-enzymatic browning reaction in which reducing sugars (carbohydrates) combine with primary amine groups to generate a brown color (Mossine & Mawhinney, 2010).

For the analysis of water content, ANOVA revealed that only roasting development time that significantly change the water content of coffee. Figure 2 shows the result of DMRT for coffee water content. It was revealed that there was a statistically significant difference between the three development time treatments of 1 minute, 3 minutes, and 5 minutes. The longer the roasting period, the lower the water content of Robusta coffee. During the roasting process, heat is transferred to the coffee beans, which results in the evaporation of water from the coffee beans, causing the water content to drop. The findings of this study is consistent with those of studies conducted by Saloko et al. (2019).
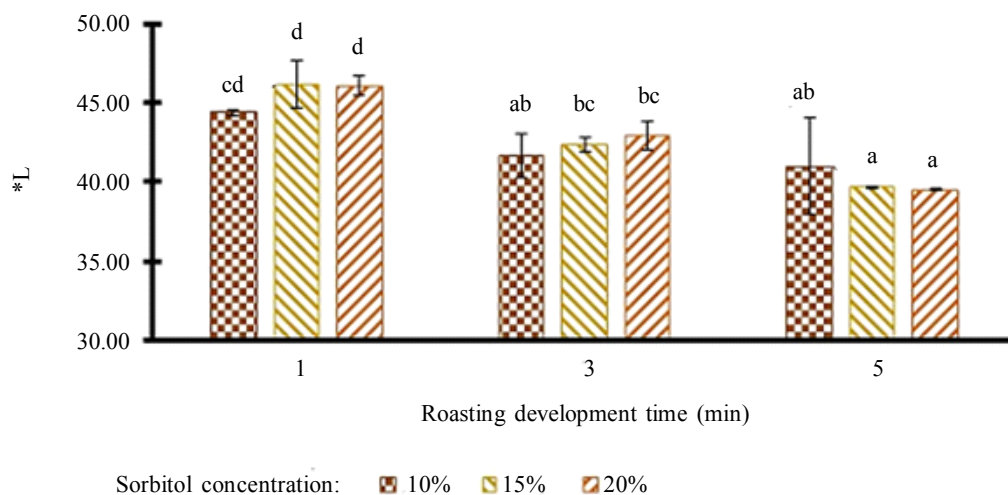

Figure 1. Effects of sorbitol concentration and roasting time on color properties (L*) of coffee produced. Similar superscript letters indicate no significant difference
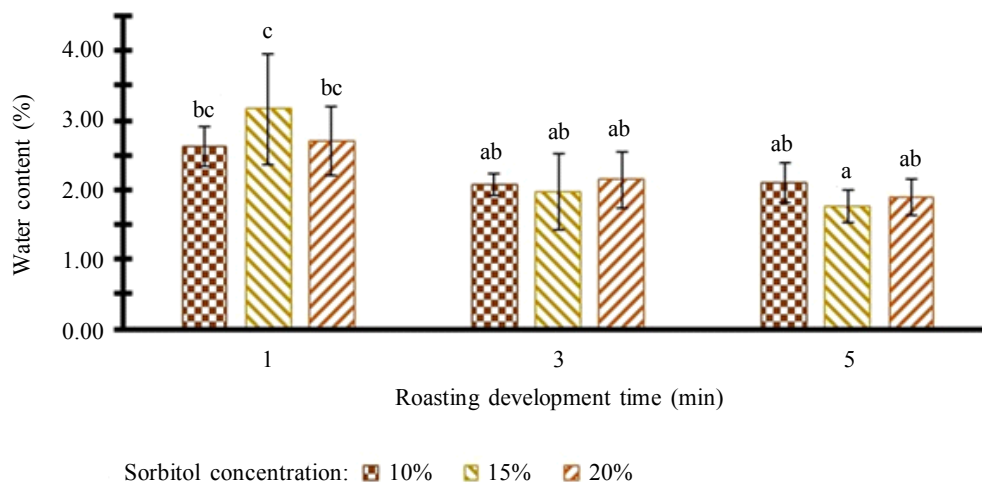
Notes: Bars indicate standard of deviation

Figure 2. Effects of sorbitol concentration and roasting time on water content of coffee produced. Similar superscript letters indicate no significant difference

Notes: Bars indicate standard of deviation

One minute after the first crack, the roasting temperature was about 174–211 ^0C; three minutes after the first crack, the roasting temperature was approximately 198–216 ^0C; and five minutes after the first crack, the roasting temperature was approximately 192–229 ^0C. This result is consistent with Bustos-Vanegas *et al.* (2018) assertion that the greater the roasting temperature, the larger the evaporative mass transfer.

