

Effect of Extraction Time and Maltodextrin Concentration on the Development of Instant Robusta Coffee with Wine Flavor (*Coffea canephora*)

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Editor: Samuel Pereira de Carvalho

Received May 29, 2025 and approved March 11, 2026

ABSTRACT

Instant robusta coffee with wine flavor is an innovation designed to enhance the value of robusta coffee through fermentation and instant processing. This study examined the effects of extraction time (30, 35, and 40 s) and maltodextrin concentration (15, 20, and 25%(w/v)) on the quality of instant robusta coffee with wine flavor. The evaluated parameters included solubility, caffeine content, moisture and ash contents, and sensory discrimination, while chemical functional groups were analyzed using Fourier Transform Infrared Spectroscopy (FTIR). FTIR analysis was employed to investigate alterations in chemical bonding characteristics resulting from the drying treatment. The results showed that the instant coffee dissolved in 15.58 ± 4.56 to 18.80 ± 0.64 s in hot water and 97.95 ± 2.05 to 144.77 ± 1.53 s in cold water, complying with the Indonesian National Standard (SNI). Maltodextrin concentration had a significant effect on solubility and moisture content, whereas extraction time significantly influenced the caffeine content of instant robusta coffee. Caffeine content from 0.23 ± 0.01 to 0.56 ± 0.56 mg/g, moisture content from $2.38 \pm 0.08\%$ to $5.78 \pm 0.13\%$, and ash content ranged from $2.89 \pm 0.07\%$ to $3.08 \pm 0.09\%$. FTIR analysis revealed degradation of volatile compounds in the instant coffee, with no significant chemical interaction between maltodextrin and the major coffee components. The discrimination test revealed that the A2B2 treatment, which yielded the highest amount, exhibited no significant differences in taste, aroma, or color compared to the control product. Furthermore, the A2B2 sample met all physicochemical and sensory discrimination criteria, indicating its potential for the development of high-quality wine-flavored instant robusta coffee.

Key words: FTIR; sensory discrimination; wine-flavored instant Robusta coffee.

1 INTRODUCTION

Coffee is one of the main agricultural commodities in Indonesia's economy, playing a significant role in both exports and domestic industrial growth. According to data from Statistics Indonesia (BPS), coffee production in Indonesia reached 794.8 thousand tons in 2022, with South Sumatra being the largest coffee-producing province, contributing 24.99% of the national total (Statistics Indonesia, 2024). The three primary coffee varieties cultivated in Indonesia are robusta (*Coffea canephora*), arabica (*Coffea arabica*), and liberica (*Coffea liberica*), with robusta accounting for approximately 73% of the country's total coffee production (Narimawati et al., 2025). This indicates that robusta coffee is abundantly available in Indonesia and plays a significant role in the global coffee market.

Robusta coffee is well known for its strong adaptability to various environmental conditions and its high caffeine content, ranging from 1.6% to 3%, which is significantly higher than that of arabica coffee, which contains only 0.6% to 1.2% (Yashin et al., 2015). However, the high caffeine content in robusta contributes to a more bitter taste, making it less preferred by both international and local consumers compared to arabica. To enhance its appeal, various innovations have

been introduced, including modifications of the flavor profile through fermentation processes (Ferreira et al., 2023).

Fermentation is an essential post-harvest step that not only removes mucilage but also reduces caffeine content and improves coffee flavor quality (de Jesus Cassimiro et al., 2023). Research indicates that caffeine in Robusta coffee can decrease from 18.64 mg/g to 13.57 mg/g after 4 days of fermentation with *Rhizopus oryzae* (Purwoko et al., 2022). In conventional wet processing, fermentation occurs after depulping to allow microbial degradation of the mucilage (Elhalis et al., 2023). Meanwhile, wine coffee fermentation utilizes whole cherries that are fermented for an extended period, producing fruity and wine-like notes. Optimal fermentation, 72 hours for Arabica and 96 hours for Robusta, enhances acidity and produces a berry-like aroma, whereas poor control can lead to sour or alcoholic defects (Halagarda & Obrok, 2023). In this study, Robusta coffee was fermented at (specified duration and temperature) using the cherry fermentation method to develop fruity flavor complexity while preventing over-fermentation.

Despite its great potential, robusta coffee remains relatively unknown among consumers. Therefore, innovations are needed, such as producing wine coffee in a practical instant form. Instant coffee is a ready-to-serve product that requires only hot water for preparation. The production of instant

coffee involves extraction, drying, and packaging stages. The selection of an appropriate extraction method is crucial for maintaining coffee quality. For instance, the espresso method produces a highly concentrated coffee extract with a strong aroma in a short amount of time, typically within 25–30 s per brew (Hidayatulloh et al., 2023; Danutirta & Setiawati, 2017).

