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Physicochemical Characteristics of Watermelon Rind Puree Ice Cream with Cornstarch Addition

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ABSTRACT

Ice cream is a frozen dairy product made from milk and other ingredients such as sugar, emulsifier, and fruit for flavoring and enhance the nutrition content. Watermelon rind, which is rich in pectin that can form gel structures, is used for nutritional ingredient of ice cream. Pectin gel plays an important role in maintaining ice cream stability and reducing melting rate. In addition, cornstarch was added to the ice cream formulation for thickening and stabilization agent. This study contributed to evaluate the effect of watermelon rind puree and cornstarch addition on the physicochemical properties of ice cream. The ice cream production using comparison of watermelon rind puree and corn starch in three variations, namely 205:5 g (F1); 200:10 g (F2); and 195:15 g (F3). The observed parameters included overrun, viscosity, melting rate, fat content, vitamin C content, and antioxidant activity. The results showed that the addition of cornstarch had a significant effect on overrun, viscosity, melting rate, vitamin C content, and antioxidant activity, but had no significant effect on fat content. The melting rate and overrun value increased, while the highest viscosity was observed in F3 (1863.00 mPa.s). Antioxidant activity also increased significantly from F1 (42,300.52%) to F3 (54,882.33%). The highest vitamin C content was found in F3 (25.63 mg/100g). These findings indicate that the addition of cornstarch and watermelon rind puree improves the physical quality of ice cream and helps retain its bioactive compounds, with F3 identified as the best formulation.

KEYWORDS

Corn starch; Emulsifier; Ice cream; Stabilizer; Watermelon rind

1. INTRODUCTION

Ice cream is a frozen dairy product that is widely favored due to its smooth texture, sweet taste, and refreshing sensation. The quality of ice cream is largely determined by its physical characteristics, such as texture, viscosity, overrun, and melting rate [1], [2]. However, problems often occur during the production process, including the formation of large ice crystals, unstable structure, and rapid melting, which can reduce product quality [3], [4]. Therefore, the addition of stabilizing agents is necessary to improve the stability and overall quality of ice cream.

One potential natural stabilizer is pectin, a polysaccharide found in plant cell walls. Pectin is a polysaccharide mostly composed of galacturonic acid linked by α-(1,4) bonds. Pectin is a multifunctional substance located in the intercellular space and middle lamella of higher plants [5]. Pectin is utilized in food and beverage goods, cosmetics, pharmaceuticals, medicinal applications, and textiles. It functions as a gelling/thickening agent and stabilizer in the food industry owing to its capacity to create aqueous gels [6]. Pectin has the ability to form gels and bind water, thereby increasing viscosity, preventing ice crystal

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formation, and improving the stability of food systems [7]. It improves the quality and texture of various food products, such as beverages, jams, jellies, dairy products, and confections [8].

The watermelon comprises roughly 2% seeds and 15–30% rind and pulp. The watermelon rind is a significant portion of solid waste that is disposed of in the environment. Over 90% of watermelon rind trash is discarded as residue, hence posing environmental issues [9]. Watermelon rind (*Citrullus lanatus*), particularly the albedo portion, is an underutilized by-product that contains pectin, vitamin C, and bioactive compounds such as flavonoids and phenolics, which exhibit antioxidant properties [10], [11]. The use of water melon rind in research on mayonnaise has been proven to be a stabilizer when the fat content in mayonnaise is reduced. The results indicated that the incorporation of watermelon rind flour significantly enhanced emulsion stability and moisture content, had a notable impact on pH, and did not significantly affect the sensory evaluation of mayonnaise. This study revealed that including 6% watermelon rind flour as a stabilizer yields high-quality mayonnaise [10]. Other research indicates that including watermelon rind into pasta production does not compromise structural integrity and imparts a richer yellowish coloration to the pasta. This would facilitate sustainable ways for minimizing food waste while generating new potential for the creation of useful foods [12].