Figure 3 displays the effect of roasting time and sorbitol concentration on the pH of Robusta coffee. ANOVA result revealed that sorbitol concentration did not affect the pH, but roasting development time gave significant effect on the pH. However, 1 minute development time did not significantly vary from the 3 minutes development time.

The pH is one aspect that influences the flavor of coffee. Roasting with a development time of 1 and 3 minutes resulted in a pH value that was smaller than the pH value at the 5 minutes of development time. It means that acid compound was decreased with roasting time (pH value increased). This occurs because the acid content of the coffee

grind decreases gradually during the roasting time (Kim *et al.*, 2021). In general, a pH value of Robusta coffee was higher than Arabica as reported by Rao & Fuller (2018), where the pH of Arabica coffee ranged between 4.85 and 5.13, while Robusta was more than 5.18. Thus, these results are relevant to many literatures that Arabica coffee has more acid taste than Robusta coffee. According to Kim *et al.* (2021), increasing temperature and roasting time will increase the pH of coffee grounds as a result of the pyrolysis of acidic chemicals, resulting in the evaporation of these compounds.

For the caffeine content, ANOVA indicated that the concentration of sorbitol solution, the roasting duration, and their interaction have no significant influence on the caffeine content of Robusta coffee. This conclusion is consistent with Herawati *et al.* (2019) assertion that roasting time appreciably affected the caffeine level of coffee. Coffee's caffeine concentration is resistant to heating. The average value of caffeine from all treatments is presented in Figure 4.
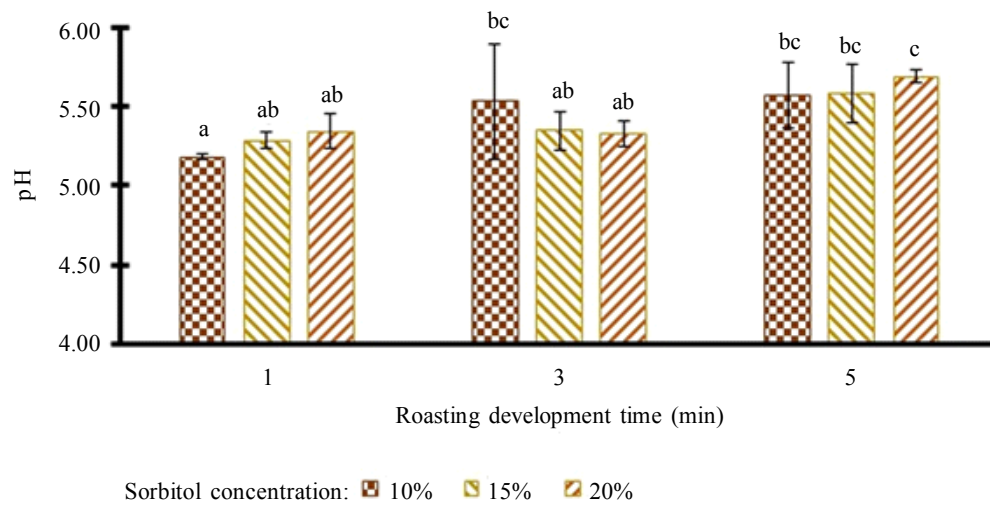
Figure 3. Effects of sorbitol concentration and roasting time on pH of coffee produced. Similar superscript letters indicate no significant difference
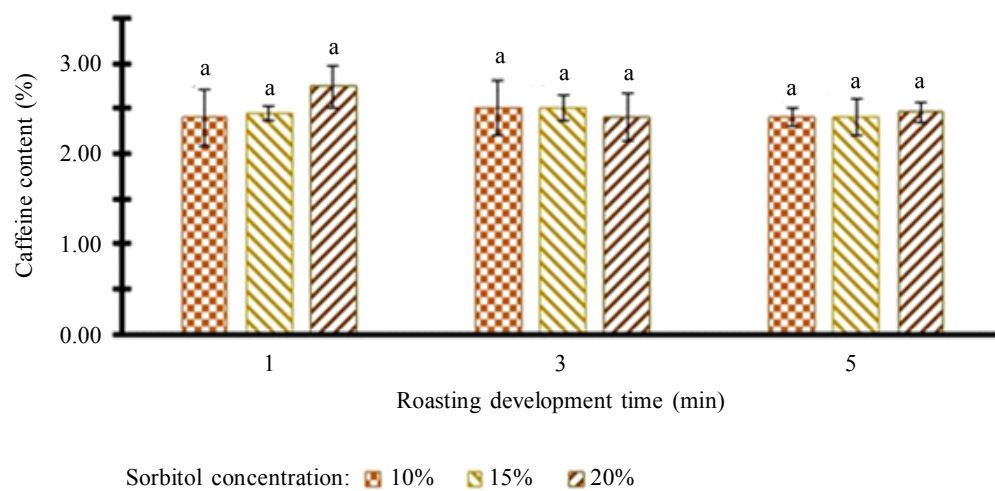
Notes: Bars indicate standard of deviation