The drying stage is crucial in instant coffee production, as it influences the final product's flavor, color, and solubility. Among various methods, vacuum drying effectively preserves aroma by removing moisture at low temperatures under reduced pressure. In industrial practice, spray drying and freeze drying are the two most common techniques. Spray drying is efficient and economical but may cause slight aroma loss and darkening due to thermal degradation (Shofinita et al., 2024). Freeze drying, although more costly and energy-intensive, operates at subzero temperatures and yields superior flavor retention and product quality (Silva et al., 2022). Emerging technologies such as microwave-assisted, vacuum belt, and foam-mat drying aim to enhance energy efficiency while maintaining desirable sensory characteristics (Leobet et al., 2020).

Maltodextrin is widely used as a carrier and encapsulating agent in instant beverages such as coffee, tea, and fruit drinks. Derived from starch hydrolysis with a dextrose equivalent (DE) below 20, it provides low sweetness and high solubility (Shishir & Chen, 2017). Its addition improves drying efficiency, enhances powder stability, reduces stickiness, and protects volatile flavor compounds during drying (Carneiro et al., 2013). Compared to carriers like gum arabic or inulin, maltodextrin is preferred for its neutral taste, low hygroscopicity, cost-effectiveness, and excellent solubility (Sukri et al., 2021). Moreover, its film-forming ability encapsulates aroma compounds and minimizes oxidation, maintaining product quality. When used at optimal levels, maltodextrin has minimal effect on coffee taste, though excessive amounts may slightly weaken flavor intensity (Jaya & Das, 2004).

This study aims to explore the effects of extraction time and maltodextrin concentration on the quality of instant robusta coffee with wine flavor. The findings are expected to contribute significantly to product innovation in the coffee sector and support the development of the coffee industry in Indonesia.

2 MATERIAL AND METHODS

2.1 Equipment and Materials

Various laboratory equipment was utilized to support the experimental procedures. These included glassware, an autoclave (All-American 25X, USA), a blender (Philips HR-2116, Netherlands), a desiccator, a hot plate (Maspion S-300,

Indonesia), an espresso machine (Delonghi “ECP”, China), filter paper (Whatman No. 42), HDPE plastic, baking trays, an analytical balance (Kenko KK-Lab, Japan), a vacuum oven (Vacuum Drying Oven Digital Maskot VOV 50 L, China), clamps, micropipettes (Dragon Lab YE5K660650, China), an 80-mesh sieve, spoons, spatulas, a spectrophotometer (A&E Lab LK044, USA), thermometers, tissues, a vortex mixer (Digisystem VM-1000, Taiwan), a coffee grinder (Maksido, Taiwan), evaporating dishes, and a muffle furnace.

A Delonghi “ECP” series semi-automatic espresso machine (Delonghi, China) was used in this study. The machine operates with a thermoblock heating system that heats water to 90–95 °C and delivers a pump pressure of up to 15 bar for efficient extraction. It is equipped with a 1.1 L water reservoir, an electric heating element, and a steam wand powered by the same system. Its stable temperature control and compact design make it suitable for consistent laboratory-scale brewing experiments.

The materials used in this study included distilled water, deionized water (Aquadest), Robusta wine coffee obtained from Kopi JagadRaye, Pagar Alam, South Sumatra, ethanol, calcium carbonate (CaCO₃), and maltodextrin.

2.2 Experimental Design

This study employed a Completely Randomized Design (CRD) in a factorial arrangement with two treatment factors: factor A (extraction time) and factor B (maltodextrin concentration), with each treatment combination replicated three times to ensure data reliability. Factor A consisted of three levels: A1 (30 s), A2 (35 s), and A3 (40 s), while factor B included B1 (15%w/v maltodextrin), B2 (20%w/v maltodextrin), and B3 (25%w/v maltodextrin). The parameters evaluated included solubility (SNI 2983-2014), caffeine, moisture, ash content (AOAC, 2005), discrimination testing (Miot et al., 2024), and Infrared spectral analysis using Fourier Transform Infrared Spectroscopy (FTIR) (Nyoro et al., 2018). was performed on three samples, namely wine-processed Robusta coffee, instant wine-processed Robusta coffee, and maltodextrin. A sensory discrimination test was conducted to assess the organoleptic properties of the product, including color, taste, and aroma.

2.3 Data Analysis

The collected data were analyzed using Analysis of Variance (ANOVA) to evaluate significant differences among treatments. When significant differences were observed, further analysis was conducted using the Honestly Significant Difference (HSD) test at a 5% significance level. All statistical analyses were performed using the Statistical Analysis System (SAS) software version 9.0 to ensure accuracy and reliability. Sensory characterization was analyzed using a discrimination test based on the critical number (minimum) of correct

responses at a 5% significance level. The sensory evaluation was conducted by 20 untrained panelists who were regular coffee consumers familiar with coffee beverages. Before testing, they were given a brief orientation on the evaluation procedure and attributes to be assessed.

