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Study on Ice Cream Incorporated with Coffee and Its Effect on the Physical Properties and Sensory Acceptance

Aniswatul Khamidah[1], Indrie Ambarsari[1]*, Milatul Ulya[2], Erliana Ginting[1], Sri Satya Antarlina[1], Handoko[3], Listy Anggraeni[3], Lilia Fauziah[4], A. M. Abdurrahman[5]

[1]Research Center for Food Technology and Processing, Research Organization for Agriculture and Food, National Research and Innovation Agency
[2]Study Program of Agroindustrial Technology, University of Trunojoyo Madura, Indonesia
[3]Research Center for Horticulture, Research Organization for Agriculture and Food, National Research and Innovation Agency
[4]Research Center for Estate Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency
[5]Indonesian Agency for Agricultural Instrument Standardization of East Java

*Corresponding author:
E-mail:
indr060@brin.go.id

ABSTRACT

Coffee, in addition to ice cream, has evolved as a result of culinary diversification. The addition of coffee to ice cream might change its physical qualities. Furthermore, the type and quantity of stabilizers used affect the quality of the ice cream. The purpose of this study was to identify the optimal percentage of Carboxy Methyl Cellulose (CMC) as a stabilizer and coffee powder added to ice cream, as well as to assess the impact on physical properties and acceptance. This study was conducted using a completely randomized design with two variables: CMC (0; 0.5; 1; 1.5% w/w) and coffee powder concentration (5 and 7.5% w/w). According to the study, increasing CMC led to a longer melting time and a decrease in overrun value. Furthermore, the addition of more coffee powder reduced the brightness of the ice cream. All sensory qualities had lower approval values as the amount of coffee and CMC increased. Ice cream with 0.5% CMC and 7.5% coffee powder produced the highest quality ice cream, with an overrun value of 42.01%, a melting time of 16.82 minutes, a lightness (L*) of 66.67, a redness (a*) of 1.67, and a yellowness (b*) of 23.33.

Keywords: CMC, coffee, ice cream, quality

Introduction

Ice cream is made up of three components: a network of fat globules and ice crystals scattered in a high-viscosity aqueous phase (Silva Junior & Lannes, 2011). Ice cream is a semi-solid frozen food produced from milk, yogurt, or fruit, as well as animal or vegetable fats, sugar, stabilizers, and emulsifiers, and may or may not contain egg, flavoring, or other allowed components. Ice cream is also high in nutrition due to its major ingredient, milk. Ice cream is a popular dessert due to its pleasant and sweet taste, as well as its soft texture (Jariyah et al., 2019; Parid et al., 2021; Kaminska-Dworznicka et al., 2022). Some factors influence ice cream quality, such as processing processes, freezing conditions, and ingredients utilized (Silva Junior & Lannes, 2011).

The ice cream invention is still growing today. One suggestion is to use coffee powder to make ice cream. Global coffee consumption is expected to rise by approximately 4.1%, primarily in African, Asian, and Oceania non-traditional coffee-drinking countries. Demand in conventional markets is expected to increase by 1% in Europe and 2.5% in North America. A preliminary analysis was conducted to determine the most popular beverages based on their bioactive non-nutrient content. The study found that instant coffee had the greatest total bisphenol level. A cup of coffee's biochemical composition is determined by various elements, including the degree of

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roasting, the exact kind of beans used, and the brewing process, which may include the type of grinding (Samoggia & Riedel, 2019).

Polyphenols in coffee beans include caffeic acid, chlorogenic acid, feuric acid, sinapic acid, and coumaric acid (Pristiana et al., 2017). Coffee is an important source of antioxidant chemicals in many people's diets (Farah & de Paula Lima, 2019). Roasted coffee contains about 1000 bioactive chemicals, which have been proven to have a variety of potentially therapeutic benefits, including antioxidant, anti-inflammatory, antifibrotic, and anticancer characteristics. Caffeine, chlorogenic acids, diterpenes, cafestol, and kahweol are the main bioactive components found in coffee. Coffee is high in vitamin B3 and magnesium, and the brewing process does not significantly reduce potassium levels in the seeds. Coffee drinking has been associated with a lower chance of acquiring some types of cancer and cardiovascular disease, as well as metabolic and neurological problems (Samoggia & Riedel, 2019). Caffeine, a psychotropic molecule found in coffee, is classed as an alkaloid due to its secondary plant origin and synthesis from purine nucleotides, a heterocyclic nitrogen atom that distinguishes real alkaloids (dePaula & Farah, 2019).