Figure 4. Effects of sorbitol concentration and roasting time on caffeine content of coffee produced. Similar superscript letters indicate no significant difference

Notes: Bars indicate standard of deviation

Antioxidant activity was assessed using the inhibition percentage and IC_{50} value. IC_{50} means the concentration of the extract (mg mL^{-1}) which can prevent oxidation up to 50%. The lower the determined IC_{50} value, the greater the antioxidant activity of the substance. The antioxidant included in coffee is chlorogenic acid, a polyphenolic molecule. Approximately 90% of the total phenol in coffee is chlorogenic acid, which is an ester of various cinnamic acids with quinic acid, caffeic acid, ferulic acid, and p-coumaric acid. Antioxidants limit the creation of new radical compounds by converting free radicals into

molecules with a lesser harmful impact before they react. Antioxidants have chain-breaking characteristics that allow them to react with lipid radicals to produce more stable products (Lobo *et al.*, 2010). The result of Duncan's multiple range tests (Figure 5) indicate that the roasting treatment and sorbitol concentration did not significantly affect the IC_{50} of coffee produced. Insignificant differences in IC_{50} may also contributed by other compounds than phenolics, such as melanoidins which formed when sugars and amino acids combine (through the Maillard Reaction) at high temperatures. However, from the result, it can be seen that there was a slight increase of IC_{50} value due to roasting process. The increase of IC_{50} value means that the antioxidant activity decrease. This revealed that the longer the roasting time, the lower the antioxidant content due to the high heating temperature. This occurs due to phenolic compounds especially chlorogenic acids are thermally unstable, so there is a consistency in reducing these compounds with a more excessive roasting process (Herawati *et al.*, 2019).

Organoleptic Responses

The sensory properties of Robusta coffee are shown in Table 1 which consisted of color, aroma, flavor, and aftertaste. ANOVA on the hedonic test of Robusta coffee color characteristics revealed that the concentration of sorbitol solution, roasting time, and their interaction greatly influenced the hedonic test's color attributes. The sample treated with 20% sorbitol concentration and 1 minute roasting development time had an unfavourable color characteristic, but the sample with a 20% sorbitol content and a roasting period of 3 and 5 minutes had the most desired color.