2.4 Experimental Procedure

2.4.1 The production of instant robusta coffee with wine flavor

Fresh red-ripe Robusta coffee cherries were used as raw material. To ensure uniform ripeness, random samples were measured for glucose content using a refractometer, with a minimum value of 10 °Brix applied as the selection criterion. The cherries were then subjected to flotation sorting in water with a pH of 6.0–8.5 and total dissolved solids (TDS) of approximately 300 mg/L to remove defective or immature fruits that floated on the surface. Sorting was conducted in three consecutive stages: (1) removal of dust and debris, (2) separation of defective fruits, and (3) selection of high-quality cherries for further processing.

After sorting, the cherries were drained using a large plastic sieve for approximately 10 minutes to remove surface moisture and reduce the risk of microbial contamination. The selected cherries were subsequently transferred into a high-density polyethylene (HDPE) fermentation tank, sealed under vacuum conditions, and oxygen levels were reduced to zero using an outlock fermentor system. Fermentation (with intermittent drying) was carried out for 28 days. At 7-day intervals, the cherries were intermittently sun-dried for 3–4 hours in the morning to control moisture content and microbial activity.

During fermentation, the coffee cherries gradually changed in color from brown to dark brown, developed a more intense wine-like aroma, exhibited a firmer texture, and experienced a reduction in moisture content to approximately 10–12%. Following fermentation, the dried cherries were hulled to obtain green beans, which were then roasted using a hot-air coffee roaster at temperatures of 180–200 °C for 15–20 minutes until a medium to dark roast level was achieved.

2.4.2 Instant robusta coffee with wine flavor production procedure

The roasted Robusta coffee beans were ground using a burr grinder to obtain a fine powder, which was then sieved through an 80 mesh sieve to ensure uniform particle size distribution. A total of 12 g of the sieved coffee powder was accurately weighed and placed into the portafilter of an espresso machine (Delonghi “ECP” series, China). Extraction was conducted under a pressure of 15 bar at a brewing temperature of 90–95 °C, following three different

extraction durations according to the treatment levels: 30 s (A1), 35 s (A2), and 40 s (A3). The extracted coffee beverage was collected immediately after brewing and filtered to remove fine residues. The obtained coffee extract was subsequently heated on a digital hot plate at 50 °C for 300 s to maintain solubility and facilitate uniform dispersion of additives. During this step, maltodextrin was added according to the respective treatment formulation, serving as a carrier and drying aid to improve powder formation and stability. The resulting mixture was stirred continuously to achieve a homogeneous solution.

The prepared coffee maltodextrin mixture was spread evenly onto a tray lined with HDPE plastic, maintaining a uniform layer thickness of 1–2 mm to ensure consistent drying. This drying procedure, including layer thickness, temperature, and drying time, was determined based on preliminary optimization experiments conducted by the authors to achieve optimal drying efficiency while preserving flavor characteristics. The samples were dried in a vacuum oven at 60 °C for 8 h under controlled pressure conditions to remove moisture while minimizing flavor degradation. After drying, the solidified coffee sheets were gently scraped off, ground using a laboratory blender, and passed through an 80-mesh sieve to obtain a fine and uniform instant coffee powder. The final instant Robusta wine coffee product was stored in airtight containers at room temperature and subsequently analyzed for physicochemical, sensory, and morphological characteristics according to the predetermined parameters.

3 RESULTS

The dissolution time of instant wine-processed Robusta coffee ranged from 15.58 ± 4.56 to 18.80 ± 0.64 s in hot water. In cold water, dissolution required longer times, ranging from 97.95 ± 2.05 to 144.77 ± 1.53 s. The average solubility rates of instant wine-processed Robusta coffee in both hot and cold water are presented in Figure 1.

Based on the results of the variance analysis, the treatments involving extraction time, maltodextrin concentration, and their interaction did not significantly affect the dissolution time of instant wine-processed Robusta coffee in hot water. However, the concentration of maltodextrin was found to affect the dissolution time of coffee in cold water significantly. According to the results of the Least Significant Difference (LSD) test at the 5% significance level, increasing the maltodextrin concentration to 15%, 20%, and 25% resulted in significantly different dissolution times, with values of 143.15 ± 1.46^a , 136.05 ± 1.19^b , and 102.42 ± 2.32^c s, respectively. Among these treatments, the longest dissolution time was observed at a maltodextrin concentration of 15%, whereas the fastest dissolution occurred at 25%.