Coffee has an impact on the physical quality of ice cream. The physical structure of ice cream affects both its melting rate and hardness (Silva Junior & Lannes, 2011). The viscosity of ice cream influences both the smoothness of the texture and its resistance to melting. Stabilizers can improve ice cream's physical attributes, such as texture, overrun, and melting speed, as well as ice cream preferences. The stabilizers help to preserve the ice cream's particular structural integrity by increasing viscosity, stabilizing the emulsion and foam, and minimizing the key shelf-life problem of ice recrystallization (Reeder et al., 2023). Stabilizers can produce micro-sized membranes that link fat molecules to air, preventing air crystallization and fat clumping. Stabilizers can also thicken the dough, resulting in stable membranes and a softening texture, consistent results, and resistance to melting (Mailoa et al., 2017).

CMC is one of the most common stabilizers. The addition of stabilizers should be minimal but also tailored to the properties of the ice cream. If the stabilizer concentration is insufficient, the ice cream will have a rough texture and melt easily (Istiqomah et al., 2017). Mailoa et al. (2017) and Manurung et al. (2021) found that 0.5% CMC was the most liked due to its soft texture, good ice cream qualities for overrun value, melting level, and sensory acceptability. As a result, the purpose of this study was to establish the optimal concentration of CMC and coffee powder to manufacture satisfactory ice cream.

Material and Methods

Materials

Robusta coffee had been used as an additional ingredient in ice cream in a prior study conducted by Khamidah et al. (2023). TTP Dillem Willis, Trenggalek, East Java, Indonesia, and the Postharvest Laboratory of the Assessment Institute for Agricultural Technology (AIAT) of East Java in Malang provided the supplies and equipment to make the ice cream. The sensory acceptance was carried out at both Trenggalek and Malang.

Location and time

The research was conducted at the Agricultural Technology Park (TTP), Dillem Wilis Trenggalek, and the Postharvest Laboratory of the Assessment Institute for Agricultural Technology (AIAT) of East Java from December 2020 to January 2021.

Data collection and analysis

Physical parameters such as color, overrun, and melting time are measured. A colorimeter (CR-10, KONICA MINOLTA, INC., Japan) was used to calculate the color index, which included lightness (L), redness (a*), and yellowness (b*) (Nuraini et al., 2024). Góral et al. (2018) used an overrun analysis method, while Kamińska-Dwórznicka et al. (2022) used a melting speed method.

Overrun was calculated by comparing the volume of ice cream after freezing to the volume of dough before combining and freezing. The formula used to calculate overrun was as follows:

$$Overrun\ (\%) = \frac{W1 - W2}{W2} x\ 100\%$$

W_1 = mass of unit volume of mixture (gram)
W_2 = mass of unit volume of ice cream (gram)

Fauziah et al. (2023) used a hedonic test to conduct the sensory test. A cup held ice cream. Each sample was assigned a random three-digit number, and participants were not provided any information about it. In between sample exchanges, drinking water was offered for gargling. Color, aroma, taste, texture, melting time, and overall look were all considered when evaluating the samples. This evaluation used a descriptive score of 1 to 5, with the following definitions: 1 - poor quality; 2 - insufficient quality; 3 - adequate quality; 4 - high quality; 5 - excellent quality (Góral et al., 2018).

Statistical analysis

The experimental design used a completely randomized factorial with two factors: (a) CMC concentration (0; 0.5; 1; 1.5%) and (b) coffee powder concentration (5 and 7.5%), with three replicates each. The data was analyzed using ANOVA (Analysis of Variance), followed by the Fisher test with a significance level of 95% ($p<0.05$) to evaluate treatment differences. The Comparative Performance Index (CPI) was used to determine the optimal treatment (Hasanah et al., 2020).

