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Effect of Soursop Puree and Gum Arabic on the Sensory Properties of Non-Dairy Coconut Milk-Based Ice Cream

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Abstract

Coconut (*Cocos nucifera*) milk-based ice cream is one of the innovative non-dairy milk products gaining popularity among consumers. The objective was to develop coconut milk-based ice cream incorporated with soursop (*Annona muricata*) fruit puree and gum Arabic from *Acacia senegal* var. *kerensis*, conduct a sensory evaluation using descriptive tests by trained panelists (n = 9) then evaluate for consumer acceptability by semi trained panelists (n = 30). A seven-point hedonic scale for colour, taste, flavour, texture and overall acceptability was used. The data obtained was subjected to analysis of variance (ANOVA) and the means were separated to determine their significance differences. Principal Component Analysis (PCA) was done for factor reduction to make it easy for the multi-dimensional descriptive data to be interpreted. PCA results indicated that unit increase in soursop and gum Arabic in the ice cream led to 83.1% increase in starchy taste, 78.3% increase in consistency and 73.6% decrease in coconut aroma. For consumer acceptability test, the obtained results showed that, soursop puree addition at successive levels led to a statistically significant effect ($p < 0.05$) on colour, flavour, texture, taste and overall acceptability while of gum Arabic incorporation was not significant ($p > 0.05$) for all attributes. The effect due to interaction between gum Arabic and soursop puree at the different levels however was significant for colour, flavour and texture but not significant for taste and overall acceptability. Our results therefore point to a potential application of soursop fruit and gum Arabic as alternative ingredients in the manufacture of a non-dairy ice cream with desirable sensory properties that would expand the variety of options consumers can choose from.

Keywords

Consumer Acceptability, Ice Cream, Non-Dairy, Sensory Properties, Soursop Puree

1. Introduction

Changing consumer trends, lactose intolerance and increased incidences of allergic reactions have led to an increased popularity of non-dairy ice creams [1]. Lactose intolerant individuals are unable to consume ice cream because of their inability to digest lactose. Lactose intolerance arises when the enzyme lactase is in insufficient amounts in the jejunum to breakdown lactose into simple sugars for ease of absorption. This results in diarrhea among other clinical discomforts [2]. Due to this, other frozen desserts belonging to the ice cream family have been made using non-dairy ingredients such as coconut milk [1]. Vegetable milks have been used to make non-dairy frozen desserts as a substitute for cow milk. Common non-dairy milks used in ice cream making include soy, almonds, rice, yams and coconut [3]. These milks contain essential nutrients and have properties that mimic those present in milk [3]. Vegetable milks are good for lactose intolerant individuals as well as consumers from certain religious groups. Frozen desserts made from vegetable milks have a good texture, viscosity and proper body formation. Soy milk has been extensively used either singly or in combination with cow milk to make ice cream and other frozen desserts. In a study by [4], addition of soy milk in yoghurt ice cream had a positive impact on the viscosity, firmness and texture of the ice cream. However, soy milk is relatively expensive and this has posed a challenge to value added products from soy. Coconut milk is preferred in ice cream making due to its affordability, availability, ease of extraction and nutritional composition [1] [5]. On the other hand, coconut milk is easily digestible and is a rich source of essential oils such as oleic and lauric acids. Coconut milk also contains minerals such as calcium, phosphorus and potassium and vitamins B, C and E [3]. Apart from its use as a flavor enhancer in baked products and confectioneries, coconut milk has been extensively used to make ice cream with good sensory and physical properties [1] [5]. Despite the potential of coconut milk in ice cream making, there is limited information on the utilization of fruit pulps in combination with plant gums in non-dairy ice cream manufacture. Soursop fruit pulp has been utilized in the food industry to make juices, shakes, yoghurts, alcoholic beverages and also canned or sold as a frozen puree. Additionally, gum Arabic from *Acacia senegal* var. *kerensis* has potential to provide both stabilizing and emulsification properties in ice cream. The aim of this study therefore was to innovatively develop a non-dairy coconut milk-based ice cream containing soursop puree and gum Arabic from *Acacia senegal var. kerensis* and to evaluate the effect of these ingredients on the sensory properties of the ice cream.

