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Validations of sensory overall acceptability optimizations on response surface methodology through just-about-right technique for coffee-leaf tea at different brewing methods

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KEYWORDS

Brewing technique
Coffee waste
Coffee leaf tea
Just-about-right
Response surface methodology

ABSTRACT

Response Surface Methodology (RSM) has been widely employed for optimizing processes. However, the implementation of RSM in sensory studies is still limited. Moreover, most publications implementing RSM on sensory disregarded the validation stage as normally applied for process optimization. In this study, validating sensory overall acceptability with RSM was proposed by the Just-About-Right (JAR) technique. Coffee-leaf tea has great commercial potential as an ethnic beverage with unique sensory attributes but is still underutilized. Optimizing sensory acceptability level by modifying temperature and duration of brewing using the RSM was expected to obtain well-accepted coffee-leaf tea. Robusta coffee leaf tea is brewed using combined Decoction - V60, French Press, combined French Press - V60, and V60 at 90ºC to 100ºC for 2 to 10 minutes. Evaluated by 110 untrained panelists, it was observed that the ideal brewing parameters for each technique were 96.6ºC for 6.5 minutes for Decoction – V60, 96ºC and 6.5 minutes for French Press, 90ºC and 2 minutes for French Press - V60, and 90ºC and 2 minutes for V60. All optimum brewing conditions based on RSM were successfully validated by overall acceptability on JAR (p-value 0.05). Thus, the JAR technique can enhance the overall sensory acceptability analysis and optimization.

Introduction

Coffee plant cultivation is carried out by regularly pruning to produce optimal coffee fruit production, meanwhile at the same time produces vastly abundant coffee leaf waste (Novita et al., 2018; Khamidah et al., 2023). Several countries use coffee leaf tea as a functional drink to remedy headache, abdominal pain, anemia, diarhea, and to aid menstrual pain (Chen, 2019). Coffee-leaf tea was reported to have a high bitterness and astringency that do not contribute to a comfortable drink. Utilization of brewing techniques could reduce bitterness and enhance the acceptability level, such as reducing the brewing temperature and duration time of infusion or decoction brewing method (Cao et al., 2021). Brewing methods can also improve sensory properties by using a brewing kit or dripper, such as French Press or V60, which can also improve the antioxidant content that contributes to bitterness and astringency (López and Carrión, 2023; Farahmandfar et al., 2023). Meanwhile, coffee leaf tea in Indonesia has developed sensorially and functionally but not yet optimized (Fibrianto, et al., 2020a; Legowo et al., 2021).

Brewing coffee leaf as a tea with optimum temperature and time might control the quality of the sensory attributes and functional properties of coffee leaf tea, such as taste, aroma, color intensity, antioxidant level, caffeine content, and total phenolic content (TPC) (Fibrianto et al., 2021a). Based on previous research, brewing robusta leaves using the decoction technique at a temperature of 95.4°C for 5.7 minutes (ratio 1:100 (w/v)) showed tannin (26.03%), total phenolic content (736 mg GAE/g), and caffeine (0.13%), which is greater than the infusion technique at 80°C for 10.4 minutes (ratio 1:100 (w/v)). Meanwhile, coffee-leaf tea produced from infusion brewing is preferred in the hedonic and

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acceptability tests compared to decoction (Fibrianto et al., 2021b).

This research analyzed the production of coffee leaf tea utilizing different brewing procedures, including V60, French Press, and decoction. The investigation focused on examining the impact of brewing temperature and duration on the coffee-leaf tea's desirable flavor profile and distinctive attributes of. Prior studies have examined the functional properties of coffee-leaf tea. However, limited studies have investigated sensory perception about brewing temperature and duration utilizing the Just-About-Right (JAR) approach. The present study used a combination of Response Surface Methodology (RSM) and JAR optimization techniques to assess the degree of likeability and consumer acceptance f coffee-leaf tea. Furthermore, the sensory attributes of sweetness, sourness, bitterness, and astringency were assessed utilizing the JAR (Just About Right) approach. Subsequently, the optimization outcomes were assessed regarding phenol content, antioxidants, caffeine, and total dissolved solids (TDS).