A recent study modelled and optimized pectin extraction from watermelon rinds regarding yield, revealing that its structural characterization indicated longer sugar side chains compared to commercial citrus or apple pectin. The existence of elongated branched chains in pectin has been associated with enhanced emulsifying characteristics; specifically, acid-extracted watermelon rind pectin has demonstrated emulsion capacity comparable to that of Arabic gum, a polysaccharide renowned for its emulsifying abilities [13], [14], [15]. Watermelon rind exhibited remarkable emulsification capacity, successfully incorporating up to 60% (v/v) oil in the emulsions while ensuring prolonged stability. The emulsification mechanism in the current situation was elucidated by the interaction of its protein content, which functions as surface-active agents, and the molecular bindings between droplets induced by the extensive chain branches of the RG-1 loaded pectin [15]. Therefore, watermelon rind has the potential to be an emulsifier agent in food products including ice cream.

Besides pectin, other stabilizers such as cornstarch are commonly used in ice cream production. Cornstarch is a popular hydrocolloid component in food industries due to its thickening, stabilizing, and texturizing qualities. It is made from maize kernel endosperm and contains amylose and amylopectin [16]. Cornstarch granules absorb water, expand, and gelatinize when heated, increasing viscosity and thickening the system. Cornstarch is frequently employed as a thickening agent in soups, sauces, gravies, puddings, pie fillings, and confections. Cornstarch not only thickens but also acts as a stabilizing agent, ensuring the even distribution of ingredients and preventing phase separation in food systems [17], [18]. Cornstarch enhances water retention and minimizes syneresis in dairy products, sweets, and processed meals, hence improving product stability during storage. It also improves in the stabilization of emulsions and suspensions by enhancing the viscosity of the continuous phase, so restricting the movement of dispersed particles and droplets [19], [20], [21]. Moreover, cornstarch does not significantly affect the taste or color of the product, making it a suitable alternative stabilizer.

The use of cornstarch is advantageous despite the presence of watermelon rind pectin, as both hydrocolloids fulfil complimentary roles within the ice cream matrix. Pectin mainly improves water retention and prevents ice crystal formation, whereas cornstarch contributes in viscosity enhancement and structural fortification via gelatinization [22], [23], [24]. During processing, hydrogen bonding transpires between the hydroxyl groups of pectin and starch polymers (amylose and amylopectin), leading in a more cohesive three-dimensional network. This integrated hydrocolloid system more efficiently retains water, stabilizes air cells and fat globules, and fortifies the frozen matrix, therefore enhancing texture and extending melting duration relative to the usage of pectin alone [22], [25], [26].

The combination of watermelon rind and cornstarch is expected to provide a synergistic effect in improving the physicochemical properties of ice cream. However, the effect of cornstarch addition on ice cream containing watermelon rind puree has not been widely studied. Therefore, this study contributes to evaluate the effect of cornstarch and watermelon rind puree on the physicochemical characteristics of ice cream, including overrun, viscosity, melting rate, fat content, vitamin C content, and antioxidant activity.

2. MATERIALS AND METHODS

2.1. Materials

The materials used in this study consisted of watermelon rind (*Citrullus lanatus*) from seedless res watermelon obtained from traditional market in Bantul, Yogyakarta, cornstarch (Rose Brand), vanilla essence (Koepoe-Koepoe), milk (Ultramilk), sugar (Gulaku), and emulsifier (Koepoe-Koepoe). Chemicals reagents that used for analysis included ethanol, 2,2-diphenyl-1-picrylhydrazyl (DPPH), hexane, starch solution, iodine solution (0.01 N), potassium iodide (KI) solution, starch indicator, dilute sulfuric acid (H_2SO_4), ascorbic acid, and distilled water (aquadest). All chemicals used for analysis were analytical grade.

2.2. Preparation of Watermelon Rind Puree

Watermelon was cut into four parts to facilitate processing. The white inner rind (albedo) was separated, cut into smaller pieces, and weighed (300 g). The rind was then blended for approximately 3 minutes until a homogeneous mixture was obtained. The puree was filtered to obtain a smooth texture.