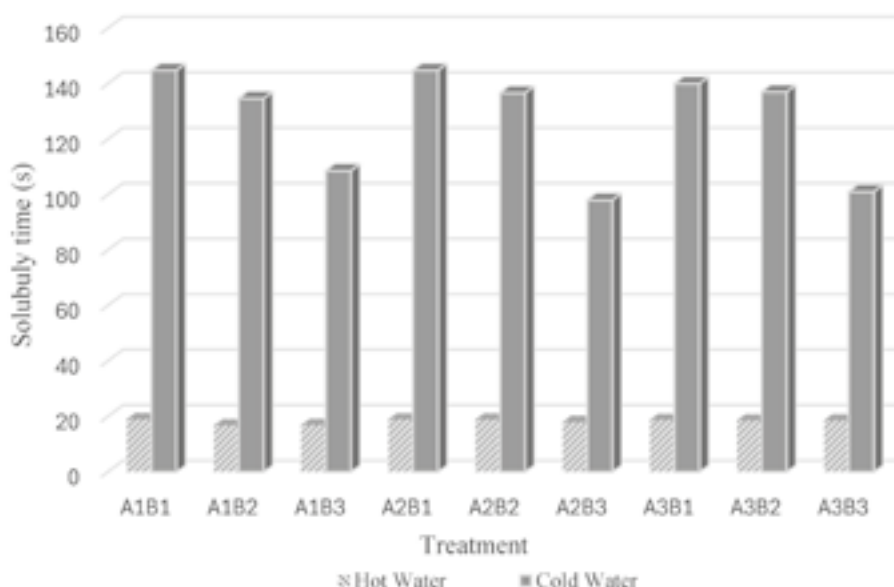


Figure 1: Average dissolution time of instant wine-processed Robusta coffee powder in hot and cold water. Nine treatment combinations were applied, consisting of three extraction times (A1 = 30 s, A2 = 35 s, A3 = 40 s) and three maltodextrin concentrations (B1 = 15%, B2 = 20%, B3 = 25%), resulting in treatments A1B1–A3B3.

The results of the study showed that the caffeine content in instant wine-processed Robusta coffee ranged from 0.23 ± 0.01 to 0.56 ± 0.56 mg/g. The detailed results of caffeine content analysis in the instant wine-processed Robusta coffee are presented in Figure 2. The results of the Least Significant Difference (LSD) test at the 5% significance level revealed that increasing the extraction time to 30, 35, and 40 s resulted in significantly different caffeine contents, with values of 0.27 ± 0.03^a , 0.43 ± 0.03^b , and 0.52 ± 0.05^c mg/g, respectively.

Based on the study's results, the moisture content of instant wine-processed Robusta coffee ranged from $2.38 \pm 0.08\%$ to $5.78 \pm 0.13\%$. The highest moisture content was observed in treatment A1B1, which involved a 30 s extraction and the addition of 15% maltodextrin, at $5.78 \pm 0.13\%$. In contrast, the lowest moisture content was recorded in treatment A2B3, which involved a 40 s extraction and the addition of 25% maltodextrin, at $2.38 \pm 0.08\%$. Based on the results of the analysis of variance, extraction time, maltodextrin concentration, and their interaction had a significant effect on the moisture content of instant wine-processed Robusta coffee. The results of the post hoc Honestly Significant Difference (HSD) test at a 5% significance level are shown in Table 1.

The analysis in Table 1 also highlights significant differences in moisture content based on the interaction between maltodextrin concentration and extraction time. These differences are indicated by the statistical lettering that differentiates among treatment groups. For example, the moisture content in treatment A1B1 ($5.78 \pm 0.13\%$) significantly differed from that in A3B2 ($3.57 \pm 0.17\%$), as demonstrated by different superscript letters (a, b, c, d, e), which denote statistically significant differences.

The average ash content of instant wine-processed Robusta coffee obtained in this study ranged from $2.89 \pm 0.07\%$ to $3.08 \pm 0.09\%$. Detailed data on the ash content for each treatment are presented in Figure 3. Analysis of variance showed that extraction time, maltodextrin concentration, and their interaction did not significantly affect the moisture content of instant wine-processed Robusta coffee ($p > 0.05$).

Sample A2B2 (extraction for 35 s with the addition of 20% maltodextrin) was selected as the best treatment based on its solubility, moisture content, and ash content, all of which met the requirements of the Indonesian National Standard (SNI) 2983-2014. This sample was subsequently subjected to sensory evaluation by 20 panelists. The discrimination test results showed that sample A2B2 had total scores of 10 for color, 4 for taste, and 14 for aroma differentiation. In this evaluation, a score of 0 represented no detectable difference between samples, while a score of 1 indicated that a difference was perceived by the panelist, as shown in Table 2.

This study examined the comparative spectra obtained from Fourier Transform Infrared Spectroscopy (FTIR) analysis between instant wine-processed Robusta coffee and fermented wine Robusta coffee powder. The sample from treatment A2B2 extraction for 35 s with the addition of 20% maltodextrin was selected for FTIR analysis based on its solubility, ash content, moisture content, and discrimination test results, all of which complied with the requirements of the Indonesian National Standard (SNI) 2983-2014. Additionally, this sample exhibited similarities in color, taste, and aroma with the control product, as confirmed through sensory evaluation using a discrimination test on these three organoleptic attributes. Figure 4 presents the FTIR spectra comparison between non-instant Robusta wine coffee,

