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Enhancing properties of coffee instant powder by microencapsulation using the freeze-drying method: comparison between wet- and dry-blending

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Abstract

Instant coffee production is generally obtained through a drying process by freeze-drying, which utilizes low temperatures, making it suitable for preserving volatile compounds. This study aimed to determine the effect of freeze-dryer conditions and the impact of wet and dry blending methods on the properties of instant coffee. The experimental variations in this study include drying time (48 and 72 h), coffee extract concentration (0.5 g/mL and 0.25 g/mL), and maltodextrin ratio (without maltodextrin, 1:10, and 1:15). The best variations of instant coffee in terms of moisture content, solubility, hygroscopicity index, light index (L), and CGA levels were the coffee powder with drying time of 48 h and extract concentration of 0.25 g/mL, with values ranging from 2.8-4.1%, 92-93%, 7-16%, 25-31, and 855-1408 ppm, respectively. Wet blending method (1:10 maltodextrin) was found to give the highest preference level, with an average preference level of 5.06 from 6.

1. Introduction

The International Coffee Organization (ICO) has noted that global coffee consumption is projected to reach 166 million bags in 2021 (60-kg bags) (International Coffee Organization, 2021). ICO has identified America and Europe as having the highest coffee consumption worldwide. Coffee serves as a significant plantation product that contributes to a country's foreign exchange earnings. As coffee productivity increases annually, the consumption of coffee is expected to continue growing. However, instant coffee lacks the authentic taste of freshly ground coffee because many volatile compounds are lost during processing. Therefore, proper processing techniques are necessary to create instant coffee with a good taste and aroma. The drying process for instant coffee can be carried out using various methods, such as spray drying, freeze drying, or spray-freeze drying. The drying conditions, including temperature, pressure, and drying time, play a crucial role in determining the characteristics of the coffee. When using a spray dryer, the high temperature can result in the loss of many aroma volatiles and a less intense coffee flavour (Shofinita *et al*., 2016).

Additionally, a significant amount of coffee powder extract may adhere to the walls of the heating device during this drying process, reducing the yield of instant coffee (Shofinita *et al*., 2023). The freeze concentrated coffee obtained better aroma retention at 86% than the thermally concentrated, with only 39% aroma retention maintained (Shofinita *et al*., 2023). Therefore, alternative drying methods must be explored to achieve better results, characteristics, and quality of instant coffee.

The drying method that can be used in instant coffee production is freeze-drying. Freeze drying involves freezing the material and removing most of the water through sublimation. The freeze-drying method is particularly suitable for thermolabile compounds, ensuring that the volatile compounds in instant coffee remain stable and are not lost during processing (Shofinita *et al*., 2023). However, determining the optimal operating conditions, including pressure, temperature, and drying time in the freeze dryer, is crucial for producing instant coffee with a strong taste and the desired characteristics. Because of unsaturated

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bonds in the instant coffee structure, polyphenols are vulnerable to oxidants, light, and heat (Zheng *et al*., 2011).

Phenolic compounds are usually encapsulated for the following reasons : (i) increase stability during instant coffee storage; (ii) improve color; (iii) masking of astringency; (iv) suitability for use as an additive functional food (Fang and Bhandari, 2010). Microencapsulation techniques can be applied using maltodextrin to preserve the aroma compounds in coffee grounds. Microencapsulation involves packaging active substances or bioactive ingredients in a protective layer to shield them from external factors that could damage or reduce their stability and effectiveness (Calderón-Oliver and Ponce-Alquicira, 2022). Maltodextrin is used as the packaging material because it forms a stable protective layer and safeguards the active substances inside. It is highly soluble in water, allowing for the formation of a stable and homogeneous solution during the microencapsulation process (Gupta *et al*., 2015). According to research conducted by Utomo (2013) on mulberry powder, the addition of maltodextrin can reduce the water content of the powder. Therefore, adding a significant amount of maltodextrin can reduce the product's water content (Shofinita *et al*., 2020).

So far, instant coffee products produced through freeze-drying are generally made using the dry blend method. The dry blend method involves adding additives or bulking agents to coffee grounds, such as maltodextrin in dry form (Shofinita *et al.,* 2024a). On the other hand, the volatile compounds in instant coffee powder are expected to be protected by the wet blending method, where maltodextrin is first dissolved in hot water, mixed into the coffee extract, and then dried (Shofinita *et al.,* 2021). Various studies have researched microencapsulation. Utomo indicated that microencapsulation has the potential to produce mulberry powder with higher yields compared to the usual freeze-drying method (Utomo, 2013). This study aimed to determine the effect of operating conditions on the microencapsulation by a freeze dryer and the effect of wet and dry blending methods on the properties and sensory characteristics of the instant coffee product. This research is expected to yield encapsulated and well-preserved instant coffee powder that consumers can receive well.

2. Materials and methods

2.1 Materials

Materials used in this study include Maltodextrin DE20 (Lihua Starch Co., LTD), Ethanol (Sigma Aldrich), Chlorogenic acid (Merck), Methanol (Sigma Aldrich), Arabica Coffee Roasted from Aceh Gayo (Votrro Coffee).

2.2 Extraction of coffee powder

Ground coffee was extracted with a hot water solvent at around 90°C for 10 min (Clarke and Vitzthum, 2001). Higher temperatures could cause the decomposition of coffee content and a decrease in the taste of instant coffee. Coffee extract concentration was made into two variations that are 0.5 g/mL (coffee: water = 1:2) and 0.25 g/mL (coffee: water = 1:4).