The color of coffee is affected by the rate of heat propagation in the roasting medium; the longer the roasting time, the darker the color of the coffee grounds as a result of the Maillard reaction that produces volatile compounds, the caramelization of carbohydrates, and the formation of CO_2 as a result of oxidation during roasting. According to Otsogile *et al.* (2022), one element affecting the color of brewed coffee is the caramelization of sugar, which results in a dark color.
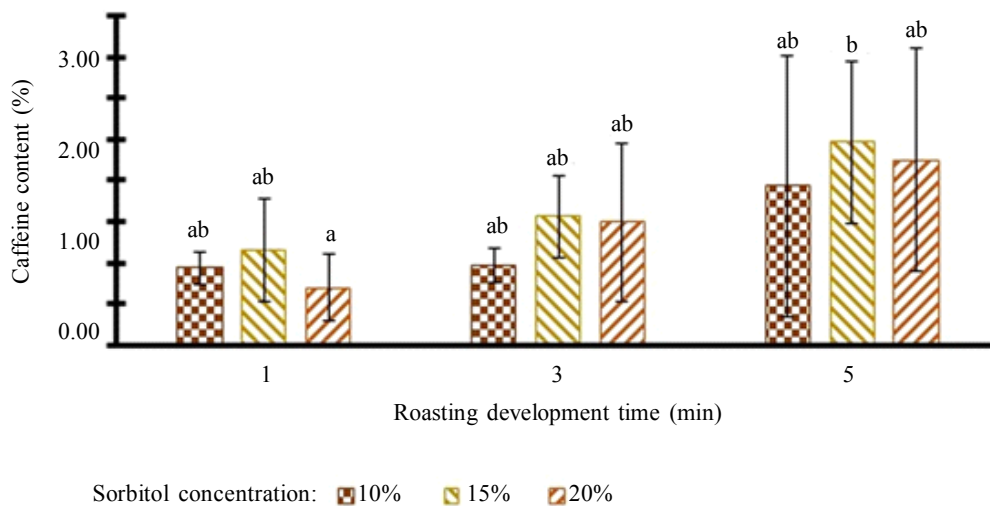

Figure 5. Effects of sorbitol concentration and roasting time on IC_{50} of coffee produced. Similar superscript letters indicate no significant difference

Notes: Bars indicate standard of deviation

ANOVA revealed that roasting time and the interaction between roasting time and sorbitol concentration had no significant influence on the hedonic test of Robusta coffee aroma attribute. However, sorbitol content had a substantial impact on the hedonic evaluation of aroma qualities.

The post-hoc test revealed that the 10% sorbitol concentration was considerably different from 15% and 20%, where 15% sorbitol concentration was not substantially different from 20% concentration. According to Otsogile *et al.* (2022), the characteristic aroma of coffee is influenced by the volatile compounds produced during the roasting process. Due to the presence of volatile chemicals produced by the Maillard process and sugar degradation, coffee emits its scent. Sorbitol which is a type of sugar causes an increase in the sugar content so that when the Maillard reaction and sugar degradation occurred, more aroma emerged from the coffee, as presented in Table 1, where 20% sorbitol concentration having the highest aroma attribute value.

ANOVA revealed that the concentration of sorbitol solution, roasting time, and their interaction substantially influenced the hedonic test of Robusta coffee flavor qualities. The findings of the two-way interaction study revealed that the sample with 10% sorbitol content and 1 minute of roasting time after the first crack had an unfavourable flavor

characteristic. The sample with a 20% sorbitol content and a roasting period of 3 minutes after the first crack had the most favoured flavor quality. The acidity of coffee influences its flavor; the longer it is roasted, the more acid evaporates. If the roasting is not perfect, the development of an acidic flavor in the coffee will not be optimal. According to Afriliana (2018), numerous components, including carbohydrates, alkaloids, volatile chemicals, and trigonelline, degrade to affect the flavor of coffee. Sorbitol may maintain flavor-forming components in coffee, therefore increasing the amount of sorbitol will enhance the coffee's flavor. Grzelczyk *et al.* (2022) states that during the roasting process, the compounds will heat up, causing the atoms to move more vigorously and break the chemical bonds that cause the coffee to change from acidic to bitter.

ANOVA on the hedonic test of Robusta coffee aftertaste qualities revealed that the concentration of sorbitol solution, roasting time, and their interaction substantially influenced the hedonic test of Robusta coffee aftertaste attributes. Two-way interaction analysis revealed that the unfavourable aftertaste characteristics were the 10% sorbitol sample concentration and the one minute roasting duration after the initial crack.

The sample with a 20% sorbitol content and a roasting period of 3 minutes after the first crack received the highest rating for

Table 1.   Influence of sorbitol concentration and roasting development time on organoleptic attributes of Robusta coffee

Sorbitol concentration (%)	Roasting development time (min)	Color	Aroma	Flavor	Aftertaste
10	1	3.83	3.92	4.00	4.00
	3	4.17	4.36	4.12	4.12
	5	3.92	3.99	4.10	4.23
15	1	5.01	4.85	4.56	4.51
	3	4.99	4.79	4.55	4.42
	5	4.42	4.34	4.22	4.19
20	1	3.72	4.47	4.20	4.11
	3	5.10	4.88	4.74	4.70
	5	5.15	5.02	4.68	4.40

*Same 1-6 (1 = really dislike, 6 = really liked)

aftertaste. According to Afriliana (2018), aftertaste is the flavor that lingers at the back of the tongue after coffee has been drunk. If the aftertaste is immediately gone and unpleasant, a low score will be assigned. The greater the roasting level, the lesser the aftertaste created.