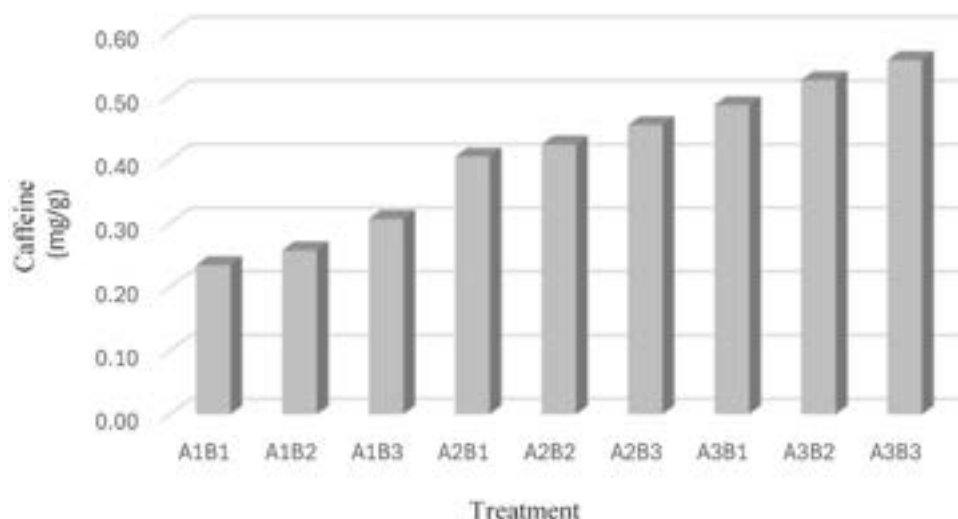


Figure 2: Average caffeine content of instant wine-processed Robusta coffee powder.

instant Robusta wine coffee, and maltodextrin. The spectra of both instant and non-instant Robusta wine coffee showed similar major absorption bands, indicating that their main functional groups remained consistent after the drying process. Characteristic peaks corresponding to O–H stretching (around 3300–3400 cm^{-1}), C–H stretching of aliphatic compounds (approximately 2920 cm^{-1}), C=O stretching of carbonyl groups (near 1650–1700 cm^{-1}), and C–O stretching of polysaccharides or phenolic compounds (around 1000–1100 cm^{-1}) were observed in both samples.

Table 1: Results of the 5% LSD test (HSD) on the effect of extraction time, maltodextrin concentration, and their interaction on the moisture content of instant wine-processed Robusta coffee.

Treatment	Water Content (%)
A1 (30 s)	4.01 ± 0.07 ^a
A2 (35 s)	3.90 ± 0.03 ^b
A3 (40 s)	3.88 ± 0.09 ^b
B1 (15% maltodextrin, b/v)	5.56 ± 0.10 ^a
B2 (20% maltodextrin, b/v)	3.64 ± 0.07 ^b
B3 (25% maltodextrin, b/v)	2.56 ± 0.04 ^c
A1B1 (30 s; 15% maltodextrin)	5.78 ± 0.13 ^a
A2B1 (35 s; 15% maltodextrin)	5.59 ± 0.03 ^a
A3B1 (40 s; 15% maltodextrin)	5.34 ± 0.14 ^b
A2B2 (35 s; 20% maltodextrin)	3.68 ± 0.01 ^c
A1B2 (30 s; 20% maltodextrin)	3.66 ± 0.05 ^c
A3B2 (40 s; 20% maltodextrin)	3.57 ± 0.17 ^c
A3B3 (40 s; 25% maltodextrin)	2.72 ± 0.02 ^d
A1B3 (30 s; 25% maltodextrin)	2.59 ± 0.05 ^{de}
A2B3 (35 s; 25% maltodextrin)	2.38 ± 0.08 ^c

Description: Values followed by different letters in the same column are significantly different at the 5% level according to the Honestly Significant Difference (HSD) test ($P < 0.05$).

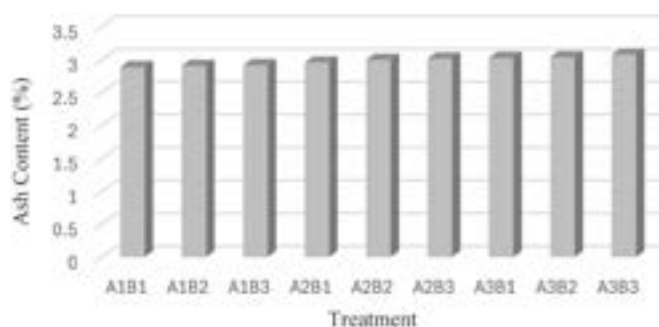


Figure 3: Illustrates the average ash content of instant wine-processed Robusta coffee powder.

4 DISCUSSION

These findings indicate that higher maltodextrin concentrations accelerate the dissolution of instant coffee. This condition is likely related to the hygroscopic properties of maltodextrin, which enhance water absorption in the coffee powder and promote the formation of an amorphous matrix that dissolves more readily. Maltodextrin is widely used as a wall material in spray- and freeze-drying because it produces fewer adhesive particles that dissolve more easily in water by creating a larger contact surface with the liquid. It can also lead to smaller, more distinct powder particles, enhancing rehydration and solubility properties of dried products (Mazar et al., 2025). According to Sutrisno et al. (2021) and Hariyadi et al. (2024), higher concentrations of maltodextrin can improve the solubility of instant coffee. This is due to the presence of hydroxyl groups in maltodextrin with a dextrose equivalent (DE) value of 20, which have a high affinity for water molecules, facilitating a faster dissolution process. Furthermore, the application of heat weakens intermolecular bonds in water, contributing to more efficient dissolution. Zakiyah and Budiandari (2023)

also noted that, chemically, maltodextrin contains a high number of hydroxyl groups, which can form bonds with water molecules, and has characteristics that make it readily soluble and easily dispersed in aqueous media.