2.3 Microencapsulation of coffee extract (wet blend method)

The addition of maltodextrin to the coffee extract for the wet blend method was carried out after extracting the coffee grounds with hot water. The maltodextrin solution was made by mixing maltodextrin with hot water (90°C) and adding it to the coffee extract at varied maltodextrin ratios (1:10 and 1:15), and then homogenized. The prepared solution was freeze-dried using an Alpha 1-2 LD Plus freeze dryer (Martin Christ Gefriertrocknungsanlagen GmbH, Germany). The operation was done in a vacuum (0.08-0.9 mbar) for varied drying times (48 and 72 h). The powder was then kept in the fridge for further analysis.

2.4 Dry blend instant coffee production

The coffee extract was produced with a hot water solvent at 90°C for 10 min (Clarke and Vitzthum, 2001), and then freeze-dried (without the addition of maltodextrin) using an Alpha 1-2 LD Plus freeze dryer (Martin Christ Gefriertrocknungsanlagen GmbH, Germany) in a vacuum (0.08-0.9 mbar). The freeze-dried coffee extract was mixed with maltodextrin powder at different ratios (1:10 and 1:15) until homogenized.

2.5 Moisture content analysis

According to Official Methods of Analysis for moisture content analysis (AOAC Official Method 925.10), the dish and lid were dried in the oven for 1 h at 105°C. Then, the dish was cooled in a desiccator for approximately 15 min and weighed. Next, 3 g of instant coffee was placed into the dish, sealed, and weighed. The coffee samples were dried in the dish for 1 h at 105°C, cooled in a desiccator for about 15 min, and weighed. This step is repeated until a constant weight is achieved.

$$Moisture\ content = \frac{m_{initial\ sample} - m_{dried\ sample}}{m_{initial\ sample} - m_{dish}} \times 100\% \quad (1)$$

2.6 Wavelength of chlorogenic acid determination

The standard chlorogenic acid solutions were prepared by diluting the chlorogenic acid mother liquor

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(CGA) with methanol as the solvent (Ayelign and Sabally, 2013). The solution concentrations used were 2, 4, 6, 8, and 10 ppm. Before measurement, all standard solutions were homogenized using a magnetic stirrer for 10 min and filtered. Then, the standard solution was measured using a Smart UV-Vis spectrophotometer (LaMotte, USA) at a wavelength range of 300-900 nm. A quartz cuvette with a thickness of 1 mm was used for the measurements, and methanol was measured as a blank before each measurement. The results of the maximum wavelength measurement indicate that chlorogenic acid exhibits maximum absorption at 329 nm.

2.7 Extraction of chlorogenic acid for UV-VIS spectrophotometer samples

In a separatory funnel, 10 mL of the standard extract solution (untreated) was mixed with 10 mL of dichloromethane at room temperature. The two liquids were separated and collected. The previous extract solution was remixed with 10 mL of fresh dichloromethane. This process was repeated a total of 4 times (Ayelign and Sabally, 2013).

2.8 Determination of chlorogenic acid concentration

The process involves analyzing the levels of chlorogenic acid in coffee that has been extracted with a 150x dilution using methanol and measuring it using a UV-Vis spectrophotometer at a maximum wavelength of 329 nm. The decaffeinated coffee extract solution, both standard and sample, was transferred into a 1 mL cuvette, and 2 mL of distilled water was added (Ayelign and Sabally, 2013).

2.9 Solubility analysis

Instant coffee (0.2 g) was dissolved in 20 mL of distilled water (temperature: 95°C) and stirred for 5 min. The solution was then centrifuged at 3000×*g* for 5 min. A 5 mL sample of the solution was taken and placed into a petri dish, then dried overnight in an oven at a temperature of 105°C (Jordán-Suárez *et al*., 2018).

$$s\ (\%) = \frac{sample\ weight\ after\ oven}{sample\ weight} \times 100\% \quad (2)$$

2.10 Hygroscopicity analysis

The hygroscopicity index measures the product's ability to absorb water from the surrounding environment, expressed as a percentage until it reaches a saturated condition (Richardson, 2011). The hygroscopicity index can be used to assess the water content's velocity profile. The samples were placed in an oven at 60°C and in a desiccator with a relative humidity of 80%. The samples were taken out and weighed every 2 h.

$$Hygroscopicity\ Index\ (\%) = \frac{\%\,WI + \%FW}{100 + \%WI} \times 100 \quad (3)$$

$$\%FW = \%\ \text{free water} \quad (4)$$

$$\%WI = \frac{m_{equilibrium\ sample} - m_{sample}}{m_{sample} - m_{dish}} \times 100 \quad (5)$$

2.11 Scanning electron microscopy

The instant coffee samples were affixed to a metallic sample holder using a 99.6% pure gold alloy at a coating rate of 0.51 Å•s and a Shimadzu Rika Inverted Microscope AE2000-HZ (Shimadzu, Japan).

2.12 Color analysis

Colorimetry is a method used in chemical analysis that involves comparing the color intensity of a solution with the color of a standard solution and measuring the intensity of the color of the solution (Hochmuth et al., 1999). The colorimeter tool is employed to quantify color using CIE Lab* coordinates, where L* represents lightness, a* denotes redness, and b* indicates yellowness. The color of the sample in this study was quantified by a 3nh NH310 portable colorimeter (Shenzhen Threenh Technology Co., Ltd., China).

2.13 Organoleptic analysis

Sensory analysis was conducted with the participation of 30 panelists. The panelists were given instant coffee powder and brewed instant coffee; each was assigned a unique 3-digit code. The organoleptic test employed was a preference test evaluating the color, aroma, and texture of the coffee grounds, and the results of brewing the instant coffee. The results were recorded on a hedonic scale ranging from "dislike very much" (1), "dislike" (2), "do not like" (3), "neutral" (4), "quite like" (5), "like" (6), to "like very much" (7).

