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https://doi.org/10.5109/7395764

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 11, pp.1910-1917, 2025-10-30. International Exchange and Innovation Conference on Engineering & Sciences
バージョン：

Physico-chemical and Sensory Evaluation of Ice Cream Enhanced with Spray-Dried Papaya (*Carica papaya* L.) Powder

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Abstract: *This study investigated the potential of spray-dried papaya (Carica papaya L.) powder as a flavor enhancer in ice cream. The research aimed to assess the effects of papaya powder, produced from fruits at two maturity stages (3 and 4), and incorporated at varying concentrations (3% and 6%), on the physicochemical and sensory qualities of ice cream. Physicochemical to evaluate were pH, total soluble solids, moisture, overrun, melting rate, and microbial quality (Staphylococcus aureus count). Sensory evaluation was conducted to determine acceptability in terms of color, aroma, taste, flavor, texture, and overall impression, as well as the intensity of papaya aroma and flavor. The results showed that adding spray-dried papaya powder significantly improved the texture, and positively influenced sensory attributes. Ice cream containing moderate levels of papaya powder from maturity stage 4 (T3) received the highest acceptability ratings. The study concluded that spray-dried papaya powder is a promising natural flavor and nutritional enhancer for ice cream.*

Keywords: Spray-dried papaya; Ice cream; flavor enhancement.

1. INTRODUCTION

Papaya (*Carica papaya* L.), is the succulent fruit of a big plant from the family Caricaceae. The most popular and extensively cultivated species belongs to the genus Carica Linn., because of its melon-like fruit taste [1]. Papayas are a reliable cash crop all year round due to their rapid fruit production and ease of cultivation [1]. Whether consumed in its raw form as an appetizer or when fully ripened and sweetened as a dessert, has emerged as a significant fruit crop in the Philippines and a common component in Filipino cuisine [2]. Originally from the American, now cultivated for both commercial and residential use in tropical and subtropical climates worldwide [3]. According to the Philippine Statistics Authority (PSA) in 2021, papaya was rated 10th in terms of the area of land used for cultivation and 4th in terms of the amount of fruit produced among the top ten fruit crops in the Philippines. Furthermore, a report from the PSA (2021), three regions that produced the highest amount of papaya were SOCSARGEN with 64,113.16 metric tons, Northern Mindanao with 38,030.41 metric tons, and Davao Region with 10,619.2 metric tons.

In addition, papaya is an excellent dietary complement because it contains many beneficial nutrients and bioactive substances [4]. The fruit is abundant in dietary fibers, which promote digestive movement, with the presence of a significant amount of papain enzyme further enhances this effect, and high content of vitamins A, B, and C, contribute in supporting overall health [5]. Its various parts, including the fruit, seeds, and leaves, have been used in medicine for their anti- inflammatory, antioxidant, anticancer and wound-healing properties. According to Abdul Mutalib (2014), immature papaya fruit is traditionally utilized for its therapeutic properties, particularly in treating ulcers and impotence. It is also employed to address menstrual irregularities and to promote the natural onset and flow of menstruation in women.

Ice cream, a frozen dairy product composed of milk and milk products, is a highly favored food delight worldwide [6]. It is consumed as a dessert or snack, with projected global sales reaching an impressive US $75 billion by 2024. Its popularity is particularly evident in hot climates, as it effectively lowers body temperature because of its cooling properties. Nowadays consumers' growing understanding of the connection between food and health has resulted in a demand for ice cream that aligns with their physical and emotional well-being requirements [7]. Ice cream has a relatively high concentration of fat and sugar, which leads to a significant intake of these substances. As a result, it raises the likelihood of obesity, including pediatric obesity, and related health issues [8]. These concerns have resulted in a growing desire for low-calorie and high-fiber foods. According to Romulo et al. [9], papaya has the potential to reduce the risk of obesity associated with adiposity, anti-inflammatory and anti-oxidation.

Several studies have looked into ways to make spray dried papaya powder and how to use it to improve the qualities of other products. For instance, Manzoor et al. [2] discovered that the viscosity and sensory appeal of yogurt were enhanced by adding papaya peel powder. Drink mixes can effectively combine papaya powder, with the former emphasizing the importance of achieving optimal scent, taste, and flavor, and finding the most preferred in terms of sensory properties and nutrition, meeting human consumption and safety standards. These studies collectively demonstrate the potential for incorporating spray-dried papaya powder into a variety of products, with improving the nutritional content, and sensory properties. By making the papaya into powder help in making new innovative nutritious products. Therefore, this study aims to evaluated spray-dried papaya powder to enhance the flavor and promote the nutrient development of ice cream.