Research and methods

Materials

The materials used in this study comprise robusta coffee-leaf tea powder sourced from Dampit. The oolong coffee leaves were processed following the instructions in Indonesian Patent Document S00202208322. The collected coffee leaf underwent a thorough washing procedure, employing a constant stream of water to remove any remaining soil and dust particles. The clean coffee leaf was stored inside a clean sack for 12 hours. Afterward, all coffee leaves were dried using the oven at 70 ± 5°C for 4 hours.

Additionally, dry ice, mineral water for palate cleansing and brewing water, W1758 Merck PA grade gallic acid powder, distilled water, Merck 106392 PA grade Na_2CO_3, Merck 1.09001 PA grade Folin-Ciocalteu reagent, 0.2 mM DPPH solution, Merck 1.06009.2500 PA grade methanol, Merck W222402 recrystallized caffeine, and Smart Lab A-1022 PA grade chloroform were utilized.

Sensory optimization

The chemical properties of this investigation were adjusted by utilizing RSM, which involved the manipulation of two variables. Specifically, the brewing duration, as the first factor of the RSM method to brew coffee-leaf tea, ranged from 2 to 10 minutes, while the brewing temperature as the second factor ranged from 90 to 100°C. Coffee-leaf tea was brewed using pour-over (V60) and non-pour over techniques (French Press – V60, Decoction – V60, and French Press). The optimal response refers to the degree of acceptance among panelists through the implementation of sensory tests utilizing five hedonic scales (i.e., very dislike, dislike, slightly like, like, and very like), subsequently validated through the JAR method (Madu et al., 2022; Addo-Preko et al., 2023).

The study included JAR testing based on the best result of the RSM method, which was determined from the most liked sample. The method evaluated the acceptability of responses and sensory attributes such as sweetness, sourness, bitterness, and astringency. Participants rated the acceptability on a scale of 1 (unacceptable), 2 (acceptable), and 3 (very acceptable) of each sensory attribute (Madu et al., 2022). The achievement of optimal optimization results is deemed when an acceptability level is obtained, as indicated by the Joint Academic Requirements. The data obtained from the verification findings were analyzed using the XLSTAT 2021 program and then validated by a one-proportion test using Minitab 19 with the hypothesis level was higher than 0.333. The present study comprised a sample of 110 individuals who had yet to receive any formal training. Subsequently, the optimized coffee-leaf tea underwent a series of quality assessments, encompassing evaluations of its antioxidant activity, total phenolic content, caffeine concentration, and TDS since these phytochemicals highly correlated with sensory attributes.

Antioxidant activity

The initial step in sample testing is creating a stock solution, wherein 0.1 mL of pro analysis dissolved in methanol was placed into a 10 mL volumetric flask. Subsequently, the initial stock solution underwent dilution to attain concentrations of 2000 ppm, 3000 ppm, 4000 ppm, 5000 ppm, 6000 ppm, and 7000 ppm. Subsequently, 1 mL of DPPH was introduced into each test tube. The contents were then subjected to vortexing until achieving a state of homogeneity, followed by an incubation period of 30 minutes in a light-free environment. In addition, the control and sample solutions were assessed using methanol pro analysis as a blank solution at a wavelength of 517 nm. The percentage of antioxidant activity was calculated using the formula % antioxidant = (Abs blank - Abs sample) / abs blank x 100%. A standard curve was constructed, with the percentage of inhibition/antioxidant activity as the y value and the concentration of the sample solution as the x value. This resulted in a linear regression equation of y = ax + b. Finally, the IC_{50} value was determined using the method described by (Fibrianto et al., 2021b; Maxiselly et al., 2022).

Total phenolic content

Total phenol content was determined by adding the sample to distilled water at a ratio of 1:10. Subsequently, about 0.8 mL of the mixture was transferred into a test tube. Subsequently, 3.2 mL of Na_2CO_3 (10%) and 4 mL of Folin reagent (7.5%) were added and mixed until homogenous, followed by an incubation period of 30 minutes at ambient temperature under reduced light exposure. Following incubation, the absorbance was quantified with a UV-Vis spectrophotometer set at a wavelength of 765 nm. Subsequently, a standard curve calibration was performed to determine the total phenol content in milligrams of gallic acid equivalent per gram (or mg GAE/g) (Dobrinas et al., 2021; Fibrianto et al., 2021a; Maxiselly et al., 2022).