2.14 Statistical analysis

The study used statistical methods and analyses to interpret and draw conclusions from the experimental data. The data are expressed as the mean±S.D. (standard deviation), and all assays from every independent treatment were duplicated. A one-way variance analysis (ANOVA) was performed to compare the mean values of the different samples. The result was considered statistically significant if the p-value was less than or equal to 0.05 ($p \leq 0.05$).

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3. Results and discussion

3.1 The effect of freeze-drying operating conditions on the physical properties of instant coffee

3.1.1 Moisture content analysis

Based on Figures 1(a) and 1(b), the analysis of the moisture content of instant coffee in the drying process for 48 h was within the range of 2.8 – 4.1%, which meets the ISO 11292 (International Organization for Standardization (ISO), 1995) requirement for instant coffee that is below 5%. The result indicated that drying time significantly affected the moisture content of freeze-dried instant coffee products (p-value < 0.05). If the drying time is too long, instant coffee products can experience an increase in water content (Bonazzi and Dumoulin, 2011). When the product is dried for an extended period, the temperature of the product will continue to rise and may result in incomplete sublimation. In addition, maltodextrin can easily absorb moisture, leading to an increase in water content. The result also showed that the coffee extract concentration had no significant effect on the water content of the freeze-dried instant coffee product.

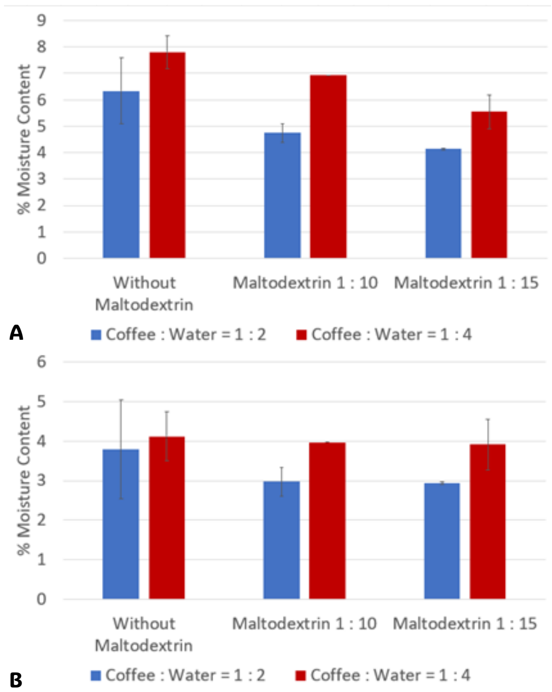

Figure 1. The effect of extract and maltodextrin concentrations on moisture content of instant coffee (a) 48 h and (b) 72 h.

3.1.2 Solubility analysis

The result in Figure 2 indicated that drying time had no significant effect on the solubility of freeze-dried instant coffee (p-value > 0.05). This is because drying time may not impact the amount of dissolved solids, which is the primary factor affecting solubility. Moreover, the concentration of the extract and water before the drying process had no significant effect on the solubility of the freeze-dried instant coffee (p-value > 0.05). In addition, the ANOVA results revealed that the amount of maltodextrin significantly affected solubility (p-value < 0.05). The greater the ratio of maltodextrin to coffee, the higher the freeze-dried instant coffee extract solubility. This can be attributed to the properties of maltodextrin, which has a dextrose equivalent (DE) value of 20, and enhances solubility in coffee (Dokic et al., 2004). The utilization of fillers such as maltodextrin can increase solubility because they possess properties that can bind hydrophobic substances and are oligosaccharides that dissolve quickly in water (Nugraheni Retnaningsih *et al*., 2014).

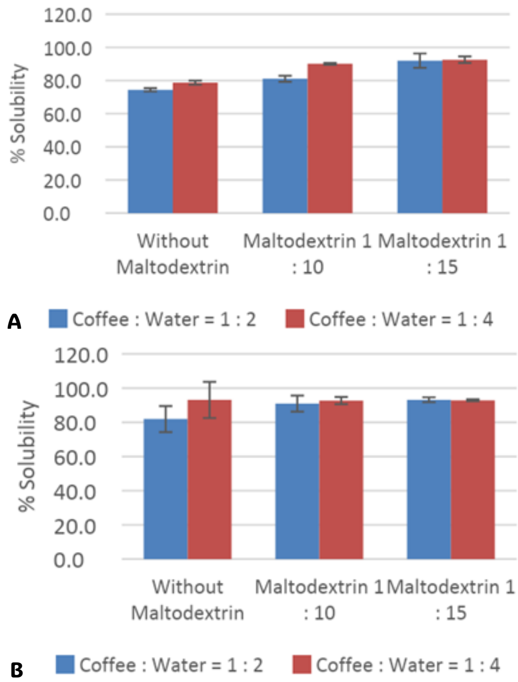

Figure 2. The effect of extract and maltodextrin concentrations on the solubility of instant coffee (a) 48 h and (b) 72 h.

3.1.3 Hygroscopicity analysis

Figures 3(a) and 3(b) showed that the coffee extract microencapsulated with maltodextrin (1:15), with drying times of 48 h and 72 h, showed the lowest hygroscopicity index and is classified as non-hygroscopic (GEA Niro Method, 2005). This classification is due to the % hygroscopicity being below 10%.