2. MATERIALS AND METHOD

2.1 Raw Materials Preparation

This study utilized the red lady papaya variety at maturity level 3 and 4. Maturity level 3 has a green that dominate over yellow color on the skin's surface, while in maturity level 4, the yellow color dominates with some green remaining on the skin [10]. The papayas were collected from Pinamanculan, Butuan City, Philippines. The collection of the commodities was done twice on different days. The first collection was for maturity level 4, and the second collection was for maturity 3. After the papayas ripened to the desired level, they were transported to the Food Innovation Center for the spray-drying process. The ripe papayas were washed with clean water, cut in half, and deseeded. The pulp was then scooped out manually to separate it from the skin. The collected pulp was weighed and placed in a clean container to freeze overnight.

2.2.1 Pulp Liquification

The extracted pulp was blended with distilled water at a 1:2 ratio—500 g of pulp with 1 liter of water—for 1 minute at high speed per batch. The mixture underwent manual water bathing [11] at 50°C for 2 hours, with intermittent stirring every 20 minutes for 5 minutes. The liquefied pulp was then filtered through a fine mesh cloth three (3) times to remove insoluble particles and ensure a smooth consistency. The puree was weighed, then mixed with 20% maltodextrin DE-10. It was stirred continuously until the two ingredients were well combined and then weighed again. The mixture was then placed in a clean container and frozen overnight (15 hours) at -40°C.

2.2.2 Spray-Dried Feed Solution

The researcher prepared two (2) different maturity levels of papaya for spray-drying. Maturity level 3 was used for T1 and T2, while T3 and T4 had maturity level 4. As stated by Apatan et al. [12], the best treatment for a flavor-enhancing spray-dried papaya powder was formulated with a 20% concentration of maltodextrin DE-10 and a spray dryer inlet temperature of 160°C. Thus, this study followed that formulation for the treatments.

2.2.3 Spray Drying Process

The frozen puree mixture was defrosted for 3 hours by partially submerging the container in water until it became liquid form. The spray dryer machine was preheated until it reached an inlet temperature of 160°C. Before initiating the spray-drying process, 1 liter of distilled water was used to clean the machine. Once cleaned, the first batch of puree mixture was processed. Prior to processing the next batch, another 1 liter of distilled water was used to remove any remaining residue from the first batch. After the final batch was completed, the machine was cleaned again using tap water from the facility to ensure proper maintenance and avoid contamination. The dried powder was collected and sieved to remove any unwanted particles that may have mixed during the process. The sieved powder was then weighed and stored in airtight containers in preparation for the ice cream-making process.

2.3.1 Ice Cream Preparation and Formulation

The ice cream formulation, as presented in Table 1, consists of cassava cornstarch (500 g), powdered milk (1500 g), coconut milk (2000 g), white sugar (2000 g), and water (4000 g), and the varying concentration of papaya powder. Cassava cornstarch serves as a natural thickening agent to improve the texture and body of the ice cream. Powdered milk provides milk solids-not-fat, contributing to the creamy mouthfeel and nutritional value. Coconut milk acts as the primary fat source, imparting a rich flavor and smooth consistency. White sugar is included to sweeten the mixture and regulate the freezing point, ensuring proper texture and scoopability. Water is used as the solvent to dissolve the ingredients and achieve the desired mix volume. Additionally, varying concentrations (3% and 6%) of spray-dried Level 3 and Level 4 papaya powders were incorporated into the formulation to enhance the ice cream's sensory qualities, including natural flavor, color, and nutritional benefits. These papaya powders also contribute bioactive compounds, enriching the functional properties of the final product.