2.3. Ice Cream Preparation

The milk, sugar, vanilla, watermelon rind puree, and cornstarch according to each formulation in Table 1 were homogenized. The mixture was pasteurized at 80 °C for 7 minutes under continuous stirring, followed by filtration process. After that, the mixture was cooled for 5 hours at -18 °C and it was mixed for 10 minutes. Subsequently, the emulsifier was added to the mixture, and it was homogenized. Finally, the ice cream mixture was frozen at -18 °C for 24 hours to obtain the final product [27], [28].

Table 1. Watermelon rind ice cream formulation.

Ingredients	F1	F2	F3
Watermelon rind puree (g)	205	200	195
Corn starch (g)	5	10	15
Milk (mL)	200	200	200
Sugar (g)	30	30	30
Emulsifier (g)	5	5	5
Vanilla extract (g)	2	2	2

2.4. Melting Time Analysis

Melting time was determined using the gravimetric method. Approximately 100 g of ice cream sample was placed on a wire mesh over a beaker and allowed to melt at room temperature (25 ± 1 °C). The melting process was observed until complete melting occurred. The time required for the sample to melt was recorded, and all measurements were conducted under similar environmental conditions to ensure consistency [29].

2.5. Overrun Analysis

Overrun was determined based on the increase in volume due to air incorporation during the freezing process. The initial volume of the ice cream mix and the final volume after freezing were measured. Overrun was calculated using the standard equation, expressed as a percentage. Higher overrun values indicate better air incorporation, which contributes to improved texture and softness of the ice cream [30]. The calculation of overrun percentage was obtained by equation (1).

$$\text{Overrun (\%)} = \frac{\text{Final volume - Initial volume}}{\text{Initial volume}} \times 100 \tag{1}$$

2.6. Viscosity Analysis

Viscosity of the ice cream mix was measured using a Brookfield viscometer (NDJ-9S). Approximately 100 mL of sample was placed in a beaker, and the measurement was performed using spindle No. 2 at a speed of 30 rpm. Then, the measurement was conducted for 2 minutes until a stable reading was obtained. The viscosity value was recorded in centipoise (cP) [31].

2.7. Fat Content Analysis

Analysis of fat content with the Soxhlet method with a sample weight of 2 g. The specimen was positioned into a paper sleeve, which was lined with cotton at both the top and bottom. The sample was subsequently heated to 60 °C for 1 hour. The sample was subsequently positioned in a Soxhlet apparatus alongside a flask containing boiling stones. Fat was extracted with hexane for a duration of 6 hours. Subsequent to this procedure, the hexane in the flask was heated until evaporation occurred, and the fat was returned to the oven to be dried at 105 °C until a consistent weight was achieved [32]. The fat content in ice cream was determined using equation (2), where W_1 was weight of flask (g), W_2 was weight of flask after extraction (g), and W was weight of sample (g).

$$\text{Fat content (\%)} = \frac{(W_2 - W_1)}{W} \times 100 \tag{2}$$

2.8. Vitamin C Content Analysis

Vitamin C content was analyzed using the iodometric titration method. Approximately 10 g of homogenized sample was diluted with distilled water and filtered. An aliquot of 10 mL filtrate was titrated with 0.01 N iodine solution using starch as an indicator until a stable blue color appeared for approximately 15 seconds. The volume of iodine used was recorded and be used to calculate vitamin C content that expressed as mg/100 g sample [33], [34]. The calculation of vitamin C value was obtained by equation (3), where V was iodine volume (mL), N was iodine normality, BE was molecular weight, and FP was dilution factor.

$$\text{Vitamin C (mg/100 g)} = \frac{V \times N \times BE \times FP \times 100}{\text{Sample weight (g)}} \tag{3}$$

2.9. Antioxidant Activity Analysis

Antioxidant activity was determined using the DPPH radical scavenging method. Approximately 5 g of sample was extracted with methanol, followed by filtration to obtain a clear solution. One mL of the extract was mixed with 3 mL of 0.1 mM DPPH solution. The mixture was incubated in the dark atmosphere at room temperature for 30 minutes. Absorbance was measured at 517 nm using a UV-Vis spectrophotometer. Antioxidant activity was expressed as percentage inhibition of DPPH radicals and calculated using equation (4) [35].

$$\text{Antioxidant activity (\% inhibition)} = \frac{\text{Control absorbantion - Sample absorbantion}}{\text{Control absorbantion}} \times 100 \tag{4}$$

2.10. Statistical Analysis

The collected data were subjected to statistical analysis using one-way Analysis of Variance (ANOVA). When the result was significant differences ($p<0.05$), then the analysis was performed using Duncan's Multiple Range Test (DMRT) to determine the differences between means. All parameters were analyzed in triplicates.