Table 2: Summary of discrimination test results for color, taste, and aroma of instant wine-processed Robusta coffee compared to the control sample (non-instant Robusta wine coffee)

Panelist	Category		
	Color	Taste	Aroma
P1	0	0	0
P2	1	0	1
P3	0	0	1
P4	1	0	1
P5	0	1	0
P6	1	1	1
P7	0	0	1
P8	1	0	1
P9	0	0	0
P10	1	0	1
P11	1	1	1
P12	1	1	0
P13	0	0	1
P14	0	0	1
P15	1	0	0
P16	0	0	1
P17	1	0	0
P18	0	0	1
P19	1	0	1
P20	0	0	1
Total	10	4	14
Interpretation	*	*	*

Note: A score greater than (>) 15 indicates a significant difference (***) from the control sample, whereas a score less than (<) 15 indicates no significant difference/similarity (*) to the control sample.

Based on SNI 2983:2014 (BSN, 2014), instant coffee must have a maximum dissolution time of 30 s in hot water. The results of this study show that the average dissolution time ranged from 4.56 to 18.80±0.64 s, indicating that all treatments met the solubility quality standards for instant coffee in hot water as stipulated by the SNI. Furthermore, the same regulation requires a maximum dissolution time of 180 s in cold water. In this study, the average dissolution time ranged from 97.95±2.05 to 144.77±1.53 s, demonstrating that all treatments also complied with the quality requirements for instant coffee solubility in cold water as defined in the SNI.

These findings indicate that longer extraction durations are directly proportional to higher levels of dissolved caffeine in the instant coffee. This increase is presumably due to the longer contact time between the coffee powder and the solvent (water), which facilitates greater caffeine release from the coffee matrix into the solution. A study on caffeine extraction found that increasing extraction time significantly raised the amount of caffeine extracted, as longer durations improved contact between solid particles and solvent, facilitating mass transfer of caffeine into the extract (Hasan & Yoqoobi, 2024).

In hot brewing, the duration of contact between ground coffee and water at high temperatures (90–100°C) plays a critical role in determining the efficiency of caffeine extraction. The elevated temperature promotes faster solubilization and diffusion of caffeine and other hydrophilic compounds, leading to a rapid increase in concentration during the initial phase of extraction. As the extraction process approaches equilibrium, the rate of caffeine extraction declines, resulting in only marginal increases in caffeine concentration with further increases in brewing time. This behavior has been observed in kinetic studies of coffee solubles, where initial rapid extraction phases are followed by markedly slower mass transfer as the system nears equilibrium (Strieder et al., 2024). Quantitative analyses indicate that hot-brewed coffee prepared at 93–98°C for approximately five minutes generally yields caffeine levels around 23.96 µg/mL, suggesting that most caffeine is extracted within the early minutes of brewing (Rahmawati & Asrori, 2024). Studies employing HPLC techniques have further confirmed that caffeine extraction under hot conditions reaches near-equilibrium rapidly, with negligible increases beyond 5–10 minutes (Mystkowska et al., 2024). Prolonged brewing primarily enhances the release of less soluble phenolic compounds and late-extracting bitter constituents rather than caffeine itself (Jeszka-Skowron et al., 2015). Therefore, optimizing the interrelated factors of time, temperature, and grind size is more effective for maximizing caffeine yield while preventing undesirable over-extraction than merely extending the extraction duration.

The caffeine content found in this study was lower than that reported by Fitri and Pratiwi (2023), who documented caffeine levels in instant coffee ranging from 3.1 to 3.2 mg/g, and in Robusta coffee beans fermented with *Leuconostoc mesenteroides* and *Lactobacillus plantarum* for 24 hours, which contained 2.3 mg/g of caffeine. On the other hand, the present results were higher than those reported by Handayani (2024), who found that Robusta coffee beans fermented with *Lactobacillus plantarum* for 24 hours contained only 0.1183 mg/g of caffeine.