Table 1. Formulations treatment of spray-dried papaya powder in the ice cream

Ingredients (g)	T1 3% at Maturity 3	T2 6% at Maturity 3	T3 3% at Maturity 4	T4 6% at Maturity 4
Cassava Cornstarch	500	500	500	500
Powdered Milk	1500	1500	1500	1500
Coconut Milk with Water	2000	2000	2000	2000
White Sugar	2000	2000	2000	2000
Water	4000	4000	4000	4000
Spray-Dried Papaya Powder	300	600	300	600
Total Formulation Weight	10300	10600	10300	10600

2.3.2 Ice Cream Making Process

The ice cream-making process began with the boiling of 2 liters of water. While the water was heating, half a kilogram of cassava flour was dissolved in 1 liter of warm mineral water. Mineral water was used throughout the procedure to ensure consistency and quality. Once the water reached a boil, it was gradually poured into the cassava mixture, with continuous stirring to ensure proper blending and to prevent lump formation. This step was performed slowly until all the boiled water was incorporated, resulting in a sticky consistency. After all the water had been added, mixing continued for 2 to 3 minutes. The mixture was then allowed to cool for approximately 1 hour.

In a separate step, 2 liters of warm water were added to freshly grated coconut. The mixture was manually squeezed to extract the coconut milk. Only the extracted coconut milk and water were used, while the coconut residue was discarded. The coconut milk was strained through a fine sieve and added to the cooled cassava mixture. The two components were thoroughly mixed until fully combined. The mixture was then placed in a large bowl and immersed in a basin containing ice water. The ice level was maintained at least 3 inches above the mixture to ensure adequate cooling. The mixture remained undisturbed in the ice bath for 4 hours.

After 4 hours, additional ice was packed around the mixture. The mixture was then slowly stirred while adding the milk in portions to achieve a creamier consistency. The gradual addition of milk allowed the mixture to expand. Once all the milk had been incorporated and the container was nearly full, white sugar was added incrementally while stirring continued. The mixing process was maintained for an additional 8 minutes to ensure complete dissolution of the sugar and even distribution throughout the mixture.

Finally, the mixture was transferred into a clean container and placed in a Styrofoam box with ice to maintain its temperature during delivery to the researcher.

2.3.3 Addition of Papaya Flavor to the Ice Cream

When the researcher received the unflavored ice cream mixture, it was divided into five equal portions: one portion served as the control, while the remaining four were designated as experimental groups (T1 to T4). To determine the amount of papaya powder to be added to each experimental portion, a ratio and proportion method was used, as shown in Equation 1. In this method, A represents the total weight of the unflavored ice cream mixture made, B refers to the desired concentration basis (such as 300 grams or 600 grams of papaya-flavored ice cream), C is the weight of each portion (calculated by dividing A by 5), and D is the unknown amount of papaya powder to be added.

$$A:B=C:D \qquad \text{Eq. (1)}$$

2.4 Physicochemical Analysis

Physicochemical analysis is considered essential in this study to better understand the impact of spray-dried papaya powder on the overall quality of the ice cream. While sensory evaluation captures consumer preferences, physicochemical data offers objective insight into the functional behavior and stability of the product. Since the formulation involves the incorporation of a new ingredient, analyzing its effects on the product's measurable properties is necessary to support the results and ensure consistency, safety, and acceptability of the ice cream

The following physicochemical parameters will be analyzed in this study: pH, moisture content, total soluble solids (TSS), melting test, and overrun.

2.4.1 pH Measurement

The pH level of the food sample was measured directly using a calibrated pH meter. This analysis was conducted in accordance with the pH and Temperature for Food Product (CHE-TM-007) method, based on the Official Methods of Analysis of AOAC international, 20th Edition, 2016. The pH value is a critical parameter in determining the acidity or alkalinity of the product, which influences both microbial stability and overall product quality.

2.4.2 Moisture

Moisture content was analyzed through the Air Oven Method (CHE-TM-004), following the Official Methods of Analysis of AOAC International (22nd Edition, 2023). This method involves drying a known weight of the sample in an oven at a specified temperature until a constant weight is achieved. The weight loss corresponds to the moisture content of the sample. This analysis is important as moisture affects product shelf life, texture, and susceptibility to microbial growth.

2.4.3 Total Soluble Solids (TSS)

To determine the total soluble solids (TSS) in the ice cream, a refractometer was used. First, the frozen ice cream samples were thawed at room temperature. Then, the refractometer was cleaned and properly calibrated.

Once calibrated, the refractometer was ready to measure the TSS of the ice cream. A small sample (T0) of the thawed mixture was placed on the prism or measuring surface. The cover plate was closed gently to distribute the sample evenly. The refractometer was held up to a light source, and the Brix value, which is the point where the light and dark areas meet, was read through the eyepiece, indicating the TSS percentage. Before measuring the next sample, the prism was cleaned with distilled water to maintain accuracy. This process was repeated for all samples, with each sample measured in three repetitions.