Table 1. Treatments of ice cream

Composition	**Treatments**							
	C_1P_1	**C_1P_2**	**C_2P_1**	**C_2P_2**	**C_3P_1**	**C_3P_2**	**C_4P_1**	**C_4P_2**
CMC (C) (%)	0	0	0.5	0.5	1	1	1.5	1.5
Coffee powder (P) (%)	5	7.5	5	7.5	5	7.5	5	7.5
Fresh milk (L)	1	1	1	1	1	1	1	1
Sugar (g)	225	225	225	225	225	225	225	225
Sweetened condensed milk (g)	80	80	80	80	80	80	80	80
Corn starch (g)	50	50	50	50	50	50	50	50
Emulsifier (g)	20	20	20	20	20	20	20	20

Results and Discussion

Overrun

The addition of CMC and coffee concentration had a significant ($p < 0.05$) effect on the overrun value of coffee ice cream (Table 2). The overrun value of coffee ice cream in this investigation ranged between 30.70 and 43.46%. Because no stabilizer was used, the treatment with 0% CMC had the lowest overrun value (Kaminska-Dworznicka et al., 2022). As a result, the control emulsion was less stable than the other treatments, affecting melting power and overrun. The use of CMC in ice cream production would improve the consistency of the liquid mixture. Because of CMC's high dispersion power, the texture of the liquid ice cream mixture would be more uniform. CMC is used as a thickening agent, primarily to provide viscosity to ice cream recipes and avoid layer formation caused by the presence of fat and protein (Parid et al., 2021).

The more CMC added, the lower the ice cream overrun value, because more CMC increased total solids and viscosity, resulting in thicker ice cream. Because the space between particles in the dough is smaller, water molecules' mobility would be limited. The small distance between particles allows less air to enter the dough during the agitation phase. This will slow the growth of the ice cream dough, lowering the overrun value (Istiqomah et al., 2017; Satriani et al., 2018; Manurung et al., 2021).

Silva Junior and Lannes (2011) found that the fat, emulsifier, and stabilizer contents, as well as the processing conditions (specifically, the whipping temperature and freezing power), can have a significant impact on the development of air cells. Manurung et al. (2021) found that adding CMC (0.5%, 0.75%, 1%, 1.25%, and 1.5%) to lemongrass ice cream formulation resulted in an overrun value of 25.18 ± 38.51 ± 0.55 (%). Another study conducted by Istiqomah et al. (2017) found that the overrun value for edamame ice cream ranged from 23.46 to 38.95%. This overrun value is appropriate for the home industry because, according to Istiqomah et al. (2017), Satriani et al. (2018), and Jariyah et al. (2019), the overrun value for the home industry ranges from 35 to 50%, but the overrun value produced by the factory is 70 to 80%. The low overrun value causes the ice cream structure after preparation to become hard and heavy, making the product unpleasant (Kaminska-Dworznicka et al., 2022).

Table 2. The effects of different treatments on the physical characteristics of ice cream coffee

Treatment	Overrun (%)	Melting time (minutes)	L	a	b
Interaction					
• CMC 0%, Coffee 5% (C1P1)	31.48^{d}	12.70^{h}	76.00^{c}	1.33^{b}	18.33^{d}
• CMC 0%, Coffee 7.5% (C1P2)	30.70^{d}	12.94^{g}	63.67^{f}	2.67^{a}	26.00^{a}
• CMC 0.5%, Coffee 5% (C2P1)	43.46^{a}	16.46^{f}	78.67^{b}	2.00^{ab}	19.00^{d}
• CMC 0.5%, Coffee 7.5% (C2P2)	42.01^{a}	16.82^{e}	66.67^{e}	1.67^{ab}	23.33^{b}
• CMC 1%, Coffee 5% (C3P1)	39.80^{b}	18.41^{d}	80.00^{b}	1.67^{ab}	20.67^{c}
• CMC 1%, Coffee 7.5% (C3P2)	38.54^{b}	18.71^{c}	68.67^{e}	2.00^{ab}	22.67^{b}
• CMC 1.5%, Coffee 5% (C4P1)	35.47^{c}	20.48^{b}	82.67^{a}	2.67^{a}	19.67^{cd}
• CMC 1.5%, Coffee 7.5% (C4P2)	34.81^{c}	20.79^{a}	71.67^{d}	2.33^{ab}	18.67^{d}

Melting time

Melting time was the time it took for the ice cream to melt at room temperature after the initial drop. Table 2 shows a substantial ($P<0.05$) effect of CMC and coffee on the melting time of coffee ice cream. Coffee ice cream melted in 12.700 to 20.794 minutes. The more CMC added, the slower the ice cream melted. CMC was a stabilizer that improved emulsion stability (Satriani et al., 2018). When the stabilizer is dispersed in the liquid phase, it binds a large amount of water and forms a gel framework that prevents water molecules from moving freely, and the membrane formed protects the ice cream components from the effects of external temperature while limiting water mobility in the emulsion. The increased free water trapped would result in ice cream that took longer to melt (Jariyah et al., 2019).