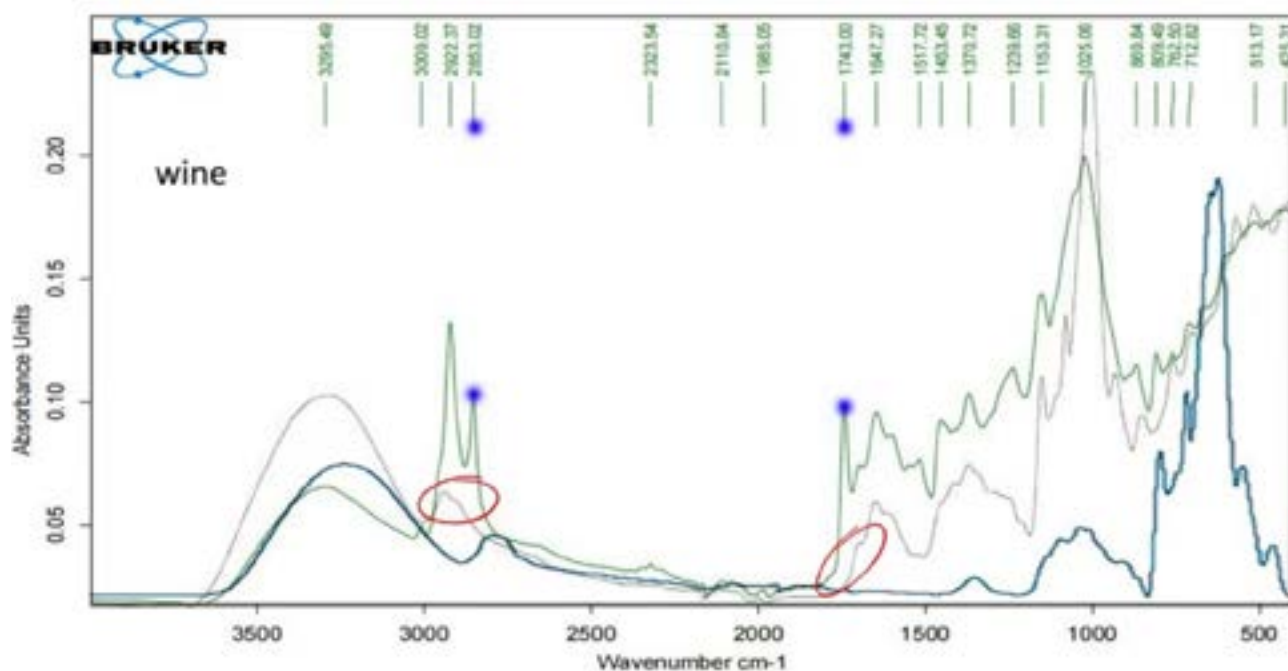


Figure 4: Presents the FTIR spectral graph of three samples: wine-processed Robusta coffee, instant wine-processed Robusta coffee, and maltodextrin. The spectra are used to compare the functional group profiles of each material based on their infrared spectral characteristics.

Based on the results presented in Table 1, it was found that an increase in extraction time was related to the moisture content of the resulting instant coffee. Specifically, longer extraction durations tended to reduce moisture levels. This reduction is presumably due to the greater amount of soluble compounds extracted from the coffee matrix. At the same time, the water content in the solution may have been lost through evaporation or absorbed during the process. Additionally, prolonged extraction times may lead to higher temperatures or extended heat exposure, which accelerates the evaporation rate and further contributes to the decrease in moisture content in the final instant coffee product.

Anggraini et al. (2025) reported that variations in extraction time using the ultrasound-assisted extraction method significantly influenced the moisture content of Robusta coffee extract. Similarly, Mursalin et al. (2019) found that longer heating durations during the production of Liberica instant coffee from Tungkal Jambi were associated with reduced moisture content in the final product.

As presented in Table 1, A clear relationship was observed between maltodextrin concentration and the moisture content of instant coffee, where increasing the concentration of maltodextrin resulted in a decrease in moisture content. This phenomenon may be attributed to the hygroscopic properties of maltodextrin, which allow it to bind water molecules during the drying process, thereby facilitating the release of moisture from the solution matrix. In addition, higher maltodextrin

concentrations contribute to an increase in total dissolved solids, which accelerates the drying process and effectively lowers the moisture content in the final product.

Sharma et al. (2023) noted that increasing the maltodextrin concentration during spray drying reduces the moisture content of the final product. This reduction is linked to the increase in total solids, which enhances drying efficiency and decreases the amount of residual water. Similarly, Yunus (2011) reported that increasing maltodextrin concentrations from 10% to 30% significantly reduced the moisture content of gac aril powder, due to the higher solid content reducing the amount of water available for evaporation during drying.

Overall, the findings of this study demonstrate that higher concentrations of maltodextrin in the solution result in lower moisture content in the final product. This moisture reduction is associated with an increase in dissolved solids, which accelerates drying and minimizes the water content in the end product. The higher the maltodextrin concentration, the more significant its contribution to moisture reduction in the instant coffee product. In addition to its hygroscopic properties that aid in water binding during drying, the elevated levels of dissolved solids also facilitate this process, leading to lower final moisture levels. While extraction time has an effect, the impact of increased maltodextrin concentration appears to be more dominant in determining the final moisture content of the product.