2.4.4 Overrun

To determine the overrun of the ice cream, the gravimetric method described by the National Dairy Development Board (2001) was used. In this method, W_1 is the weight of the container filled with the unfrozen ice cream mixture, and W_2 is the weight of the container filled with the frozen ice cream. The overrun was then calculated based on the difference in weight before and after freezing, reflecting the amount of air incorporated into the mixture during the freezing process.

$$\%\text{Overrun}=((W2-W1)/W2)/100 \qquad \text{Eq. (2)}$$

2.4.5 Melting Test

The melting resistance of ice cream was assessed following the method of Goh et al. [13]. Ice cream samples (8 cm × 3 cm) were stored overnight at -18°C and then placed on a metal mesh at room temperature (25°C). The mesh allowed the melted portion of the ice cream to drip through into a funnel positioned below, which directed the liquid into a beaker. The beaker was placed on a digital weighing scale to measure the weight of melted ice cream. Melted weight was recorded every 5 minutes over a 60-minute period to monitor the melting rate. Additionally, photographs were taken at 20-minute intervals to document visual shape deformation. The melting rate was determined from the slope of the plot of time versus melted weight.

2.5 Microbial Analysis

Microbial testing was conducted to assess the presence of pathogenic microorganisms and ensure the safety and quality of the developed food product. This analysis is essential for identifying potential sources of contamination and verifying compliance with food safety standards [14].

Staphylococcus aureus was enumerated using the 3M™ Petrifilm™ Staph Express Count Plate, following the protocol described in the Bacteriological Analytical Manual (BAM) Online, January 2001, Chapter 12: *Staphylococcus aureus*. This method provides a rapid and reliable means of detecting *S. aureus* in food samples.

2.6 Sensory Evaluation

To evaluate consumer acceptability for the developed ice cream containing papaya, we employed a two-step approach. First, a semi-trained sensory panel (8 judges) to assess the sensory characteristics of five (T0 - T5), including a control. Then, 70 untrained (student) judges from Carga State University, bringing the total number of panelists to 78. Panelists evaluated the color, aroma, taste/sweetness, flavor, texture/smoothness, and overall acceptability of each sample using a nine-point hedonic scale and evaluating the intensity of papaya aroma and flavor using intensity rating scale.

Prior to the sensory evaluation, participants were asked to read and sign an informed consent form. They were then given five ice cream samples: one control and four with spray-dried papaya powder at 3% and 6% concentrations, with two samples representing each papaya maturity stage (Stages 3 and 4). To minimize bias, the samples were presented in random order, each labeled with a unique sample code.

Participants were instructed to sit at tables with a maximum of three participants and to taste the samples in the sequence indicated on the forms. They were asked to evaluate the samples based on sensory attributes: color, aroma, taste, flavor, texture/smoothness, and overall acceptability. To ensure accurate assessment, they were briefed on the following: (1) they were not allowed to say out loud what they tasted to avoid bias, (2) they should cleanse their mouths with water between each sample, and (3) they were not allowed to disturb fellow judges and could only approach the researchers if they had any concerns or questions.

2.7 Statistical Data Analysis

The experiment employed a Completely Randomized Design (CRD) consisting of five (5) treatment samples: a control, and papaya-enriched ice cream formulations using spray-dried papaya powder at two maturity stages (maturity 3 and maturity 4) each have 3% and 6% concentrations. All samples were subjected to sensory evaluation using a 9-point Hedonic scale and an intensity rating scale (0 = no perceptible papaya to 10 = very perceptible papaya).

To analyze the data, one-way ANOVA were employed using a tool, Kruskal-Wallis test, a non-parametric. While ANOVA is a standard method for comparing treatment means, it assumes that the data are normally distributed. In this study, normality tests revealed that some datasets in sensory scores were skewed or contained outliers, violating this assumption. To address this, the Kruskal-Wallis test was applied as it does not require normal distribution and is more robust under such conditions. This allowed for more reliable comparisons of median values across treatment groups. Statistical significance was set at $p \leq 0.05$.

3. RESULTS AND DISCUSION

3.1 Physiochemical Properties of Papaya Ice Cream

The physicochemical properties described the physical and chemical characteristics of the ice cream, as shown in 2. These included pH level, total soluble solids (TSS), moisture content, overrun, and melting rate.