Caffeine content

A standard curve was generated by preparing a caffeine stock solution with a concentration of 100 ppm. This was achieved by dissolving 0.01 g of recrystallized caffeine in 100 mL of chloroform using a volumetric flask. The caffeine stock solution was used to create dilutions at concentrations of 0.1 ppm, 0.5 ppm, 1 ppm, 1.5 ppm, 2 ppm, and 2.5 ppm. The absorbance measurement was conducted at a specific wavelength of 275.8 nm, followed by the creation of a curve. In addition, the sample extraction stage is meticulously prepared. 45 mL of the sample was subsequently supplemented with an equivalent mass of 4.5 g of sodium carbonate. The solution was heated to a temperature range of 95-100°C and agitated until complete dissolution occurred. Subsequently, the solution was concentrated until the final volume reached 15 mL. The sample was allowed to equilibrate at ambient temperature until a decrease in temperature was seen. Then, the sample was transferred into a separating funnel, to which 11.25 mL of chloroform was added. The separatory funnel was securely sealed and agitated until homogeneously blended. The separatory funnel was affixed to the clamp and left undisturbed until a distinct, transparent layer precipitated at the lowermost part. The lowermost stratum containing caffeine was isolated and analyzed for its caffeine concentration using a UV/Vis spectrophotometer. 0.1 mL of each tea extract was combined with 10 mL of chloroform and transferred onto a quartz cuvette. The absorbance at a wavelength of 275.8 nm was recorded (Horvat et al., 2022).

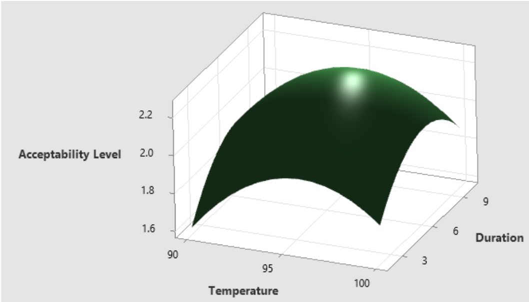
Total dissolved solids (TDS)

The TDS (degree brix) was measured using a refractometer to analyze the total solids. The method involved pouring the brewed tea onto a hand refractometer. The measurement results were then obtained and documented (Nurhayati, 2017).