3. RESULTS AND DISCUSSION

3.1. Melting Time

Melting rate is an important quality parameter that reflects the stability of ice cream at ambient temperature. The melting behavior is influenced by composition, consistency, air incorporation, ice crystal properties, and the fat globule network [36]. As can be observed from the Table 2, the melting rate increases significantly, along with the addition of corn starch, around 10.19–13.60 minutes.

Table 2. Melting rate of watermelon rind ice cream.

Formulation	Melting rate (minutes)
F1	10.19 ± 0.09[a]
F2	11 56 ± 0.64[b]
F3	13.60 ± 0.50[c]

Notes: Different letter notations indicate significant differences between formulations ($p<0.05$).

Raising the concentration of corn starch in watermelon rind ice cream prolongs the melting duration. This phenomenon is attributed to gelatinized cellulose starch's capacity to bind a larger volume of water, hence enhancing the mixture's viscosity. Increased viscosity leads to a more stable ice cream structure, minimizing free water and reinforcing the network among water, fat, and air. Consequently, the ice cream melts at a reduced rate, leading to an extended melting duration as the concentration of corn starch increases [16], [37], [38].

In addition, the presence of pectin enhances the gel structure, further strengthening the matrix and limiting water mobility. A stronger matrix reduces structural collapse during melting, thereby prolonging the melting time [39]. Stabilizers improve melting resistance by enhancing structural integrity and reducing ice crystal growth. Interestingly, the improvement in melting resistance is closely related to viscosity and overrun. A more viscous system with higher air incorporation tends to exhibit better melting stability due to stronger structural support [40], [41]. Utilizing roasted or grilled maize powders in ice cream manufacturing shown an enhancement in melting duration. The prolonged melting time may be attributed to the maize starch samples' capacity to retain water [42].

3.2. Overrun

Overrun is a critical attribute of ice cream that denotes the percentage increase in volume resulting from the incorporation of air during the freezing and whipping process. overrun in frozen desserts strongly impacts the melting process for two reasons. The insulating characteristics of air limit heat transfer during the melting process. Secondly, an increased volume of air encapsulated inside the fat matrix typically improves the stability of the melted ice cream foam, resulting in reduced melting rates and foam collapse, so yielding a greater quantity of melted foam at the conclusion of the test [43]. As can be seen from Table 3, the overrun value rise significantly ($p<0.05$), along with the addition of corn starch. The number of overrun in three formulations ranging from 87.89–120.05%. If the overrun is higher, the melting time will be slower. This phenomenon can be ascribed to both the elevated quantity of air bubbles encapsulated in the melted foam, which contributed to structural integrity, and alterations in further structural components, such as fat instability, which was enhanced by the enhanced overrun [44].

Table 3. Overrun of watermelon rind ice cream.

Formulation	Overrun (%)
F1	87.89 ± 0.05[a]
F2	107.50 ± 0.03[b]
F3	120.05 ± 0.13[c]

Notes: Different letter notations indicate significant differences between formulations ($p<0.05$).

This trend indicates that the addition of cornstarch improves the ability of the ice cream mix to entrap and stabilize air bubbles. Cornstarch, as a starch-based stabilizer, undergoes gelatinization during heating, forming a viscous matrix that enhances the resistance of air bubbles to coalescence and collapse. As a result, more air is retained within the structure, leading to higher overrun values [21], [45].