3.1.1 pH Level

The measurement of pH provides essential insights into the acid-base balance and overall quality of ice cream, especially when incorporating fruit-based additives such as spray-dried papaya powder. In this study, the addition of spray-dried papaya powder at varying concentrations and maturity stages resulted in notable changes in pH level of the ice cream samples.

Table 2 presents the measured pH levels of the ice cream samples across the five treatments. The results demonstrated that increasing the concentration of spray-dried papaya powder, particularly from riper papaya (maturity stage 4), led to a slight but consistent decrease in pH values. This trend can be attributed to the presence of organic acids-such as ascorbic acid and citric acid-in papaya, which are introduced into the ice cream matrix during formulation [5]. Lower pH values in ice cream can influence not only the flavor, imparting a subtle tartness, but also the product's microbial stability and shelf life.

3.1.2 Total Soluble Solid (TSS)

Total soluble solids (TSS), measured in degrees Brix (°Brix), are an important parameter in evaluating the quality of ice cream, as they reflect the concentration of dissolved sugars and other soluble components in the product. In this study, the addition of spray-dried papaya powder at increasing concentrations resulted in a corresponding increase in the TSS values of the ice cream samples, as shown in Table 2. This trend can be attributed to the inherent sugar content and soluble solids present in papaya powder, which are incorporated into the ice cream matrix during formulation. As the amount of papaya powder increases, more sugars and soluble solids are introduced, thereby elevating the overall TSS of the final product.

Furthermore, the results indicated that ice cream samples containing spray-dried papaya powder from maturity stage 4 exhibited higher TSS values compared to those from maturity stage 3. This observation is consistent with the natural ripening process of papaya fruit, during which starches are enzymatically converted into simple sugars such as glucose, fructose, and sucrose [15]. As papaya matures, particularly at stage 4, the fruit resulting in a sweeter and more flavorful profile. Consequently, the spray-dried powder derived from maturity 4 papaya contributes a greater quantity of soluble solids to the ice cream, thus increasing its TSS compared to powder from less mature fruit.

Table 2. Physicochemical parameters assessment of ice cream

Ingredients	**T0** Control	**T1** (3% of Maturity 3 Papaya)	**T2** (6% of Maturity 3 Papaya)	**T3** (3% of Maturity 4 Papaya)	**T4** (6% of Maturity 4 Papaya)
pH level	7.01^{a}	6.95^{a}	6.93^{a}	6.85^{b}	6.94^{a}
Total Soluble Solids (ºBrix)	32.53^{c}	34.3^{b}	36.53^{a}	34.43^{b}	36.00^{a}
Moisture (%)	66.1^{a}	64.18^{b}	62.93^{c}	64.69^{b}	63.12^{c}
Overrun (%)	43.97^{b}	43.78^{b}	44.36^{a}	44.77^{a}	43.96^{b}
Melting Rate (g/min)	1.86^{c}	1.71^{d}	1.99^{b}	2.06^{b}	2.52^{a}

The increase in TSS not only enhances the sweetness and sensory appeal of the ice cream but also influences its freezing point, texture, and overall mouthfeel. Higher TSS levels can improve the smoothness and palatability of the product, making it more desirable to consumers. These findings are in agreement with previous research, which demonstrated that the addition of fruit powders to dairy-based products leads to a significant increase in TSS, particularly when using powders derived from fully ripe fruits [16].

3.1.3 Moisture

Moisture content reflects the water content in the ice cream. Table 2 shows that the most notable shift was in maturity 3 at 6% treatment, with the lowest moisture content (62.93%). This outcome can be linked to the high dry matter content of the papaya powder, which effectively decreases the proportion of free water in the formulation. Reduced moisture levels enhance product stability by limiting ice crystal formation, improving texture, and extending shelf life [17].

3.1.4 Overrun and melting test

Overrun and melting rate were essential physicochemical parameters in evaluating the quality attributes of ice cream. Overrun refers to the percentage of air incorporated during the freezing process. A higher overrun typically resulted in a lighter, creamier ice cream, while a lower overrun produced a denser and heavier product. Meanwhile, the melting rate served as an indicator of the ice cream's resistance to melting under ambient conditions, a critical factor in consumer acceptability and product shelf-life

As presented in Table 2, The overrun percentages observed in the ice cream formulations were as follows: 43.97% for the control sample, 43.78% for T1 (3% maturity stage 3 papaya), 44.36% for T2 (6% maturity stage 3 papaya), 44.77% for T3 (3% maturity stage 4 papaya), and 43.96% for T4 (6% maturity stage 4 papaya). These values indicated a relatively consistent overrun across all treatment groups, suggesting that the inclusion of different papaya maturity levels (3% and 6% of maturity stages 3 and 4 papayas) did not significantly affect the air incorporation during the freezing process.