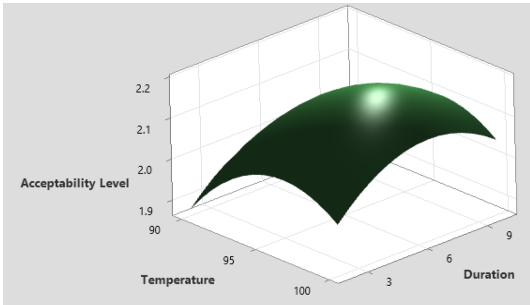
Results and Discussion

The acceptance level

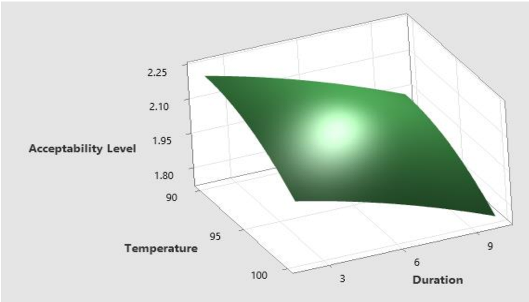
Figures 1 (a), (b), and (c) illustrate the RSM curves that portray the correlation between brewing time and temperature parameters on the acceptance of robusta coffee-leaf tea. Figures 1 (a) and (b) exhibit a concave parabolic shape. The peak with the greatest elevation on the graph signifies the highest level of acceptance, whereas the peak with the lowest elevation signifies the lowest level of acceptance. Figure 1a illustrates the optimization of temperature and time utilizing the decoction technique - V60, was achieved at 96.6°C for 6.5 minutes. The best brewing conditions for the French Press were characterized by an acceptability level peaked at 2.2, as shown in Figure 1b. This peak was achieved when the brewing temperature was set at 96.2°C and the brewing time was maintained for 6.5 minutes. Figure 1c also shows that the most favorable acceptance outcomes were observed in coffee-leaf tea prepared by the French Press - V60 method, with a brewing temperature of 90°C for 2 minutes. Figure 1d illustrates that the V60 brewing method yields the most favorable acceptability outcomes when performed at 90.2°C for 2 minutes. It is evident that the highest level of acceptance was achieved when employing lower temperatures and shorter brewing times for the non-pour over brewing technique. However, acceptance diminishes with higher temperatures and longer brewing durations for pour over brewing technique. Longer brewing duration and higher brewing temperature allowed for higher antioxidant, caffeine, and TPC extraction, which were highly correlated with bitterness and astringency intensity (Ye et al., 2022; López and Carrión, 2023).



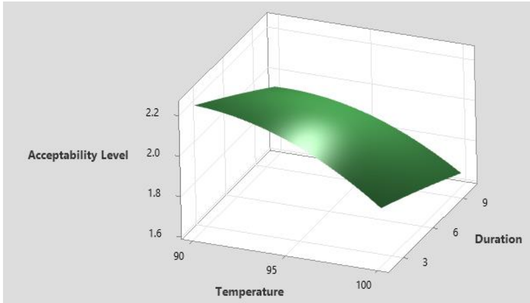
(a)



(b)



(c)



(d)

Figure 1. 3D surface graph describing the relationship between brewing time and temperature factors on acceptability (a) Decoction - V60, (b) Frencpress, (c) Frenchpress - V60, and (d) V60.

The acceptance outcomes for coffee-leaf tea prepared using the V60 decoction technique can be diminished by increasing the temperature and duration of the brewing process. An extended brewing duration and elevated brewing temperature have the potential to enhance customer acceptability. The duration of this increase persists until the appropriate temperature and timing conditions are attained. Nevertheless, should the brewing temperature and duration be beyond the ideal threshold, the level of acceptance may diminish.

Verification of sensory optimization using JAR

Figure 2 depicts the percentage evaluation results of 110 panelists for the acceptability attribute of robusta coffee-leaf tea brewed with the decoction technique filtered with the V60, French Press technique, French Press technique filtered with V60, and V60. The panelists' acceptance level attribute that is meeting the JAR standard was 55% (the decoction – V60), 59% (the French press), 75% (the French press - V60), and 61% (the V60), respectively.

The JAR analysis confirmed by the one proportion test in Table 1 revealed that the proportion of acceptability levels of the four tea-making techniques, i.e., decoction - V60, French Press, French - V60, and V60, significantly differentiated the highest JAR score (P <0.05).

Figure 2 illustrates the evaluation from 110 panelists on the sensory attributes of sweetness, bitterness, sourness, and astringency in robusta coffee-leaf tea prepared using various methods. Figure 2a shows that, by using the decoction-V60 brewing technique, 39% of panelists indicated that the sweetness, sourness, bitterness, and astringency were at the optimal level (JAR), followed by 47% for sourness, 52% for bitterness, and 51% for astringency. Using the French press - V60 method, panelists found a sweet flavor by 54%, an acidic taste by 52%, a bitter taste by 55%, and an astringent sensation by 46% (Figure 2c). Figure 2c illustrates that, when prepared by the French press, panelists found the tea to have sweetness by 55%, sourness by 57%, bitterness by 54%, and astringency by 40%. Figure 2(d) depicts 55% sweetness, 40% sourness, 35% bitterness, and 66% astringency, resulting from the tea prepared with the V60 method.

The JAR analysis results were confirmed by a one-proportion test. Table 1 reveals, based on the findings of a proportional characterization test, that the results for decoction - V60 for all attributes are significantly different (P <0.05). The attributes of acidic flavor, bitter taste, and astringent sensation were statistically significant (p-value 0.05) when brewed with a French Press. Bitter flavor was statistically significant (P <0.05) when brewed with the French press - V60. Bitter flavor and acidic taste were statistically significant (P <0.05) when using the V60 tea brewing method. Bitter taste and astringency were mainly affected by high antioxidant, caffeine, and TPC levels (López and Carrión, 2023).