2. Materials and Methods

2.1. Raw Material Preparation

Coconuts, ripe soursop fruits (**Figure 1**) and gum Arabic used in this study were obtained from local stores in Kenya. The raw material preparation method used was as described by [6] [7] with modifications. The coconut fruits were split into

Figure 1. Soursop (*Annona muricata*) fruit.

halves and the copra scrapped using a coconut scrapper. The scrapped copra was mixed with water (70˚C) at 1:1 (w/v) and blended using an electric blender. A clean muslin cloth was used to squeeze the milk from the mix. Soursop fruits were cleaned using running portable water, peeled and then sliced into halves. The seeds were manually separated and the flesh blended to obtain a homogenous puree.

2.2. Preparation of Coconut Milk-Based Ice Cream

The ice cream was prepared according to the method described by [8] with modifications. The coconut milk, fruit pulp (0%, 10%, 20% and 30%), sugar (10%) and gum Arabic (0%, 0.5%, 1% and 1.5%) were mixed at the specified ratios to obtain the ice cream mix. The mix was pasteurized at 85˚C for 30 minutes, cooled to about 25˚C, aged at 4˚C for 4 hours and then whipped to incorporate air using a Watoor ice cream machine (Model number ICM-16A). The machine was set at −18˚C for 20 minutes per batch. Cups previously stored at 4˚C were used for packaging the ice cream and then stored at −18˚C awaiting further analysis.

2.3. Descriptive Sensory Evaluation

2.3.1. Panel Selection and Pre-Screening

This process involved pre-screening and training students and staff from the Faculty of Agriculture in Egerton University as potential panellists to carry out descriptive sensory evaluation on the ice cream samples. The original number of panellists taken through the pre-screening procedure was sixteen which was later reduced to twelve. The reduction was on the basis of allergic reactions, non-preference for foods with sugar and health conditions. The twelve panellists were further screened on their ability to identify and categorise, according to intensities, the four tastes (salty, sweet, bitter and sour). Eight panellists remained after this final stage of pre-screening.

2.3.2. Panel Training and Lexicon Development

The panellists were taken through a two hour training session per day for one week. The panelists described the attributes of the ice cream (Figure 2) several times to ensure that there was uniformity in the descriptors among the panelists. Using a method described by [9], a lexicon was developed through consensus with the specific descriptors and scale anchors assigned for each descriptor. The descriptors developed for the different ice cream attributes were refined using literature and this process yielded 18 descriptors grouped into appearance, texture, taste, after taste and aroma (Table 1). The panelists were trained on how to rate the attributes of the ice cream samples against the developed lexicon to achieve a uniformity in the data obtained.

2.3.3. Sensory Evaluation

The eight panelists presented with seven coded ice cream samples. The order of presentation of the samples was randomized. With reference to the training and the developed lexicon, the panel was tasked to rating the intensities of the different attributes of the samples against the lexicon provided.

2.4. Consumer Acceptance Test

Sensory evaluation was carried out according to [10]. Thirty semi-trained panellists were randomly recruited for sensory evaluation of the ice cream using a 7-point hedonic scale. The panellists were first asked to consent on the tests and complete a pre-screening questionnaire. Acceptance testing was used to determine how much each sample was liked based on the 7-point hedonic scale for a set of attributes: overall acceptability, flavour, taste, texture and colour, where; 7 = like extremely, 6 = like moderately, 5 = like slightly, 4 = neither like nor dislike, 3 = dislike slightly, 2 = dislike moderately, 1 = dislike extremely. In addition, consumers were asked on what they liked and disliked about each sample in the comment section of the score sheet. The panellists evaluated samples in individual testing booths under white lighting where each panellist entered their sensory information.