The slight variations in overrun between the different formulations were minimal, with the highest overrun observed in T3 (44.77%) and the lowest in T1 (43.78%). These small differences may be attributed to the changes in the papaya concentrations and their corresponding physicochemical properties, such as moisture content and total soluble solids, which could slightly influence the air incorporation. However, the overall consistency in overrun values suggests that the freezing and mixing processes were effectively controlled and that the incorporation of air remained stable throughout the experiment.

These overrun results align with standard expectations in ice cream production, where air incorporation typically falls within a similar range when the freezing conditions and mix composition are consistent [18].

In terms of melting rate, more pronounced differences were observed among the treatments, with values ranging from 1.71 g/min to 2.52 g/min, as shown in Table 2. The lowest melting rate was recorded in the sample with 3% maturity 3 papaya powder (1.71 g/min), indicating enhanced structural stability and resistance to melting. This suggested that, at this particular maturity and concentration level, the spray-dried papaya powder may have contributed positively to the water-holding capacity and matrix integrity of the ice cream. The control sample exhibited a slightly higher melting rate (1.86 g/min), indicating that the inclusion of papaya powder, particularly at moderate levels, may have enhanced the product’s thermal resistance.

The highest melting rate was noted in the sample with 6% maturity 4 papaya powder (2.52 g/min), suggesting a significant reduction in melt resistance. This outcome was attributed to the excessive presence of non-fat solids, such as dietary fiber and sugars, which could have interfered with the emulsion stability and the protein-fat network necessary for maintaining structural cohesion in the ice cream. The melting rate is strongly influenced by the microstructure of the ice cream, including the size and distribution of air cells, ice crystals, and fat globules. A disruption in this microstructure, potentially caused by an imbalance in solids or interactions among ingredients, could have led to increased meltability. Moreover, the higher melting rate observed in maturity 4 at 6% treatment may have been associated with compositional differences related to the maturity stage of the fruit, such as increased sugar and enzyme content that could have destabilized the frozen matrix.

Overall, the results indicated that spray-dried papaya powder had a variable impact on the overrun and melting rate of ice cream, depending on both the concentration and the maturity stage of the papaya. The treatment with 3% maturity 3 papaya powder achieved the most favorable results for both overrun and melting stability, suggesting that this formulation achieved an optimal balance between structural integrity and product quality.

These findings were consistent with previous studies that emphasized the importance of formulation balance in functional ice cream products [19].

3.2 Microbial Analysis (*Staphylococcus aureus* count)

Microbial quality evaluates the presence of harmful microorganisms and the overall microbial safety of the food product. Table 3 showed that the microbiological evaluation confirmed that all samples were microbiologically safe for human consumption. No detectable levels of *Staphylococcus aureus* counts were found. *Staphylococcus aureus* counts did not exceed 10 CFU/g in any sample and were within the permissible limits established by food safety guidelines.

Table 3. *Staphylococcus aureus* counts of ice cream at different treatments

Treatment	Formulation	Temperature	*S. aureus* (CFU/ g)
T0	Control	4.2°C	< 10
T1	Maturity 3 (3%)	4.2°C	< 10
T2	Maturity 3 (6%)	4.2°C	< 10
T3	Maturity 4 (3%)	4.2°C	< 10
T4	Maturity 4 (6%)	4.2°C	< 10

3.3 Assessment of sensory evaluation properties of the ice cream

Table 3. Comparison of acceptability and intensity between control and treatments

Treatment	Papaya concentration (%)	Color*	Aroma*	Taste (Sweetness)	Flavor*	Texture (smoothness)	General Acceptability*
T0	0	7.27±1.56	6.69±1.54	7.15±1.34^{a}	7.13±1.27	6.95±1.28^{a}	7.32±1.21
T1	3	7.28±1.48	7.01±1.47	7.24±1.29^{a}	7.03±1.34	6.91±1.31^{a}	7.26±1.13
T2	6	7.23±1.40	6.68±1.45	6.59±1.65^{b}	6.71±1.68	7.23±1.52^{b}	6.99±1.45
T3	3	7.28±1.55	7.05±1.55	7.00±1.74^{a}	6.99±1.81	7.23±1.47^{b}	7.42±1.38
T4	6	7.51±1.61	7.15±1.41	7.01±1.59^{a}	7.08±1.61	7.50±1.18^{c}	7.33±1.47

A one-way Kruskal-Wallis test was used to determine significant differences between treatments at a significance level of α = 0.05. Means followed by the same superscript letter are not significantly different. An asterisk (*) indicates no significant difference.