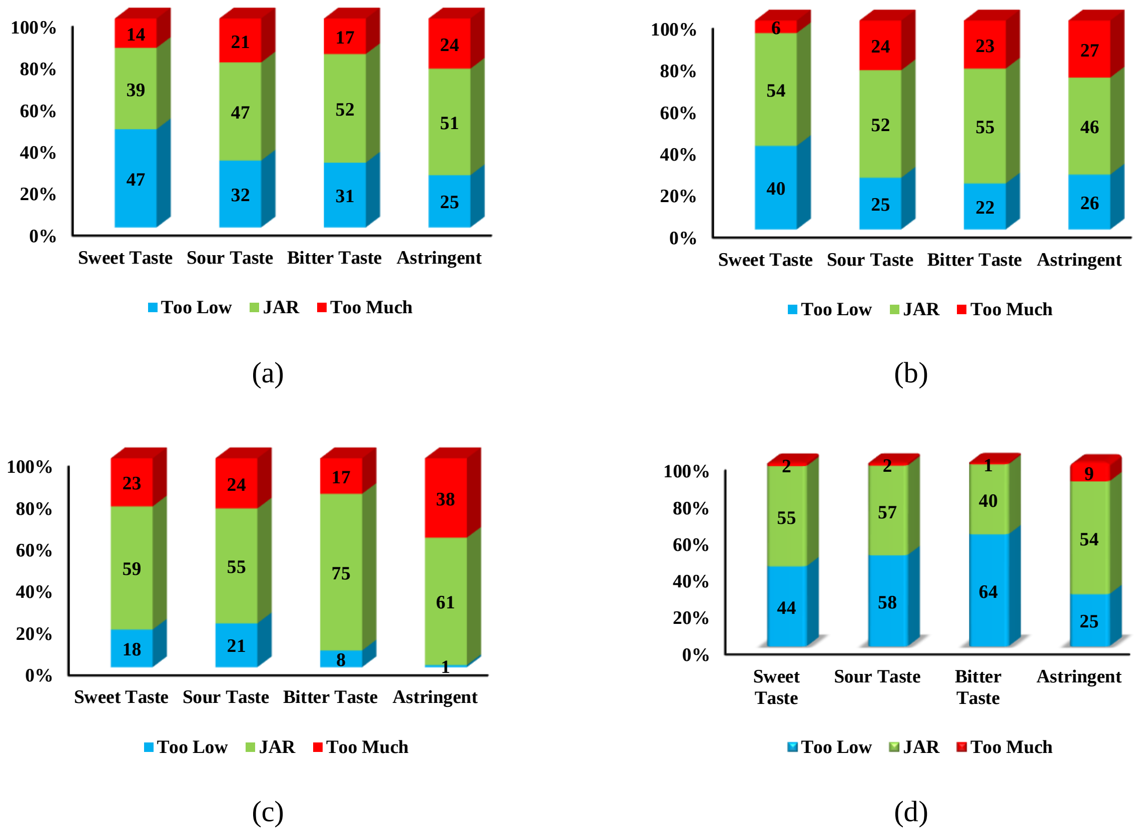


Figure 2. Percentage of panelists' ratings of sensory attributes of robusta coffee-leaf tea (a) Decoction filtered with V60, (b) French press - V60, (c) French press, and (d) V60.