Figure 3 also shows that drying time and extract concentration had no significant effect on the hygroscopicity index of freeze-dried instant coffee (p-value > 0.05). The hygroscopicity of instant coffee is more likely to be influenced by other factors such as temperature, pressure, and relative humidity within the freeze dryer during the drying process (Richardson, 2011). Based on Figures 3(a) and 3(b), it can also be observed that the higher the ratio of maltodextrin to coffee, the lower the hygroscopicity index of freeze-dried instant coffee extract (p-value < 0.05). Adding maltodextrin to coffee extract facilitates the encapsulation of the resulting instant coffee product and helps reduce its hygroscopicity index. This is due to the low hygroscopic properties of maltodextrin (Nadali *et al*., 2022).

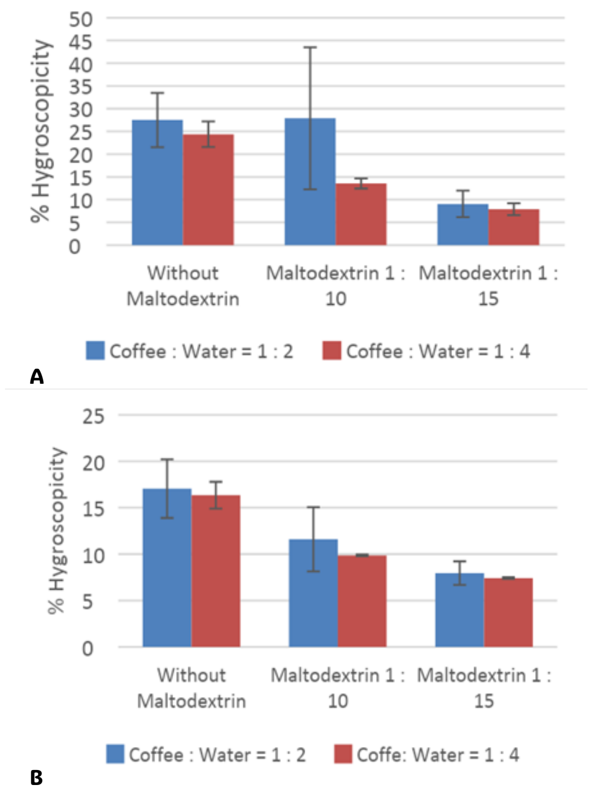

Figure 3. The effect of extract and maltodextrin concentrations on hygroscopicity of instant coffee (a) 48 h, (b) 72 h.

3.1.4 Color analysis

Figure 4 indicates that drying time does not significantly affect the color of freeze-dried coffee (p-value > 0.05). This is attributed to the low temperature in the freeze-drying process, which prevents browning and Maillard reactions. The Maillard reaction is a browning reaction between carbohydrates, particularly reducing sugars, and primary amine groups (Feiner, 2006). The freeze-drying method is known for effectively preserving coffee's natural color because the rapid freezing process helps prevent significant discoloration. Also, freeze-drying can help inhibit oxidation, which can alter coffee's color, as oxygen's presence is significantly reduced. This reduction in oxygen exposure lowers the risk of discoloration caused by oxidation (Oyinloye and Yoon, 2020).

The extract was found to have a significant effect on the color of instant coffee (p-value < 0.05). As observed in Figures 4(a) and 4(b), instant coffee with a concentration of 0.25 g/mL of coffee extract to water tends to exhibit a lighter color. This can be attributed to the lower amount of dissolved coffee solids than the extract, with a concentration of 0.5 g/mL. A lower total solids concentration results in reduced turbidity and a lighter color in the coffee solution before drying. During the process of coffee extraction, pigment compounds present in coffee grounds, such as chlorophyll and melanoidin, interact with hot water and contribute to the dark color of the coffee extract.

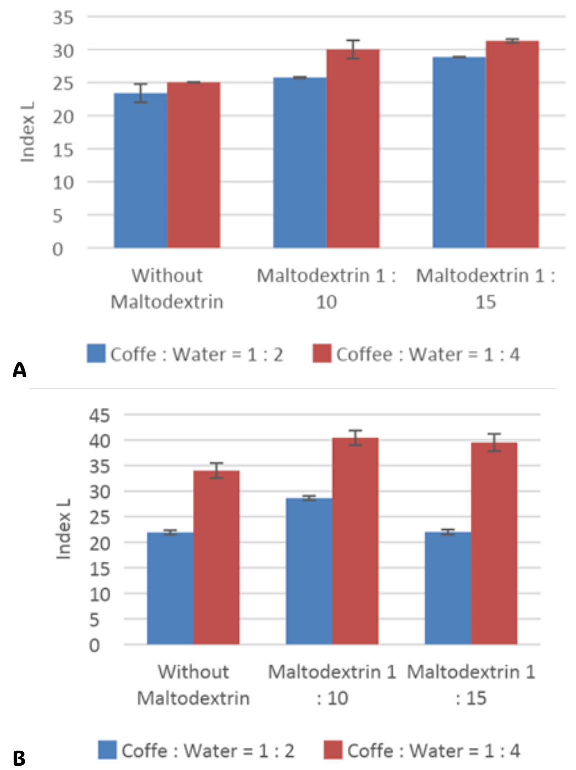

Figure 4. The effect of extract and maltodextrin concentrations on the color of instant coffee (a) 48 h and (b) 72 h.

Based on Figures 4(a) and 4(b), it can be observed that instant coffee powder with the addition of maltodextrin exhibits a brighter color compared to samples without maltodextrin, as indicated by the increased L (light) value. Moreover, the greater the ratio of maltodextrin, the higher the brightness of the coffee powder. The ANOVA results confirmed that the amount of maltodextrin significantly affected the color of freeze-dried instant coffee (p-value < 0.05). This phenomenon can be attributed to the physical properties of maltodextrin, which is white and quickly disperses in the coffee solution before freeze-drying. Additionally, maltodextrin can inhibit the Maillard reaction, which typically occurs between sugar and amino compounds in coffee when exposed to heat or extracted with hot water (Wang and Zhong, 2014).