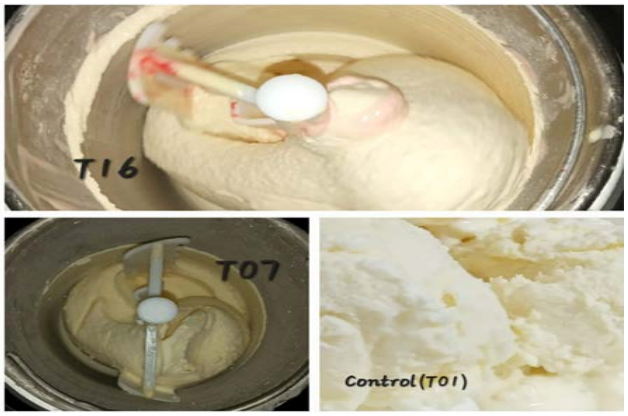

Figure 2. Ice Cream Samples (T01 = 0.0% Soursop and 0.0% Gum Arabic; T07 = 10.0% Soursop and 1.0% Gum Arabic; T16 = 30.0% Soursop and 1.5% Gum Arabic).

Table 1. Descriptive sensory evaluation lexicon.

Attribute	Definition	Reference	Rating Scale
	Appearance		
Porosity	The number of pores visible on the sample surface.	1 = The surface of an egg shell. 9 = A slice of bread	1 = Compact 9 = Porous
Colour	The intensity of the cream colour.	1 = Skim Milk 9 = Soya beans.	1 = White 9 = Cream
Consistency	Degree of visual uniformity of the sample/level of smoothness.	1 = Cookies 9 = Medium fat margarine	1 = Rough 9 = Smooth
Glossiness	The degree of shiny appearance on the surface of the ice cream.	1 = Egg 9 = Apple	1 = Dull 9 = Glossy
	Texture		
Sandiness	The immediate perception of crystal like particles in the sample.		1 = Mild 9 = Intense.
Creaminess	Combination of thickness and lubricative feeling in the mouth as ice cream melts.		1 = Mild 2 = Intense
Melt-ability	Time required for the sample to completely melt in the mouth.	1 = Ice crystal from frozen water. 9 = A piece of biscuit.	1 = Short time 9 = Lasts longer
Mouth coating	Residual perceived on the oral surface after sample is swallowed.		1 = Mild 9 = Intense
	Taste		
Sweetness	The degree of taste associated with presence of sugars.		1 = Mild 9 = Intense
Sourness	The extent of perception of the taste associated with fermentation		1 = Mild 9 = Intense
Astringency	The degree of sensation that causes puckering/shrinking of the tongue surface.	9 = Tamarind juice.	1 = Less perceivable 9 = Highly perceivable
Starchy	Taste associated with high starch foods.	9 = Porridge made from maize flour.	1 = Less perceivable 9 = Highly perceivable
	After-taste		
Sweet Aftertaste	How long the sweet taste lasts/lingers in the mouth after swallowing.		1 = Short time 9 = Lasts Longer
Sour Aftertaste	How long the sour taste lasts/lingers in the mouth after swallowing.		1 = Short time 9 = Lasts Longer
	Aroma		
Coconut	The extent to which the aroma associated with coconut is perceived.		1 = Mild 9 = Intense
Caramel	The extent to which the aroma associated with caramelization is perceived.		1 = Mild 9 = Intense
Fruity	The extent to which the aroma associated with soursop fruit is perceived.		1 = Mild 9 = Intense
Rancid	The extent to which the aroma associated with rancidity of fats is perceived.		1 = Mild 9 = Intense

2.5. Statistical Data Analysis

The experiment employed a completely randomized design (CRD) in a 4 × 4 factorial arrangement. The first factor was the % of soursop puree in 4 levels; 0%, 10%, 20% and 30% while the second factor was the gum arabic levels (0%, 0.5%, 1.0% and 1.5%). The control had 0% of both factors incorporated with a conventional stabilizer and emulsifier. Data obtained was analysed using the Statistical Analysis System (SAS, 2006) software Version 9.1.3. Study hypotheses were tested by performing an analysis of variance (ANOVA). Significance ($p < 0.05$) was established and means separation done using Duncan's Multiple Range Test (DMRT). Data obtained from descriptive tests was analyzed using SAS JMP Pro 16.0 Software. ANOVA was used to test the effect of soursop and gum Arabic on sensory attributes of ice cream and post-hoc analysis carried out using Tukey's HSD at 95% confidence level. Factor reduction using PCA based on correlation method was done.