Sensory evaluation involves assessing consumer perception and acceptance of food products using human senses. This study evaluates the various ice cream treatments. The evaluation includes attributes such as color, aroma, taste/sweetness, flavor, texture/smoothness, and overall acceptability, as presented in Table 4.

3.3.1 Color Acceptability

Color acceptability referred to the visual appeal of the ice cream as perceived by the judges. The analysis presented in Table 4 indicated no statistically significant differences in color acceptability among the various ice cream treatments. Although the differences were not statistically significant, qualitative observations suggested that all samples were generally rated as "Like moderately,". For the sample formulated with maturity stage 4 at 6%, which received a notably higher mean rating (mean = 7.51). This enhanced visual appeal was likely attributed to the increased concentration of natural pigments, particularly carotenoids such as β-carotene and lycopene, present in riper papayas, and a more vibrant orange hue to the product. This observation was consistent with the findings of Farina et al. (2020), who emphasized the significant role of color in shaping consumer perceptions of freshness and overall product appeal.

3.3.2 Aroma Acceptability

Aroma acceptability referred to the degree to which the scent or smell of the ice cream was perceived as pleasing by the judges. Although statistical analysis did not reveal significant differences in aroma acceptability across treatments, mean scores increased with greater fruit maturity and higher concentrations of papaya powder. Specifically, the treatment with maturity stage 4 at 6% achieved the highest aroma acceptability rating (mean = 7.15). This enhanced aromatic perception may have been attributed to elevated volatile aromatic compounds, such as esters and alcohols, which are more prominent in mature papayas [15]. These compounds, partially retained during the spray-drying process, contributed to the intensified fruity aroma of the final ice cream product.

3.3.3 Taste (sweetness) and flavor acceptability

Taste and flavor acceptability referred to the overall gustatory impression of the ice cream, encompassing both the basic taste sensations and the complex combination of flavor compounds. Although no statistically significant differences were observed across treatments ($p > 0.05$), the data exhibited a consistent trend favoring samples prepared with more mature fruit. Specifically, the samples using papaya at maturity stage 4 received higher ratings for taste and flavor, while the maturity stage 3 sample at 6% received slightly lower ratings in both parameters (taste mean = 6.59; flavor mean = 6.71). These variations could be attributed to the relatively underdeveloped sugar profiles and flavor precursors in less ripe papayas, which may have contributed subtle bitter or astringent notes. In contrast, riper papayas contained higher concentrations of natural sugars, particularly sucrose, glucose, and fructose, which enhanced flavor intensity and overall palatability.

3.3.4 Texture Acceptability

Texture acceptability referred to the extent to which the mouthfeel and physical consistency of the ice cream were favorably received by the panelists. Among the sensory parameters assessed, texture was the only attribute that exhibited statistically significant differences among the treatments. The sample containing maturity stage 4 papaya at 6% received the highest texture acceptability rating (mean = 7.51), which may have been attributed to its higher content of soluble fibers and natural thickeners inherent in riper papayas. These components likely enhanced creaminess and contributed to a smoother mouthfeel. Furthermore, the elevated dry matter content of the spray-dried papaya powder possibly reduced free water, promoting the formation of finer ice crystals and thereby improving scoop ability and overall textural quality. These findings were consistent with existing literature, which indicated that formulations incorporating papaya powder benefit from enhanced freezing efficiency and improved textural stability [17].

3.3.5 Overall Acceptability

Overall acceptability encompassed the overall impression and satisfaction of the judges based on all evaluated sensory attributes. The overall acceptability scores followed trends similar to those observed in the texture and color parameters; however, no statistically significant differences were recorded among the treatments. The highest overall acceptability ratings were observed in the maturity stage 4 samples at 3% (mean = 7.42) and 6% (mean = 7.33). These results suggested that papaya at more advanced ripening stages, when incorporated at appropriate concentrations, was well-integrated into the ice cream matrix and contributed positively to the overall sensory quality of the product without introducing undesirable characteristics.to the product's overall sensory quality without introducing adverse attributes.