Principal Component Analysis Result

Figure 6 displays the PCA result of the physicochemical and organoleptic properties of Robusta coffee sample from all treatments. A loading plot of principal component 1 (PC1) and principal component 2 (PC2) may be used for describing the relationship between dependent variables observed. The total variation explained by both PCs was 81.44%, where PC1 contributed 46.92% and PC2 contributed 34.52%. IC_{50} and pH were within the same

direction which indicates these parameters were positively correlated, where lower pH values have higher potential for antioxidant activity (lower IC_{50} value). Both were conversely or negatively correlated with water content and lightness (L*) and slightly correlated with caffeine content. The preference for organoleptic parameters (color, flavor, aroma, and aftertaste) has no correlation with variables of IC_{50}, pH, L*, and caffeine, thus the sensory properties of coffee were found not to be influenced by these parameters. For further analysis regarding correlated parameters, Pearson correlation were calculated which were presented in Table 2. It was shown that water content has strong positive correlation with L*, and negatively correlated with IC_{50}. Furthermore, pH shows positively correlated with IC_{50} and negatively correlated with L*.

Table 2. Correlation analysis between variables

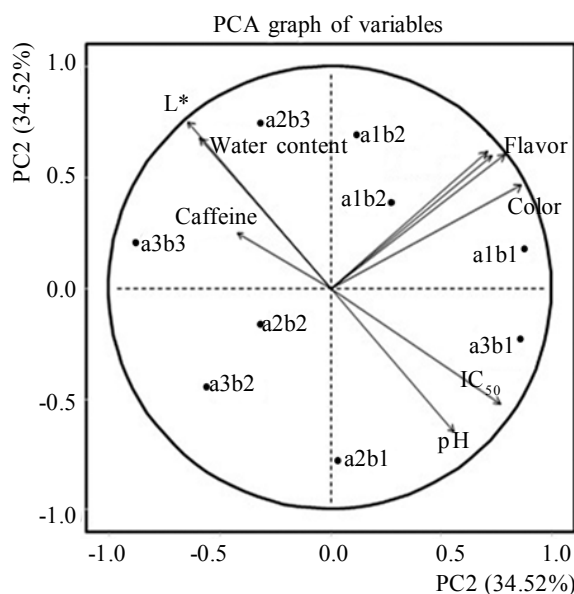| Parameter relation		Pearson correlation
Water content (%)	L*	0.93
Water content (%)	IC_{50} (ppm)	-0.72
L*	pH	-0.85
pH	IC_{50} (ppm)	0.73
Caffeine (%)	IC_{50} (ppm)	-0.52
IC_{50} (ppm)	L*	0.40

Figure 6. Biplot obtained from PCA of variables comprising physicochemical and sensory properties of Robusta coffee from this experiment: a1-10%, a2-15%, a3-20%, b1-1 min, b2-3 minutes, b3-5 minutes

CONCLUSIONS

Results based on studies examining the influence of sorbitol solution concentration and roasting duration on the properties of Robusta coffee cherries, the following conclusions may be drawn: The effect of sorbitol concentration on lightness, water content, pH, antioxidant activity, and caffeine levels was insignificant. In the range of tasted concentration, the sorbitol content greatly influenced the sensory characteristics, where the preference for color, aroma, flavor and aftertaste increased with the increase in sorbitol concentration. The duration of roasting has a substantial influence on the physico-chemical reaction of lightness, water content, pH, and antioxidant activity, but not on caffeine level. The roasting duration has a substantial impact on the organoleptic responses of color, flavor, and aftertaste, but has little influence on aroma. PCA showed that sensory properties had no correlation with IC_{50}, caffeine, L*, and pH. This finding can be a solution to improve the sensory quality of Robusta coffee where the use of sorbitol by 20% in the cherry coffee soaking process can improve the taste attributes of Robusta coffee without changing the essential content of coffee such as caffeine and anti-oxidants. Also, appropriate roasting duration also need to be used a reference to produced better quality of brewed coffee.

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