3. Results and Discussion

Intensity mean scores for appearance and textural properties of ice cream samples containing different levels of soursop puree and gum Arabic are shown in Table 2 below. Higher degree of porosity was exhibited for ice cream T11 (6.33 ± 0.67) and T14 (5.58 ± 0.56). The degree of porousness also increased with increase in levels of soursop and gum Arabic. However, addition of soursop and gum arabic beyond 30% and 1% respectively caused a decrease in the degree of porousness in the ice cream. High degree of porosity is desirable in ice cream as it relates to higher overrun, lower melting rates and low crystal formation [11]. At higher levels of soursop and gum Arabic, the ice cream mix was too thick making it difficult to incorporate air during whipping. These findings are consistent with [12] where higher percentages of date paste in the ice cream mix

Table 2. Mean scores ± standard deviation of appearance and textural properties of ice cream samples. Means followed by different superscript letters in the same column are significantly different ($p < 0.05$).

Sample	Appearance properties				Texture properties			
	Porosity	Colour	Consistency	Glossiness	Sandiness	Creaminess	Meltability	Mouth coating
T01	4.67 ± 0.69^{ab}	4.00 ± 0.59^{b}	6.33 ± 0.54^{abc}	6.33 ± 0.56^{abc}	3.17 ± 0.52^{b}	5.08 ± 0.67^{a}	2.92 ± 0.63^{b}	2.92 ± 0.53^{a}
T04	3.08 ± 0.53^{b}	4.25 ± 0.64^{b}	7.25 ± 0.57^{a}	7.08 ± 0.69^{a}	3.42 ± 0.61^{ab}	6.00 ± 0.66^{a}	3.00 ± 0.66^{b}	3.83 ± 0.44^{a}
T07	3.42 ± 0.43^{b}	5.50 ± 0.58^{ab}	6.67 ± 0.45^{ab}	6.92 ± 0.62^{ab}	4.17 ± 0.61^{ab}	6.17 ± 0.60^{a}	4.08 ± 0.63^{ab}	4.67 ± 0.47^{a}
T10	5.17 ± 0.61^{ab}	5.42 ± 0.60^{ab}	5.50 ± 0.47^{abc}	5.33 ± 0.53^{abc}	5.33 ± 0.54^{ab}	5.17 ± 0.56^{a}	4.75 ± 0.52^{ab}	4.67 ± 0.61^{a}
T11	6.33 ± 0.67^{a}	5.33 ± 0.64^{ab}	4.33 ± 0.54^{bc}	4.42 ± 0.48^{bc}	5.67 ± 0.74^{ab}	5.42 ± 0.53^{a}	5.50 ± 0.62^{a}	5.33 ± 0.78^{a}
T14	5.58 ± 0.56^{ab}	6.58 ± 0.65^{ab}	4.75 ± 0.62^{bc}	3.92 ± 0.63^{c}	6.00 ± 0.56^{a}	5.83 ± 0.64^{a}	6.17 ± 0.47^{a}	5.42 ± 0.77^{a}
T16	5.33 ± 0.59^{ab}	7.25 ± 0.52^{a}	4.08 ± 0.65^{c}	4.00 ± 0.67^{c}	5.75 ± 0.65^{ab}	4.83 ± 0.68^{a}	5.58 ± 0.48^{a}	5.42 ± 0.75^{a}

Key: T01 = 0.0% Soursop and 0.0% Gum Arabic; T04 = 0.0% Soursop and 1.5% Gum Arabic; T07 = 10.0% Soursop and 1.0% Gum Arabic; T10 = 20.0% Soursop and 0.5% Gum Arabic; T11 = 20.0% Soursop and 1.0% Gum Arabic; T14 = 30.0% Soursop and 0.5% Gum Arabic; T16 = 30.0% Soursop and 1.5% Gum Arabic.