3.4 Papaya intensity rating to the ice cream

The papaya intensity of the ice cream samples was evaluated by a sensory panel using a rating scale. Intensity attributes referred to the degree or strength of specific sensory properties. The evaluation focused specifically on the papaya aroma and flavor intensity across the different ice cream formulations. The result of intensity ratings for treatments are presented in Table 5

Table 5. Intensity ratings of papaya aroma and flavor for the five (5) treatments

Treatment	Papaya Level (%)	Intensity scale rating Aroma	Flavor
T0	0	3.90 ± 2.44^{a}	4.17 ± 2.59^{a}
T1	3	4.73 ± 2.59^{ab}	5.15 ± 2.59^{b}
T2	6	5.13 ± 2.65^{b}	5.91 ± 2.51^{c}
T3	3	4.88 ± 2.59^{b}	5.37 ± 2.55^{b}
T4	6	5.36 ± 2.36^{b}	6.14 ± 2.11^{c}

A one-way Kruskal-Wallis test was used to determine significant differences between treatments at a significance level of $\alpha = 0.05$. Means followed by the same superscript letter are not significantly different.

3.4.1 Aroma Intensity

Aroma intensity refers to the perceived strength of the ice cream's scent or aroma. The higher intensity of aroma observed in treatments T2 and T4 of the papaya ice cream, as indicated by the papaya intensity rating in Table 5, was primarily attributed to the use of spray-dried papaya powder derived from papayas at more advanced maturity stages and at higher concentrations. Specifically, T2 (mean = 5.13) and T4 (mean = 5.36) incorporated spray-dried powder from papayas at maturity stages 3 and 4, respectively, with T4 having a higher concentration of papaya powder. The fully ripe papayas at maturity stage 4 had undergone extensive biochemical changes during ripening, leading to increased synthesis of key volatile compounds such as linalool and benzaldehyde, which are responsible for the characteristic sweet and fruity aroma of papaya [20]. The spray-drying process further concentrated these aroma-active compounds by reducing water content and preserving phenolic and flavonoid compounds, which contributed to aroma stability and intensity [21]. In contrast to papaya puree, which contained higher moisture and could dilute aroma perception, the powdered form used in T2 and T4 provided a more concentrated and stable source of aroma compounds, enhancing the sensory aroma intensity in the ice cream [19]. Therefore, the combination of using papaya from advanced maturity stages and the concentrated nature of spray-dried powder led to significantly higher aroma intensity ratings in T2 and T4 treatments compared to others.

3.4.2 Flavor Intensity

Flavor intensity referred to the strength or concentration of flavor perceived by the judges. The higher intensity of flavor observed in T2 and T4 treatments of the papaya ice cream, as indicated by Table 5, papaya flavor intensity rating, was primarily due to the use of spray-dried papaya powder from papayas at advanced maturity stages and higher concentrations. Papayas at maturity stage 4, which were used in T4, had undergone more extensive ripening, resulting in the accumulation of sugars, organic acids, and volatile flavor compounds that contribute to a richer and more pronounced papaya flavor profile [20]. The spray-drying process itself played a significant role in concentrating these flavor compounds, as it removed much of the water content while retaining the essential flavor-active constituents, such as esters, aldehydes, and terpenes, which are responsible for the characteristic taste of papaya [25]. This concentration effect was further enhanced in T4 due to the higher percentage of papaya powder used, resulting in a more intense flavor experience compared to formulations with lower concentrations or those using papaya puree.

Moreover, the use of spray-dried powder minimized the dilution of flavor that typically occurs when using fresh or pureed papaya, which contains a higher moisture content and can lead to a less intense flavor perception in the final ice cream product [17]. The retention of both sugars and flavor volatiles during spray drying ensured that the ice cream maintained the authentic and robust flavor of ripe papaya. Additionally, the advanced maturity of the papaya used in T2 and T4 meant that the fruit had developed a more complex flavor profile, with increased sweetness and reduced bitterness, which are desirable attributes in ice cream formulations. Therefore, the combination of using papayas at optimal ripeness and the application of spray-drying technology resulted in the significantly higher flavor intensity ratings observed in T2 and T4 treatments.

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