The pace of ice cream melting is related to overrun and total solids. CMC increases viscosity and narrows the area between particles, reducing the amount of free air trapped. The smaller free air trapped causes ice cream to melt more slowly. Increasing the amount of stabilizer affected the binding of free air, causing the ice cream mixture to thicken and take longer to melt (Manurung et al., 2021).

The addition of stabilizers to ice cream increases its melting resistance due to its capacity to hold water and raise the mixture's viscosity. According to Satriani et al. (2018), good ice cream is resistant to melting when served at room temperature. Ice cream's rapid melting was a negative attribute because it was prone to heat shock. Because of their propensity to hold moisture, hydrocolloids have a considerable impact on the melting properties of ice cream.

Brightness Color

Ice cream with CMC and coffee had L*, a*, and b* values ranging from 63.67 to 82.67, 1.33 to 2.67, and 18.33 to 26.00, respectively (Table 2). CMC had no significant effect on color values, while coffee powder had a substantial effect on the ice cream's brightness value (L*). The more coffee powder used, the darker the ice cream becomes. Panelists chose darker ice creams because black ice cream is still uncommon.

Sensory acceptance

Consumer preferences describe a person's requirements and aspirations for a product. This was critical to meeting the rising demand for food production and producing items that meet customer preferences and needs. Consumer preferences can be determined by examining the features related to the product and its categories (Antarlina et al., 2024). Color, scent, taste, texture, and general approval were important factors influencing consumer acceptance. This study also examined the impact of CMC and coffee powder treatments on the sensory profiles of ice cream coffee (Figure 1). This analysis showed that CMC and coffee were the most important factors influencing ice cream acceptability (Table 3).

Color

Color qualities were critical in determining a product's quality because the color was the quickest way to make a favorable impression (Khamidah & Antarlina 2022). The presence of CMC had no effect on the color preference of the ice cream. The more coffee powder was used, the darker the ice cream became, and the panelists preferred it because it was more fascinating and unusual.

Aroma

The aroma is a sensory component that comes from the interaction of volatile food components with olfactory receptors in the nasal cavity and determines food deliciousness (Nuraini et al., 2024). CMC is an odorless chemical; hence, increasing the CMC concentration does not affect the aroma of ice cream. The addition of coffee powder had a noticeable effect on the aroma of the ice cream. Panelists liked the ice cream with the highest percentage of coffee powder.

Texture

Texture is described as the physical and mouthfeel properties of a meal or beverage. Ice cream has a unique texture because it contains all three phases of matter: solid (ice crystals and fat globules), liquid (sugar solution), and gas (air bubbles) (Parid et al., 2021). Large ice crystals hurt the ice cream's texture. The inclusion of hydrocolloids increases the diameter of ice crystals. Ice cream with hydrocolloids showed smaller ice crystals and a more homogeneous structure than samples without. The shape of ice crystals is determined by the type of stabilizer used, while ice cream composition also influences the diameter.

Panelists in this study reported that the more CMC there was, the more they disliked the ice cream texture since it became tougher. Panelists found it challenging to consume because of the rough texture. Meanwhile, adding extra coffee did not affect the preference for the texture of the ice cream. The ice cream's texture was softer due to the inclusion of CMC in the dough. Furthermore, the formation of lactose crystals would provide a smoother surface and avoid retrogradation. However, extra CMC produced a hard ice cream texture, which panelists disliked. Panelists prefer an ice cream texture that is neither too soft nor too hard. A good ice cream texture, according to Mailoa et al. (2017), is smooth or soft (smooth) and not firm, whereas a bad texture is greasy (feels like fat lumps), grainy (feels like flour), flaky/snowy (feels like ice flakes), lumpy/gelatin (like jelly), and sandy.

Taste

Texture and taste were crucial factors in producing high-quality ice cream. Flavor was a chemosensory quality perceived by receptors in the tongue and nose, whereas texture was completely perceived in the mouth during chewing (Parid et al., 2021). The gustatory nerves received a perception known as taste. It determines ice cream preference (Fauziah et al., 2023).

The taste of ice cream is affected by stabilizers and component composition. Texture variations can also have an impact on the flavor of ice cream. The higher the CMC concentration, the less preferred the ice cream taste because it provided a thick mouthfeel. However, as the volume of coffee increased, panelists' preference increased as the flavor became stronger.