resulted into a higher fibre into paste ratio and consequently lower overrun. The increased degree of porosity with increased soursop and gum can be attributed to the emulsifying properties of gum and the increased viscosity of the mix hence ease of air incorporation and the stabilizing properties that give the ice cream form [13] This phenomenon can also be used to explain the consistency in the ice cream where at higher soursop addition levels, the ice cream appeared less smooth although the difference was not significant ($p > 0.05$) for the different levels of soursop puree and gum Arabic addition. However, T04 (7.25 ± 0.57) exhibited a uniform and smooth consistency compared to T16 (4.08 ± 0.65). Colour intensity increased with increased levels of soursop puree. At higher percentages of soursop puree, ice creams T16 (7.25 ± 0.52) and T14 (6.58 ± 0.65) exhibited the highest colour intensities. On the other hand, ice creams T01 (4.00 ± 0.59) and T04 (4.25 ± 0.64) had the lowest colour intensities. The type and composition of ingredients affects the colour of ice cream. Gum Arabic is colorless and does not impact on the colour of the product [14]. However, soursop puree has a characteristic cream colour that turns to brown during heating. The brown colour can be attributed to non-enzymatic browning in the soursop puree [15]. [16] also found that a fruit bar made from pineapple pulp had a higher browning index at higher temperatures. There was no significance difference ($p > 0.05$) in terms of colour for T01 (4.00 ± 0.59) and T04 (4.25 ± 0.64) as they had no soursop puree added and therefore maintained the white colour associated with coconut milk.

Across the treatments, the degree of sandiness increased with increased substitution levels of both gum Arabic and soursop puree. Treatment T14 (6.00 ± 0.56) exhibited the highest degree of sandiness but decreased in T16 (5.75 ± 0.65) upon addition of gum Arabic beyond 1%. However, there was no significant difference ($p > 0.05$) on the degree of sandiness for most samples. Sandiness in ice cream is a defect caused by recrystallization of water during storage associated with heat shock. Use of hydrocolloids in the ice cream mix lowers recrystallization in that they act as a cryoprotectants [10]. Cryoprotectants are compounds that are added to foods to prevent undesirable changes caused by temperature fluctuation during storage. In ice cream, cryoprotectants control water diffusion and the formation of ice crystals by steric hindrance and water holding [17].

Treatment T07 (6.17 ± 0.60) was rated highest on the level of creaminess while T16 (4.83 ± 0.68) was rated lowest. In terms of mouth coating, the level was higher in treatments T14 (5.42 ± 0.77) and T16 (5.42 ± 0.77) and lowest in the T01 (2.92 ± 0.53). The degree of mouth coating increased with increased levels of both gum Arabic and soursop puree. However, there was no significant difference ($p > 0.05$) among the ice cream samples for creaminess and mouth coating. The levels of creaminess and mouth coating in ice cream are attributed to the fat content of the mix. According to [18], fat content in ice cream mix contributes to the nature and formation of the creamy texture and flavor of the resulting ice cream. Fats achieve this phenomenon by stabilizing air bubbles in the

ice cream. In their study, [18] found out that increasing the levels of maltodextrins in the formulation of ice cream mix led to a decrease in the fat content and consequently a decrease in the creamy texture and flavor of the resulting ice cream.

In terms of meltability, as the levels of both gum and soursop increased there was an increase in the amount of time required for the ice cream to melt. Treatments T01 (2.92 ± 0.63) and T04 (3.00 ± 0.66) took the shortest time to melt while T14 (5.83 ± 0.64) and T16 (5.58 ± 0.48) took the longest time. The stabilizing and emulsification properties of gum Arabic in the mix gave ice creams which could stand long before melting. Extended melting times was attributed to the formation of a gel matrix by the hydrophilic gum Arabic. This gel matrix reduces the amount of free water and results into a softer ice cream with high resistance to heat shock and longer melting time while still maintaining the body of the ice cream [19]. The same phenomenon was observed with soursop levels at higher concentrations where it increased the viscosity of the mix and hence improved body formation after whipping and freezing. In a study by [20], where different frozen products were made by substituting yoghurt and ice cream mix in different ratios, it was observed that mixes displaying the highest viscosities took longer time to melt.