3.2 Analysis of chlorogenic acid content

The analysis of chlorogenic acid content in dried coffee extract with a drying duration of 48 h is shown in Figure 5. Based on Figure 5, it can be observed that the levels of chlorogenic acid in the coffee and water extract

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with a ratio of 1:2 are lower compared to the extract with a ratio of 1:4. This difference can be attributed to the fact that the coffee and water extract with a ratio of 1:2 may not have fully extracted the chlorogenic acid present in the coffee grounds. During the preparation process of the coffee extracts, it may be challenging to extract coffee with a high concentration due to the abundance of coffee solids, resulting in a higher amount of residue or dregs. These dregs contain a significant amount of coffee liquid extract that contains chlorogenic acid, caffeine, and other compounds found in coffee. Increasing the amount of solvent while using the same coffee grounds will create a higher concentration gradient between the coffee solution and the solvent (Oteef, 2022). As a result, the extraction rate will increase, meaning that the chlorogenic acid compounds in coffee will dissolve more readily in water. The level of chlorogenic acid increases with the addition of maltodextrin in the drying process. The highest concentration of chlorogenic acid recorded was 1400 ppm, obtained when using a coffee extract and water ratio of 1:4 and a maltodextrin ratio of 1:15. This increase can be attributed to the ability of maltodextrin to preserve the flavor of instant coffee during the freeze-drying process. Chlorogenic acid, known for its dominant bitter and sour taste, is one of the flavors present in instant coffee (Shofinita *et al.,* 2024b).

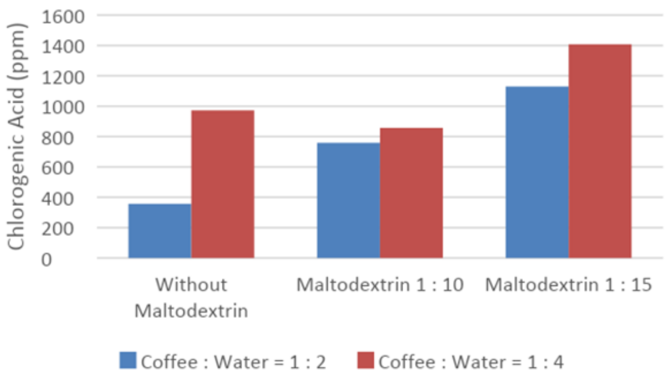

Figure 5. Chlorogenic acid content in coffee freeze-drying (48 h).

3.3 Analysis characteristics of instant coffee produced with wet blend and dry blend methods

Based on Figure 6(a), the wet blend process produces a lower water content in the instant coffee powder than the dry blend process. In the wet blend method, coffee powder with a ratio of 1:15 maltodextrin has a lower water content than 1:10 maltodextrin. Besides that, based on Figure 6(b), instant coffee-added maltodextrin with the wet blend method obtained a greater solubility value than the dry blend method. The solubility of coffee in the wet blend method increases as the amount of maltodextrin increases. In Figure 6(c), the hygroscopicity of instant coffee with the addition of maltodextrin with the wet blend method is lower than that with the addition of maltodextrin with the dry blend method. Based on this phenomenon, it can be proven that instant coffee using the dry blend method will produce less good physical properties than wet blends, such as higher water content, lower solubility, and higher hygroscopicity. Maltodextrin can reduce the water content in instant coffee because it can absorb moisture from the surrounding air. When maltodextrin and coffee grounds are mixed with water, the water molecules can form hydrogen bonds with the maltodextrin and coffee grounds molecules. These hydrogen bonds help bind water molecules to the surface of the maltodextrin and coffee grounds, thereby reducing the availability of free water in the mixture. Therefore, maltodextrin mixed with the dry blend method will not have hydrogen bonds between maltodextrin, water, and ground coffee because there is no dispersion process (water and maltodextrin powder). This hydrogen bonding that does not occur can increase the water content in instant coffee powder with the dry blend method.

The high water content leads to strong bonds between the particles of instant coffee, resulting in the agglomeration of coffee grounds and reducing solubility.

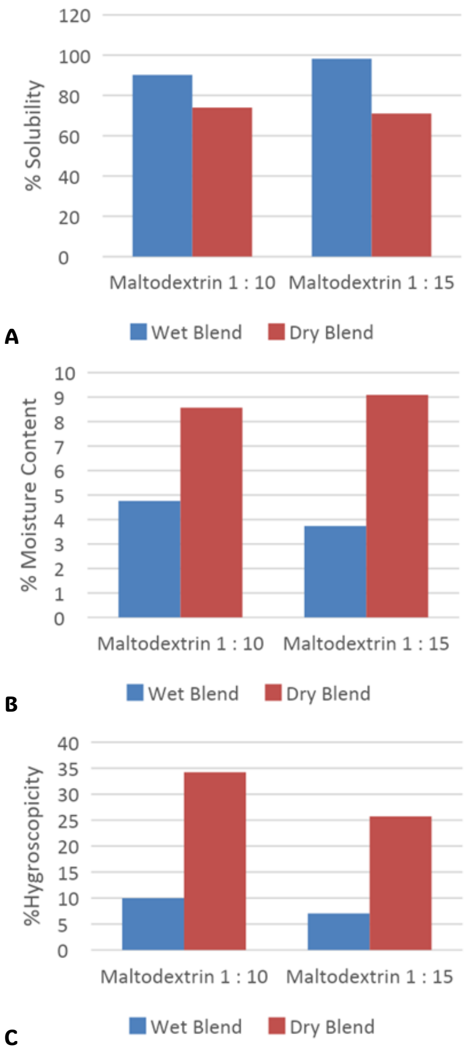

Figure 6. The effect of dry blend and wet blend for (a) moisture content, (b) solubility and (c) hygroscopicity.