Overall acceptance

The addition of high doses of CMC reduced the level of liking for ice cream. The decline in ice cream palatability was linked to the total solids and viscosity of the cream. If the total solids and viscosity were too high, the ice cream became denser and tougher to melt in the tongue (Manurung et al., 2021). The panelists preferred the coffee-infused ice cream because it provided a distinct coffee color, scent, and flavor, making it more appealing and unique. However, the increased quantity of CMC rendered the ice cream less appealing.

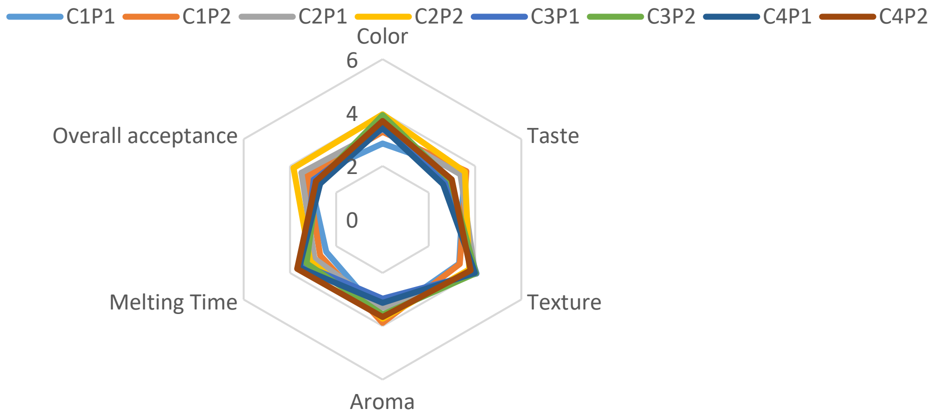

Figure 1. The sensory characteristics of ice cream coffee

Table 3. The effects of different treatments on the panelist preferences

Treatment	Color	Taste	Texture	Aroma	Melting time	Overall acceptance
Interaction						
• CMC 0%, Coffee 5% (C_1P_1)	2.84^{c}	3.53^{a}	3.31^{b}	3.66^{ab}	2.44^{e}	3.16^{bcd}
• CMC 0%, Coffee 7.5% (C_1P_2)	3.28^{bc}	3.62^{a}	3.34^{b}	3.87^{a}	2.69^{de}	3.25^{bc}
• CMC 0.5% Coffee 5% (C_2P_1)	3.37^{b}	3.37^{ab}	4.00^{a}	3.31^{bc}	2.94^{cd}	3.50^{ab}
• CMC 0.5%, Coffee 7.5% (C_2P_2)	3.94^{a}	3.56^{a}	3.75^{ab}	3.72^{a}	3.12^{bcd}	3.84^{a}
• CMC 1%, Coffee 5% (C_3P_1)	3.41^{b}	2.81^{c}	4.06^{a}	2.97^{c}	3.41^{abc}	2.97^{cd}
• CMC 1%, Coffee 7.5% (C_3P_2)	3.91^{a}	2.94^{bc}	4.03^{a}	3.56^{ab}	3.28^{abc}	2.81^{cd}
• CMC 1.5%, Coffee 5% (C_4P_1)	3.44^{b}	2.62^{c}	4.00^{a}	3.12^{c}	3.60^{ab}	2.69^{d}
• CMC 1.5%, Coffee 7.5% (C_4P_2)	3.70^{ab}	3.00^{bc}	3.81^{a}	3.66^{ab}	3.70^{a}	2.87^{cd}

Best treatment based on the CPI Method

The optimum treatment for coffee ice cream based on overrun, color, melting time, and sensory acceptance was discovered in C2P2 treatment (addition of 0.5% of CMC and 7.5% of coffee). This is evidenced by the highest alternative value computed in C2P2 therapy (Table 4).

Table 4. CPI method on coffee ice cream

Treatment	Alternative value
C_1P_1	107.86
C_1P_2	112.02
C_2P_1	122.36
C_2P_2	128.72
C_3P_1	119.43
C_3P_2	122.49
C_4P_1	118.43
C_4P_2	124.16

Conclusion

The use of CMC as a stabilizer and coffee powder has a substantial impact on ice cream's physical qualities and acceptance. The ice cream with 0.5% CMC and 7.5% coffee powder proved to be the optimum treatment in terms of overrun, melting time, color, and sensory acceptability. Overall, this research is useful in the production of ice cream varieties employing readily available and preferred ingredients, such as coffee.

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