3.1. Flavour Properties

Intensity mean scores for flavour properties of ice cream samples containing different levels of soursop puree and gum Arabic are shown in **Table 3** below. Taste was described in terms of sweetness, sourness, astringency and starchiness. The highest intensity of sweetness was perceived in treatment T07 (7.17 ± 0.60) and lowest in T14 (5.42 ± 0.76). Treatment T11 (4.92 ± 0.66) recorded the highest intensity for starchiness while the control sample T01 (2.67 ± 0.80) scored lowest. The trend observed was that sweetness and starchy taste increased with increased levels of soursop puree and gum Arabic addition. However, there was no significance difference ($p > 0.05$) among the treatments in terms of degrees of sweetness and starchy tastes. Soursop has a starchy pulp which is high in sugars. According to [21], sugars in soursop fruit pulp constitute 67.2% to 69.9% of the total solids with the reducing sugars (glucose and fructose) comprising 81.9% to 93.6% of the total sugar content. It was observed that treatments T14 (6.17 ± 0.72) and T16 (6.17 ± 0.56) scored highest in terms of intensities of sourness while T01 (2.42 ± 0.58) scored lowest. Similarly, T14 (6.25 ± 0.59) also scored highest for astringency while T04 (3.00 ± 0.63) scored lowest. From **Table 3**, the observed trend is that sourness and astringency intensities increased with increased levels of soursop addition. Soursop has a characteristic sweet-sour taste that explains the significant difference ($p < 0.05$) in terms of sourness and astringency among the treatments without soursop and those with soursop. The acid-sweet taste in soursop fruit is associated with the presence of sugars, malic and citric acid in the pulp [22] hence the significant difference ($p < 0.05$) on the intensities of astringency and sourness.

Table 3. Mean scores ± standard deviation of flavour properties of ice cream samples. Means followed by different superscript letters in the same column are significantly different ($p < 0.05$).

	Taste properties			Aftertaste properties			Aroma properties			
	Sweetness	Sourness	Astringency	Starchy	Sweet	Sour	Coconut	Caramel	Fruity	Rancid
T01	6.25 ± 0.68^{a}	2.42 ± 0.58^{c}	3.17 ± 0.74^{c}	2.67 ± 0.80^{a}	4.92 ± 0.69^{a}	2.42 ± 0.47^{d}	5.83 ± 0.81^{a}	3.17 ± 0.76^{a}	3.42 ± 0.72^{b}	2.58 ± 0.50^{a}
T04	5.92 ± 0.73^{a}	2.92 ± 0.58^{c}	3.00 ± 0.63^{c}	3.33 ± 0.71^{a}	5.17 ± 0.60^{a}	2.92 ± 0.76^{cd}	5.67 ± 0.83^{a}	3.25 ± 0.68^{a}	4.17 ± 0.72^{ab}	2.92 ± 0.50^{a}
T07	7.17 ± 0.60^{a}	3.25 ± 0.54^{bc}	3.50 ± 0.51^{bc}	3.58 ± 0.57^{a}	6.33 ± 0.56^{a}	3.25 ± 0.54^{bcd}	5.25 ± 0.82^{a}	3.50 ± 0.47^{a}	6.33 ± 0.54^{a}	3.00 ± 0.62^{a}
T10	6.92 ± 0.45^{a}	4.50 ± 0.58^{abc}	4.67 ± 0.62^{abc}	3.92 ± 0.62^{a}	5.83 ± 0.56^{a}	3.83 ± 0.58^{bcd}	5.92 ± 0.62^{a}	4.08 ± 0.73^{a}	6.08 ± 0.56^{ab}	3.33 ± 0.67^{a}
T11	5.83 ± 0.39^{a}	5.50 ± 0.63^{ab}	6.00 ± 0.51^{ab}	4.92 ± 0.66^{a}	5.42 ± 0.57^{a}	5.33 ± 0.66^{abc}	6.75 ± 0.59^{a}	4.08 ± 0.69^{a}	5.92 ± 0.60^{ab}	3.58 ± 0.66^{a}
T14	5.42 ± 0.76^{a}	6.17 ± 0.72^{a}	6.25 ± 0.59^{a}	4.75 ± 0.75^{a}	5.67 ± 0.73^{a}	6.00 ± 0.71^{a}	6.01 ± 0.17^{a}	3.83 ± 0.74^{a}	6.50 ± 0.73^{a}	4.33 ± 0.86^{a}
TI6	6.17 ± 0.63^{a}	6.17 ± 0.56^{a}	6.08 ± 0.51^{a}	4.33 ± 0.57^{a}	5.17 ± 0.67^{a}	5.83 ± 0.67^{ab}	5.42 ± 0.72^{a}	4.08 ± 0.79^{a}	6.42 ± 0.77^{a}	4.08 ± 0.83^{a}

Key: T01 = 0.0% Soursop and 0.0% Gum Arabic; T04 = 0.0% Soursop and 1.5% Gum Arabic; T07 = 10.0% Soursop and 1.0% Gum Arabic; T10 = 20.0% Soursop and 0.5% Gum Arabic; T11 = 20.0% Soursop and 1.0% Gum Arabic; T14 = 30.0% Soursop and 0.5% Gum Arabic; T16 = 30.0% Soursop and 1.5% Gum Arabic.