Furthermore, the presence of pectin from watermelon rind contributes synergistically to this effect by forming a hydrocolloid network that stabilizes the dispersed air phase. The interaction between starch and pectin creates a more structured and elastic matrix, which supports air incorporation and retention during freezing [46]. However, although higher overrun is generally desirable for improving volume and lightness, excessively high values may negatively affect texture, resulting in a product that is too airy and less creamy. Therefore, formulation optimization is necessary to balance overrun and sensory quality [47].

3.3. Viscosity

During the ice cream crystallization process, viscosity is the most dynamic attribute. This is caused by the liquid transitioning into a semi-solid due to the formation of ice crystals. The viscosity of the ice cream mixture escalates due to two factors: a reduction in the temperature of the liquid mixture and an increase in the volume fraction of solid particles (ice crystals). Consequently, the viscosity of ice cream is dictated by the viscosity of the non-frozen phase and the proportion of ice formed during the freezing process [31], [39]. As can be seen from Table 4, the viscosity results showed a significant increase ($p<0.05$), along with the addition of corn starch. The number of viscosities in F1–F3 ranging from 350.66–1863.00 mPa.s approximately.

Table 4. Viscosity of watermelon rind ice cream.

Formulation	Viscosity (mPa.s)
F1	350.66 ± 39.31^{a}
F2	1745.33 ± 10.06^{b}
F3	1863.00 ± 119.60^{b}

Notes: Different letter notations indicate significant differences between formulations ($p<0.05$).

The increase in viscosity is primarily attributed to starch gelatinization. When heated, starch granules absorb water, swell, and release amylose, forming a continuous network that increases resistance to flow. This results in a thicker and more stable system [48]. Additionally, pectin from watermelon rind acts as a hydrocolloid that enhances viscosity by forming a gel-like structure. The combined effect of starch and pectin creates a synergistic interaction that significantly improves the rheological properties of the ice cream mix [49].

However, the absence of a not significant difference between F2 and F3 suggests that the system reached a saturation point, where further addition of cornstarch no longer contributes significantly to viscosity enhancement. This indicates the existence of an optimal concentration of stabilizer [50]. Higher viscosity positively influences other properties such as overrun and melting rate. A thicker matrix is more capable of retaining air and slowing down melting, demonstrating the interdependence of physicochemical parameters [51].

3.4. Fat Content

Frozen desserts encompass ice cream, gelato, frozen yogurt, ice milk, milkshakes, sherbets, and frozen mousse, with fat content generally varying from 0% to 18%. In typical cow milk, saturated fats constitute roughly 70% of the total fat content by weight. Saturated fats facilitate fat crystallization by establishing dense crystal networks, so enhancing structural rigidity, decreasing the melting rate, and eventually elevating ice cream quality [52], [53], [54]. As can be seen from Table 5, the fat content value does not show a significant different among the formulation and the fat content number ranging from 2.10–1.12%. This issue indicates that the addition of cornstarch does not influence lipid content in ice cream.

The low-fat content in watermelon rind ice cream affects the resulting texture. This outcome is probable as cornstarch is predominantly constituted of carbohydrate molecules and lacks fat content [55]. In ice cream made from European Cranberry bush, the fat content obtained is more than 6.5% [29]. This value is higher than the ice cream fat content in this study. The lipid content primarily originates from milk, which is the main source of fat in the formulation. The slight increase observed in F3 may be attributed to improved fat dispersion within a more viscous matrix. A thicker system can stabilize fat globules more effectively, leading to a more uniform distribution. However, these differences are not statistically significant. In frozen desserts, fat might improve quality by enhancing sensory attributes such as creaminess, mouthfeel, water holding capacity (WHC), flavor retention, and structural stability, while it may also present some obstacles. From a physiochemical perspective, decreasing fat content disrupts the fat globule network, leading to brittleness, iciness, coarseness, and shrinking of the final product [28], [56], [57].

Table 5. Fat content of watermelon rind ice cream.