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Maltodextrin, a water-soluble carbohydrate, can be crucial in improving solubility. Coffee contains various compounds, such as coffee oil and aromatic components, less soluble in water. However, when maltodextrin is added at the beginning (wet blend method), these less soluble compounds can easily dissolve in water. This is because maltodextrin helps dissolve coffee oil and other compounds with lower solubility, thereby enhancing the overall solubility of coffee grounds.

On the other hand, in the dry blend method, maltodextrin is added to the coffee grounds at the end of the drying process. Consequently, the maltodextrin dissolves first compared to the coffee grounds, which still contain less soluble compounds like chlorogenic acid, phenolic acid, and melanoidin. Maltodextrin contributes to the increased hygroscopicity (ability to absorb moisture) of coffee grounds due to its chemical properties. Maltodextrin is hydrophilic, which means it has a strong affinity for water and can readily attract or absorb moisture from the surrounding environment. The structure of maltodextrin consists of numerous hydroxyl groups (OH), allowing for polar interactions with water molecules. This hydrophilic property enables maltodextrin to absorb moisture from the air or the surrounding environment when exposed, including when it is used in coffee grounds. In the case of dry blend coffee powder, the high hygroscopicity is primarily caused by maltodextrin, which can easily absorb moisture from the air due to its chemical properties. It is important to note that the dry blend method has no chemical bond between maltodextrin and coffee grounds.

3.4 Scanning electron microscopy analysis

Based on Figure 7a, it can be observed that the structure of coffee without microencapsulation (with the addition of maltodextrin) has a longer and flatter shape, and it appears tidy. Despite its flat and neat shape, coffee grounds without maltodextrin are more vulnerable to losing active substances since they are not protected by a coating agent (Hasna et al., 2018). On the other hand, in Figures 7b and 7c, the structure of coffee with microencapsulation (with the addition of maltodextrin at ratios of 1:10 and 1:15) appears wrinkled and needs to be neatly coated. The coffee powder structure with added maltodextrin appears wrinkled and not neatly coated, which may be due to the efficiency of microencapsulation (Hasna *et al*., 2018). Based on Figures 7b and 7c, no ballooning was observed in the structure of the coffee grounds. Therefore, the encapsulation process is still relatively good. The ballooning formation would indicate that the microencapsulation is not strong enough to withstand the pressure inside the particles. As shown in Table 1, the

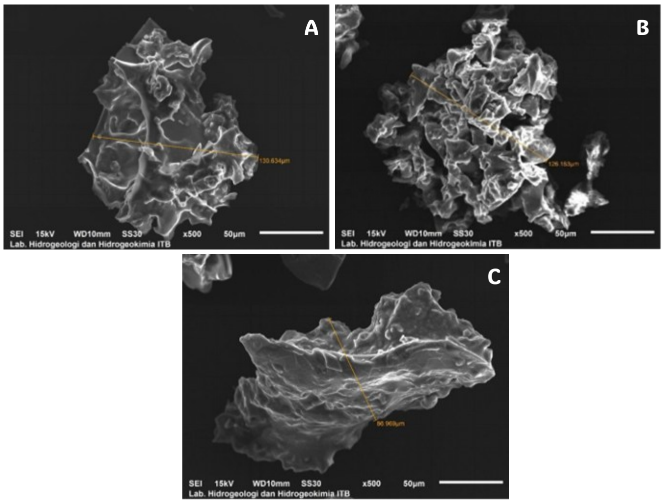

Figure 7. Coffee freeze drying structure (extract: water = 1:4) with SEM (a) without maltodextrin; (b) maltodextrin 1:10; (c) maltodextrin 1:15.

size of the coffee particles increases as the amount of maltodextrin added during the drying process increases. This is because maltodextrin can act as a coating or encapsulant for coffee particles, protecting them from damage during the drying process. According to Shofinita *et al*. (2023), the vacuum freezing time process was affected by increased extract layer thickness or decreased pressure drop rate. Based on the frozen coffee extract produced, it was known that vacuum freezing increased the rate of freezing coffee extract and created a highly porous frozen matrix. In contrast, the others obtained irregular ice crystals.

Table 1. Size and morphology.

Variation (Extract coffee : water = 1 : 4)	Size (μm)	Morphology
Without maltodextrin	86.969	Flaky, not many pores
Maltodextrin 1 : 10	126.183	Porous and looks brittle
Maltodextrin 1 : 15	130.634	There are not many pores

3.5 Organoleptic analysis

Figure 8 shows that the color with the highest level of preferred acquisition is dry blend coffee (maltodextrin 1:10), with an average preference rating of 5.16 from 6. The aroma that received the highest preference level was wet blend coffee (1:15 maltodextrin), with an average rating of 5.7. Additionally, wet blend coffee (1:10 maltodextrin) achieved the highest preference level for taste and acidity, with average ratings of 4.7 and 4.4, respectively. Overall, the panelists favored wet blend coffee (maltodextrin 1:10) the most, with an average preference rating of 5.06 from 6, which was slightly higher than wet blend coffee (maltodextrin 1:15), which attained an average preference rating of 4.96 from 6. Based on Figure 8(b), it is evident that wet blend coffee (maltodextrin 1:15) has the highest level of preference for color, aroma, and general acceptance, with average preference ratings of 6.53, 6.3, and 6.03 from 7, respectively. On the other hand, wet blend coffee (1:10 maltodextrin) received the lowest level of preference for color, aroma, and general acceptance, with average preference ratings of 4.3, 4.4, and 4.5 from 7, respectively.