Aftertaste was categorized into sweet and sour aftertastes. Treatment T07 (6.33 ± 0.56) was ranked highest on the retention of the sweet taste in the mouth after swallowing. On the other hand treatment T14 (6.00 ± 0.71) ranked highest on the intensity of sour aftertaste while both sweet and sour aftertaste intensities were least perceived in treatments T01 (4.92 ± 0.69 and 2.42 ± 0.47 respectively). Gum Arabic has a neutral taste and does not impact on the sweet aftertaste [23]. On the contrary, soursop is high in sugars [21], but the effect on the intensities of sweet aftertaste was not significantly different ($p > 0.05$) among the treatments with different levels of soursop puree. The intensities of the sour aftertaste increased with increased levels of soursop levels. It was observed that the intensities were significantly different ($p < 0.05$) for treatments with 20% and 30% soursop puree levels. However, treatments that contained 10% soursop and those with 0% did not differ significantly ($p > 0.05$) on the degrees of sour aftertaste. The presence of malic and citric acid in the soursop puree [22] can be used to explain this difference in terms of sour aftertaste.

T01 (3.42 ± 0.72) that did not contain any fruit was significantly different ($p < 0.05$) in terms of fruity aroma from T07 (6.33 ± 0.54), T14 (6.50 ± 0.73) and T16 (6.42 ± 0.77). In terms of aroma properties, the intensities for coconut, caramel and rancid aromas increased with increased levels of soursop although the increase was not significantly different ($p > 0.05$). The coconut aroma was linked to the coconut milk used as the base ingredient. On the other hand, increase in rancidity intensity due to increased soursop levels could be attributed to the acidity of the fruit pulp. According to [24], soursop pulp has a pH of between 4.1 and 4.8. The caramel aroma increased with soursop addition. This could be explained by caramelization of the sugars in the soursop during the ice cream mix heating. Caramelization is a non-enzymatic browning reaction that occurs when sugars are heated resulting into a caramel like flavour [25]. The acidity of the ice cream mix could also be attributed to offering a favorable chemical environment for caramelization reactions to occur. According to [26], the rate of caramelization is highest at extreme pH values and lowest at neutral pH. For fruity aroma, the intensities were significantly affected by the addition of soursop puree. Soursop fruit has a strong fruity aroma that can be perceived even at small concentrations. During ripening process most fruits produce volatile aroma compounds through various metabolic paths. Esters, aldehydes, alcohols, terpenes and lactones are some of the volatile compounds produced during the different ripening stages of soursop fruit with esters being the most dominant [27].

3.2. Principal Component Analysis

Principal Component Analysis (PCA) is a statistical multivariate analytical technique used in quantitative descriptive analysis to explain the variability in the original set of data [28]. PCA helps reduce a set of dependent variables into factors, depending on the correlation of the original set of variables [29]. The factors are further categorized into unrelated principal components in the order of decreasing variation. The first principal component is loaded with more factors. PCA is essential in linking products and their attributes as in descriptive sensory evaluation [30]. Loading matrix of descriptive attributes on principal components are shown in **Table 4**. Colour, sweetness, sweet aftertaste, rancid aroma and fruity aroma were eliminated on factor reduction to obtain a Kaiser-Meyer-Olkin (KMO) value of 0.838 and 3 principal components with eigenvalues of above 1.0 (**Figure 3**). The 0.838 KMO value meant that the remaining sensory attributes after factor reduction explained 83.8% of the treatments (that is, increasing both soursop and gum Arabic levels) while the remaining 16.2% would be as a result of other factors such as random error. Principal component one had strong positive coefficients for starchy taste (0.83), sour aftertaste (0.81), sourness (0.79), astringency (0.78), melt-ability (0.78), caramel aroma (0.77), mouth coating (0.77), sandiness (0.74) and porousness (0.64). Principal component two had strong positive coefficients for consistency (0.78), glossiness (0.77) and (0.72) while principal component three had a strong negative coefficient for coconut aroma (−0.74). Of the nine sensory attributes loaded on principal