Based on the results of the analysis of variance (ANOVA), extraction time, maltodextrin concentration, and their interaction had no significant effect ($p > 0.05$) on the ash content of instant wine-processed Robusta coffee. This finding is consistent with the study by Pigozzi *et al.* (2018), which reported that the ash content in coffee samples was below the maximum limit established by the regulations of the State of São Paulo, Brazil, i.e., less than 5%. The ash content of instant coffee in the present study was lower than that reported by Wahyuni *et al.* (2020), who found ash contents in Robusta coffee ranging from 4.66% to 5.10%. It was also lower than the threshold set by the Indonesian National Standard (SNI 01-2983-1992), which specifies that the ash content of coffee should be between 7% and 14%. However, the ash content observed in this study was higher than the findings of Agustini and Yusya (2020), who reported ash contents ranging from 1.19% to 1.48% in Robusta coffee powder packaged in aluminum-laminated polyethylene (ALP) and polyethylene terephthalate (PET).

Based on the analysis using the critical number at a 5% significance level, all discrimination test scores for color, taste, and aroma attributes were below the threshold value of 15 (Table 2). This indicates that sample A2B2 does not exhibit significant sensory differences compared to the control sample (commercial coffee). The formulation with a 35s extraction time and the addition of 20% maltodextrin did not result in perceptible changes in the main sensory attributes of the product. These findings suggest that the processing and formulation modifications applied to sample A2B2 are still acceptable from a sensory standpoint, as they did not affect panelists' perception of the color, taste, or aroma of the instant coffee.

Several studies have demonstrated that the addition of maltodextrin in instant coffee formulations positively affects the physicochemical and sensory characteristics of the product. Hariyadi (2025) reported that the use of 15% maltodextrin resulted in instant coffee with a moisture content of 3.94%, ash content of 6.66%, solubility of 98.22%, and good acceptance in sensory evaluation. Meanwhile, Mursalin *et al.* (2019) stated that variations in heating schedules during the co-crystallization process did not significantly affect the ash content of instant coffee, with values ranging from 6.12% to 6.16%. Furthermore, Novitasari *et al.* (2021) found that filler types such as maltodextrin and dextrin did not influence physical properties such as pH, solubility, and brightness, but did affect the chemical and sensory characteristics of the product. These findings suggest that the appropriate use of maltodextrin can help maintain the physicochemical quality of instant coffee without reducing consumer sensory acceptance.

The FTIR spectrum analysis presented in Figure 4 reveals the absence of two absorption peaks in sample A2B2 (extraction for 35 s with the addition of 20% maltodextrin). The first peak, observed at a frequency of 2853.02 cm^{-1} , is associated with the C-H stretching vibrations of alkane

functional groups. Although this peak was not distinctly observed, it is suspected to have merged with the peak at 2922.37 cm^{-1} , which also corresponds to alkane compounds. According to Obeidat *et al.* (2018), absorption peaks within the frequency range of $2850\text{--}2920\text{ cm}^{-1}$ are attributed to the symmetric and asymmetric stretching vibrations of C-H bonds in CH_2 groups, which are major components of lipid structures in coffee beans.

The second undetected absorption peak appears at 1743.00 cm^{-1} , indicating the presence of a carbonyl (C=O) group in ester compounds. These ester compounds play a crucial role in the formation of coffee aroma, as they often contribute fruity, sweet, and complex notes that are key characteristics of the coffee flavor profile (Cao *et al.*, 2023). Aung Moon *et al.* (2024) reported that the absorption peak at approximately 1745 cm^{-1} corresponds to the stretching vibration of the carbonyl (C=O) group in esters, which significantly contributes to coffee aroma development. This peak reflects the presence of ester groups in triglycerides, which are major components of coffee oil. Variations in the intensity of this peak during storage can provide insight into quality changes and the shelf life of Arabica coffee beans.

Additionally, the FTIR spectrum of maltodextrin displayed in Figure 4 does not show influence on the spectrum of the instant wine-processed Robusta coffee, suggesting that maltodextrin does not directly interact with the major coffee components during the production process. This implies that although maltodextrin is used as an additive to enhance solubility, its impact on the spectral profile of instant coffee is relatively minimal and does not alter the aroma and flavor characteristics of the final product. The incorporation of 15% maltodextrin in instant coffee produced by spray drying did not cause adverse or dominant alterations in aroma, which remained moderately intense and was well accepted by the panelists (Hariyadi, 2025).

5 CONCLUSIONS

This study concludes that extraction time and maltodextrin concentration significantly dictate the physicochemical quality of instant wine Robusta coffee. Maltodextrin improves solubility without chemically altering the inherent flavor profile, whereas extraction time primarily governs caffeine yield. Ultimately, combining an intermediate extraction duration with an optimal maltodextrin concentration produces a high-quality, stable instant coffee, demonstrating its strong viability as a value-added product.

6 AUTHOR CONTRIBUTIONS

Conceptual Idea: Santoso, B.; Methodology Design: Rahmawati, L; Syaiful, F.; Syafutri, M.I.; Data Collection:

Kinanti, A.P.; Lidiyasari, E.; Data Analysis and Interpretation: Defira, C.; Pratiwi, C; Writing and Editing: Santoso, B.; Icschan, O.A.N.

7 DATA AVAILABILITY STATEMENT

Data Available upon Request to Authors.

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