Formulation	Fat Content (%)
F1	2.10 ± 0.03
F2	2.10 ± 0.01
F3	2.12 ± 0.05

3.5. Vitamin C

Analyzing vitamin C is crucial for fruit-flavored ice creams that include elevated vitamin C levels [58]. As can be seen Table 6, the vitamin C content show significant increase in all the formulations. The higher the corn starch in the formulation, the higher vitamin C content. The number of vitamin C number ranging from 11.85–25.63 mg/100g.

Table 6. Vitamin C content of watermelon rind ice cream.

Watermelon Puree Ice Cream	Vitamin C (mg/100g)
F1	11.85 ± 2.96[a]
F2	17.24 ± 3.89[a]
F3	25.63 ± 3.34[b]

Notes: Different letter notations indicate significant differences between formulations ($p<0.05$).

Vitamin C in this study originates from watermelon rind puree, which contains bioactive compounds with antioxidant properties [12]. The increase in vitamin C retention at higher cornstarch concentrations is likely associated with the formation of a more viscous and compact matrix. Vitamin C is highly sensitive to oxidation, especially in the presence of oxygen, heat, and light. A more viscous system reduces oxygen diffusion and limits oxidative reactions, thereby preserving vitamin C content [59], [60]. Moreover, the gel matrix formed by starch and pectin may act as a protective barrier, reducing exposure to environmental factors that promote degradation. This finding highlights the indirect role of stabilizers in preserving bioactive compounds in food systems.

3.6. Antioxidant Activity

Watermelon rind had an antioxidant inhibition of 344,800%, while the pulp was around 330,500%. As can be seen in Table 7, the antioxidant inhibition level decreased significantly with decreasing amount of watermelon rind puree. The antioxidant activity level of watermelon rind puree ice cream ranged from 42,300.52–54,882.33%. The decrease in the level of antioxidant activity in watermelon rind after being processed into ice cream is quite significant, but the value still shows that there is still free radical inhibition activity in watermelon rind ice cream.

Table 7. Antioxidant activity of watermelon rind ice cream.

Formulation	Antioxidant activity (%)
F1	54,882.33 ± 223.96[c]
F2	48,286.29 ± 229.86[b]
F3	42,300.52 ± 300.22[a]

Notes: Different letter notations indicate significant differences between formulations ($p<0.05$).

This trend is primarily attributed to the dilution effect caused by increasing the proportion of cornstarch in the formulation. Since cornstarch does not contain antioxidant compounds, its addition reduces the relative concentration of bioactive compounds derived from watermelon rind, such as phenolics and vitamin C. In addition, the formation of a dense gel matrix may hinder the release or extraction of antioxidant compounds during analysis, particularly in the DPPH assay. The effectiveness of radical scavenging depends on the accessibility of active compounds, which may be limited in a more structured system [61]. Processing conditions such as heating, mixing, and freezing may also contribute to the degradation of antioxidant compounds. Phenolic compounds and vitamin C are sensitive to oxidation, and their stability can be affected by processing intensity [62], [63].

4. CONCLUSION

The addition of cornstarch significantly affected the physicochemical characteristics of watermelon rind puree ice cream. Variations in cornstarch concentration showed a significant influence ($p < 0.05$) on physical properties, including overrun, viscosity, and melting rate. In contrast, the fat content was not significantly affected by the treatments. Regarding chemical properties, the addition of cornstarch significantly influenced vitamin C content and antioxidant activity. Higher concentrations of cornstarch improved overrun, viscosity, melting resistance, and vitamin C retention. However, antioxidant activity tended to decrease due to the dilution effect and possible limitations in the release of bioactive compounds within a more structured matrix. Overall, the formulation with the highest cornstarch concentration (F3) exhibited the best physicochemical characteristics in terms of physical stability and vitamin C content. Therefore, cornstarch can be effectively utilized as a stabilizer to enhance the quality of watermelon rind-based ice cream, while also supporting the valorization of agricultural by-products.

AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Ali Jebreen**: Writing (review & editing) and translating. **Maretha Indra Puspa**: Writing (review & editing), writing (original draft), and formal analysis. **Safinta Nurindra Rahmadhia**: Writing (review & editing), investigation, supervision, and conceptualization. **Swapnil Prashant Gautam**: translating.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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