Table 1. Effect of different brewing techniques on sensory attributes of coffee-leaf tea

Brewing Techniques	**Sensory attributes**	***P-value***
Decoction - V60	Sweet taste	0.000
	Sour taste	0.000
	Bitter taste	0.000
	Astringent mouthfeel	0.006
	Overall acceptability	0.000
French Press	Sweet taste	0.224
	Sour taste	0.003
	Bitter taste	0.000
	Astringent mouthfeel	0.000
	Overall acceptability	0.000
French Press - V60	Sweet taste	0.000
	Sour taste	0.000
	Bitter taste	0.156
	Astringent mouthfeel	0.000
	Overall acceptability	0.000
V60	Sweet taste	0.000
	Sour taste	0.156
	Bitter taste	0.686
	Astringent mouthfeel	0.000
	Overall acceptability	0.000

Sugars, glycols, alcohols, aldehydes, ketones, amides, esters, amino acids, sulfonic acids, halogen acids, and the inorganic compounds (i.e., lead and beryllium) combined to form a sweet flavor (Shivgankar et al., 2016). Coffee leaves contain 15 aldehyde group compounds, 6 alcohol group compounds, and 4 ketone group compounds. The acidic flavor detected in brewed coffee-leaf tea is a result of the acid content in coffee leaves, including carboxylic acid groups such as formic acid, acetic acid, oxalic acid, citric acid, lactic acid, malic acid, and quinic acid (Asiah et al., 2017; Fibrianto et al., 2020a). Alkaloids, saponins, caffeine, flavonoids, and polyphenols are present in coffee leaves (Yuwono et al., 2019), andsome phenolic compounds (i.e., caffeic acid, chlorogenic acid, ferulic acid, and synaptic acid) (Goulas and Manganaris, 2012; Fibrianto et al., 2020b). High temperature degrades chlorogenic acid into simple aliphatic acid compounds (i.e., acetic, citric, malic, and pyruvic acids), which impart an acidic taste to brewed coffee-leaf tea.

Bitterness is caused by phenol compounds, flavonoids, isoflavones, terpenes, and glucosinolates, which produce a bitter, pungent odor or astringent feeling. Elevated flavonoids and tannins concentrations in tea are responsible for its increased bitterness (Zhao et al., 2018; Fibrianto et al., 2020b). Higher temperatures to steep coffee-leaf tea could induces bitterness since it enables more extraction of antioxidant, caffeine, cathecin, and TPC levels (Liu and Tzen, 2022; Ye et al., 2022; López and Carrión, 2023). According to Blumberg et al. (2010), the acrid flavor of tea results from the degradation of chlorogenic and caffeic acids during the brewing process. The astringent sensation is a physical sensation in the buccal cavity induced by food or drink, causing a distinction in the flavor. The astringent sensation is essential in determining the sensory quality of beverages such as tea, coffee, juice, and wine is. Tannins and catechins play an important role in influencing the astringency sensation. Caffeine and flavonol glycosides also contribute to astringency (Zhao et al., 2018; Asiah et al., 2017).

Phytochemical characteristics of coffee-leaf tea

As shown in Table 2, the TPC of coffee-leaf tea brewed with the optimal brewing temperature and time was 11.31 mg GAE/g (the French press), 10.41 mg GAE/g (the French press - V60), 12.45 ± 2.37 mg GAE/g (the decoction – V60), and 5.56 mg GAE/g (the V60). The TPC can be affected by the brewing temperature and duration. Within the range tested, the higher the temperature and the longer brewing time tended to increase the TPC. An increase in the brewing time could lengthen the extraction, resulting in a higher TPC (Waterhouse, 2002). In addition, variations in brewing techniques may influence TPC produced. Temperature plays a significant role in the diffusion of water to tea particles and the solubilization of tea constituents in the leaf matrix, thus increasing the component solubility and, consequently, exterior diffusion (Yadav et al., 2018). According to previous research, the phenol content of robusta coffee-leaf tea prepared using the traditional tubruk method was 13.00 ± 1.08 mg GAE/100 g (Maxiselly et al., 2022) and 12.05 ± 0.08 mg GAE/g prepared with 75°C water for 5 minutes (Fibrianto et al., 2021a).

Phenolic compounds are the largest antioxidant component of plant-derived materials; therefore, TPC could influence antioxidant activity (Su et al., 2022). The relationship between TPC and antioxidant activity is directly proportional, where increasing TPC increases the antioxidant activity. The IC_{50} of French Press brewed coffee leaf tea is 6,858.34 ppm, French Press filtered V60 is 7,628.98 ppm, and V60 yields 10,350.54 ppm. The IC_{50} value indicates the concentration of a compound that inhibits DPPH radicals by 50%. A higher IC_{50} value reflects a lower antioxidant activity. Furthermore, antioxidant compounds in leaves can be altered, mainly when prolonged and high temperatures occur (Defri et al., 2022).