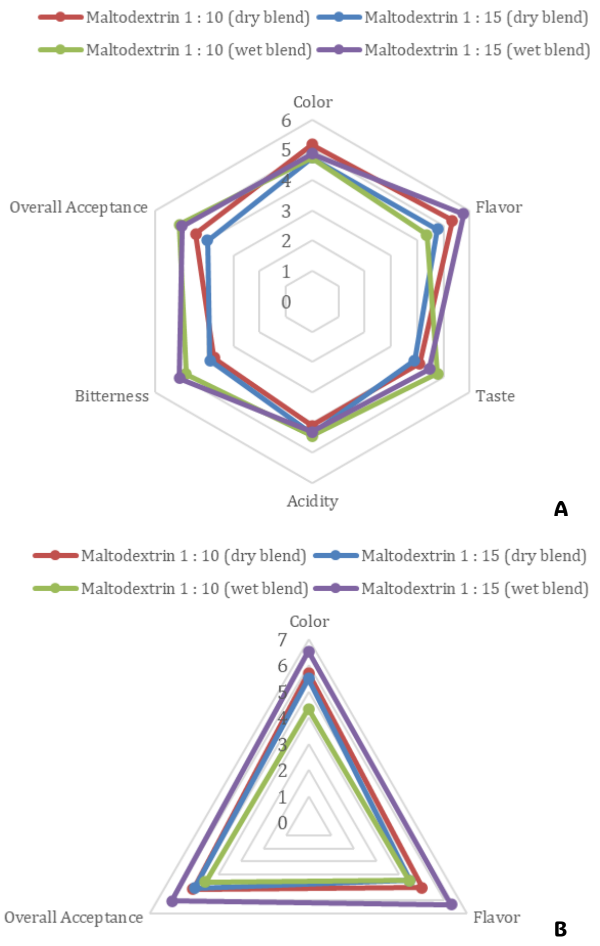

Figure 8. Organoleptic analysis (a) brewed coffee (b) powder coffee.

4. Conclusion

The moisture content of the instant coffee powder produced during the 48-h drying process ranges from 2.8±0.54% to 4.1±0.236%, while for the 72-hour drying time, it ranges from 4.2±0.03% to 7.2±0.62%. Longer drying times lead to higher water content and lower powder solubility. The concentration of the extract did not significantly impact the water content and solubility of the freeze-dried instant coffee product. However, higher concentrations of maltodextrin resulted in lower water content and higher powder solubility. In terms of water content, solubility, hygroscopicity, and sensory evaluation, the production using a wet blend for instant coffee is superior to the dry blend. The organoleptic test of brewed instant coffee showed the highest average preference for wet blend coffee (maltodextrin 1:10) with a general acceptance rating of 5.06 from 6. Likewise, for the organoleptic test of powdered instant coffee, wet blend coffee (maltodextrin 1:15) received the highest average preference rating of 6.03 from 7 regarding general acceptance.

Conflict of interest

The authors declare no conflict of interest.

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References

AOAC INTERNATIONAL. (1995). Solids (Total) and Moisture in Flour. Air Oven Method. Official Methods of Analysis of AOAC INTERNATIONAL. Washington DC, USA: AOAC INTERNATIONAL.

Ayelign, A. and Sabally, K. (2013). Determination of Chlorogenic Acids (CGA) in Coffee Beans using HPLC. *American Journal of Research Communication*, 1(2), 78–91.

Bonazzi, C. and Dumoulin, E. (2011). Quality Changes in Food Materials as Influenced by Drying Processes. Retrieved from website: https://www.wiley-vch.de/books/sample/3527315586_c01.pdf

Calderón-Oliver, M. and Ponce-Alquicira, E. (2022). The Role of Microencapsulation in Food Application. *Molecules,* 27(5), 1499. https://doi.org/10.3390/molecules27051499

Clarke, R. and Vitzthum, O.G. (Eds.) (2001). Coffee: Recent Developments. USA: Blackwell Science Ltd.

Utomo, D. (2013). Pembuatan serbuk effervescent murbei (*Morus alba* L.) dengan kajian konsentrasi maltodekstrin dan suhu pengering. *Journal of Food Technology*, 5(1), 56-57. https://doi.org/10.35891/tp.v5i1.498 [In Bahasa Indonesia].

Dokic, L., Jakovljevic, J. and Dokic, P. (2004). Relation between viscous characteristics and dextrose equivalent of maltodextrins. *Starch/Staerke*, 56(11), 520–525. https://doi.org/10.1002/star.200400294

Fang, Z. and Bhandari, B. (2010). Encapsulation of polyphenols - A review. *Trends in Food Science and Technology,* 21(10), 510-523. https://doi.org/10.1016/j.tifs.2010.08.003

Feiner, G. (2006). Definitions of terms used in meat science and technology. In Meat Products Handbook. Practical Science and Technology, p. 46-71. USA: Woodhead Publishing Limited. https://doi.org/10.1533/9781845691721.1.46

GEA Niro Method. (2005). Analytical methods for dry milk products. Retrieved from website: https://www.gea.com/en/products/dryers-particle-processing/spray-dryers/spray-dryer-efficiency-quality/analytical-methods-dry-milk-products/

Gupta, C., Chawla, P., Arora, S., Tomar, S.K. and Singh, A.K. (2015). Iron microencapsulation with blend of gum arabic, maltodextrin and modified starch using modified solvent evaporation method - Milk fortification. *Food Hydrocolloids*, 43, 622–628. https://doi.org/10.1016/j.foodhyd.2014.07.021

Hasna, T., Anandito, B.K., Khasanah, L.U., Utami, R. and Manuhara, G.J. (2018). Effect of Maltodextrin and Whey Combination as Wall Material on The characteristics of Cinnamon (*Cinnamomum burmanii*) Oleoresin Microencapsule. *Agritech*, 38(3), 259–264. https://doi.org/10.22146/agritech.12725

Hochmuth, G.J., Brecht, J.K. and Bassett, M.J. (1999). Nitrogen Fertilization to Maximize Carrot Yield and Quality on a Sandy Soil. *Hortscience*, 34(3), 641-645. https://doi.org/10.21273/HORTSCI.34.4.641

International Coffee Organization. (2021). Annual review 2021–2022. Retrieved from website: https://www.ico.org/documents/cy2022-23/annual-review-2021-2022-e.pdf

International Organization for Standardization (ISO). (1995). Instant coffee – Determination of free and total carbohydrate contents – Method using high-performance anion exchange chromatography (ISO 11292:1995). Retrieved from https://cdn.standards.iteh.ai/samples/19270/12f510ca625a4ec5b694d2b41613db54/ISO-11292-1995.pdf

Jordán-Suárez, O., Glorio-Paulet, P. and Vidal, L. (2018). Microstructure of *Annona muricata* L. Leaves Extract Microcapsules Linked to Physical and Chemical Characteristics. *Journal of Encapsulation and Adsorption Sciences*, 8(3), 178–193. https://doi.org/10.4236/jeas.2018.83009

Nadali, N., Pahlevanlo, A., Sarabi-Jamab, M. and Balandari, A. (2022). Effect of maltodextrin with different dextrose equivalents on the physicochemical properties of spray-dried barberry juice (*Berberis vulgaris* L.). *Journal of Food Science and Technology*, 59(7), 2855–2866. https://doi.org/10.1007/s13197-021-05308-w

Nugraheni Retnaningsih, O. and Intan Niken Tari. (2014). Secang Instant Drink Analysis: Egg Whites, Maltodextrin Properties, And Feasibility of The Business. *AGRIN*, 18(9), 139. https://doi.org/10.20884/1.agrin.2014.18.2.219

Oteef, M.D.Y. (2022). Comparison of Different Extraction Techniques and Conditions for Optimizing an HPLC-DAD Method for the Routine Determination of the Content of Chlorogenic Acids in Green Coffee Beans. *Separations*, 9(11), 15-16. https://doi.org/10.3390/separations9120396

Oyinloye, T.M. and Yoon, W.B. (2020). Effect of Freeze-Drying on Quality and Grinding Process of Food Produce: A Review. *Processes*, 8(3), 354. https://doi.org/10.3390/pr8030354

Richardson J.F. (2011). Thermopedia. Hygroscopicity. Retrieved on August 01, 2023 from Thermopedia Website: https://www.thermopedia.com/content/869/

Shofinita, D., Bindar, Y., Samadhi, T.W., Jaelawijaya, A.A. and Fawwaz, M. (2020). Reducing the stickiness of dragon fruit skin extract powder as food colorant by addition of maltodextrin during freeze drying. *AIP Conference Proceedings*, 2219, 070011. https://doi.org/10.1063/5.0003030

Shofinita, D., Bindar, Y., Samadhi, T.W., Choliq, N.S. and Jaelawijaya, A.A. (2021). Increasing the Yield of Powder and Bioactive Materials during Extraction and Spray Drying of Dragon Fruit Skin Extracts. *Journal of Engineering and Technological Sciences*, 53(6), 1221-1234. https://doi.org/10.5614/j.eng.technol.sci.2021.53.6.12

Shofinita, D., Harimawan, A., Putri N.C. and Maharani, S. (2024a). Microencapsulation of honey as flavouring agent in milk powder. *Food Research*, 8(3), 154–162. https://doi.org/10.26656/fr.2017.8(3).358

Shofinita, D. and Langrish, T.A. (2016). Redox (pro-oxidant/antioxidant) balance in the spray drying of orange peel extracts. *Drying Technology,* 34(14), 1719-1725. https://doi.org/10.1080/07373937.2016.1175471

Shofinita, D., Lestari, D., Aliwarga, L., Sumampouw, G.A., Ambarwati, S.A., Gunawan, K.C. and Achmadi, A.B. (2023). Drying Methods of Coffee Extracts and Their Effects on Physicochemical Properties: A Review. *Food and Bioprocess Technology*, 17(2), 50-59. https://doi.org/10.1007/s11947-023-03067-4

Shofinita, D., Lestari, D., Purwadi, R., Sumampouw, G.A., Gunawan, K.C., Ambarwati, S.A., Achmadi, A.B. and Tjahjadi, J.T. (2024b). Effects of different decaffeination methods on caffeine contents, physicochemical, and sensory properties of coffee. *International Journal of Food Engineering,* 20(8), 561-581. https://doi.org/10.1515/ijfe-2024-0013

Wang, W. and Zhong, Q. (2014). Properties of whey protein-maltodextrin conjugates as impacted by powder acidity during the Maillard reaction. *Food Hydrocolloids*, 38, 85–94. https://doi.org/10.1016/j.foodhyd.2013.11.018

Zheng, X., Liu, B., Li, L. and Zhu, X. (2011). Microwave-assisted extraction and antioxidant activity of total phenolic compounds from pomegranate peel. *Journal of Medicinal Plants Research*, 5(6), 1004–1011.