Caffeine compounds are also present in coffee-leaf tea. Numerous factors influence the amount of caffeine in tea and coffee, including growing region, plant variety, plant age, length of growing season, field conditions, soil nutrients, rainfall, insect pressure, and brewing method (Ratanamarno and Surbkar, 2017). Temperature and preparation time can affect the caffeine content of brewed coffee. The higher the temperature, as nearly as 100°C, the quicker the caffeine complex bond compounds may be broken and form leaching, resulting in a greater yield of caffeine (Mitraka et al., 2021; Yong et al., 2022).

Table 2. Effect of different brewing techniques on chemical characteristics of coffee leaf tea

Brewing Techniques	Optimum Temperature and Time (°C; minutes)	Total Phenolic Content (mg GAE/g)	IC50 (ppm)	Caffeine (mg/mL)	Total Dissolved Solids (°Brix)
Decoction - V60	95.6°C; 6.5	12.45 ± 2.37[a]	4596.95 ± 498.53[a]	0.188 ± 0.029[a]	0.77 ± 0.06[a]
French Press	96.2°C; 6.5	11.31 ± 1.57[a]	6858.34 ± 569.42[b]	0.106 ± 0.07[a]	0.67 ± 0.15[ab]
French Press - V60	90°C; 2	10.29 ± 1.75[ab]	7628.98 ± 348.11[b]	0.125 ± 0.07[a]	0.57 ± 0.06[ab]
V60	90°C; 2	5.56 ± 1.59[b]	10350.54 ± 308.93[c]	0.074 ± 0.04[a]	0.50 ± 0.00[b]

Notes: Different letters mean significant value from the Fisher comparison test (P <0.05). All responses were analyzed in duplicate form. ± is standard deviation from two measurement

Due to the disintegration of the compound bond, the quantity of caffeine collected increases proportionally with the length of time used. The fragmented caffeine compounds will become free caffeine compounds of a reduced size, allowing them to dissolve in the beverage and easily permeate through the cell wall. Using a too high temperature can also damage the caffeine in the material (Efthymiopoulos et al., 2018). In this study, the caffeine tended to be constant among brewing methods as the brewing temperature range was too narrow.

TDS was 0.77°Brix for the decoction -V60, 0.67°Brix for the French Press, 0.57°Brix for the French Press-V60, and 0.50°Brix for the V60, respectively. Temperature tends to affect extraction yield in term of TDS, as the decline temperature reduces the TDS level. As the temperature and duration of the brewing process were increased, the amount of TDS continued to rise. The decoction method tended to have higher concentration of TDS since it was done by using boiling water, which had constant temperature, followed by the pour-over and espresso method (Batali et al., 2020; Santanatoglia et al., 2023). On the other hand, the carbohydrate chain was quickly hydrolyzed into sugar compounds, which at higher temperatures and longer brewing times may increase the TDS values (Christina et al., 2022). Moreover, the extraction time incrementally affects the dissolved chemical content and linearly increases the TDS (McNutt, 2019). The finding confirmed that the decoction technique had the highest optimum brewing temperature (96.6°C) and the longest optimum brewing duration (6.5 minutes), compared to other brewing techniques.

Conclusions

The findings demonstrated that the optimum brewing temperature and duration varied for each brewing method: 96.2°C and 6.5 minutes (the French Press), 90°C and 2 minutes (the French Press – V60), 95.6°C and 6.5 minutes (the decoction – V60), and 90°C and 2 minutes (the V60). The JAR results confirmed that all treatments have an overall sensory acceptability well-within the JAR standard (P <0.05). Thus, it can be recommended that overall sensory acceptability from the RSM test should be validated by the JAR technique. Furthermore, combining brewing methods could improve the sensory overall acceptability of coffee-leaf tea.

Declarations

Conflict of interests The authors declare no competing interests.

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