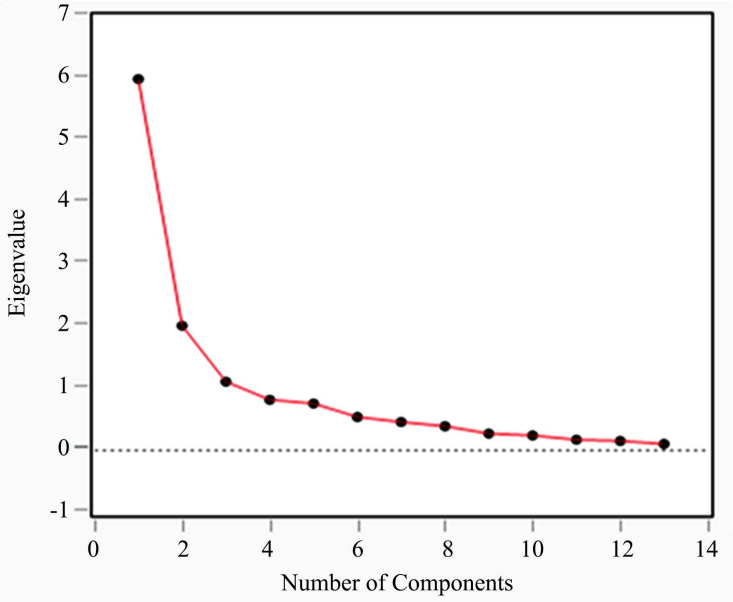

Figure 3. Scree plot for the different components.

Table 4. Loading matrix of descriptive attributes on principal components.

Attribute	Prin1	Prin2	Prin3
Starchy	0.830654	-	-
Sour Aftertaste	0.809463	-	-
Sourness	0.786665	-	-
Astringency	0.784800	-	-
Meltability	0.784195	-	-
Caramel aroma	0.773052	-	-
Mouth Coating	0.771606	-	-
Sandiness	0.737756	-	-
Porousness	0.636665	-	-
Coconut aroma	-	-	−0.736220
Consistency	-	0.782994	-
Glossiness	-	0.772016	-
Creaminess	-	0.718640	-

Key: Prin = Principal component.

component 1, starchy taste had the strongest correlation. A 10% increase in soursop and 0.5% increase in gum Arabic led to an 83.1% increase in the starchy taste. Additionally, for principal component 2, a unit increase in both soursop and gum Arabic led to an increase in the consistency of the ice cream by 78.3%. Coconut aroma decreased by 73.6% whenever there was a unit increase in the soursop and gum Arabic levels.

Varimax rotation was used to determine the multicollinearity of the descriptors loaded on the different principal components and the pictorial representation is shown in Figure 4. The descriptors were independently loaded on the three principal components and hence the conclusion that there was no multicollinearity among the descriptors. Principal component one accounted for 46%, component two 15.4% and component three 8.52% giving a total of 69.9%.

3.3. Effect of Soursop Puree and Gum Arabic on the Sensory Properties of Coconut Milk Ice Cream

The mean square values for the main effect and interaction effect are presented in Table 5. Addition of soursop puree in the ice cream mix at successive levels was associated with a statistically significant ($p < 0.05$) effect on colour, flavour, texture, taste and overall acceptability of the resulting ice cream. The effect of adding soursop puree in the ice cream mix resulted in a high preference in terms of colour followed by taste and flavour. This observation could be attributed to the physicochemical changes that occur during mix preparation. Caramelization of sugars present may have resulted in the caramel colour and flavour that made it desirable to consumers [25]. Addition of soursop puree also caused a significant difference ($p < 0.01$) in preference for samples in terms of texture and overall acceptability. Soursop puree has a creamy texture and this may have contributed to the body and texture of the resulting ice cream. Additionally, the volatile aroma compounds present in the soursop puree [27] made the ice cream desirable to consumers.

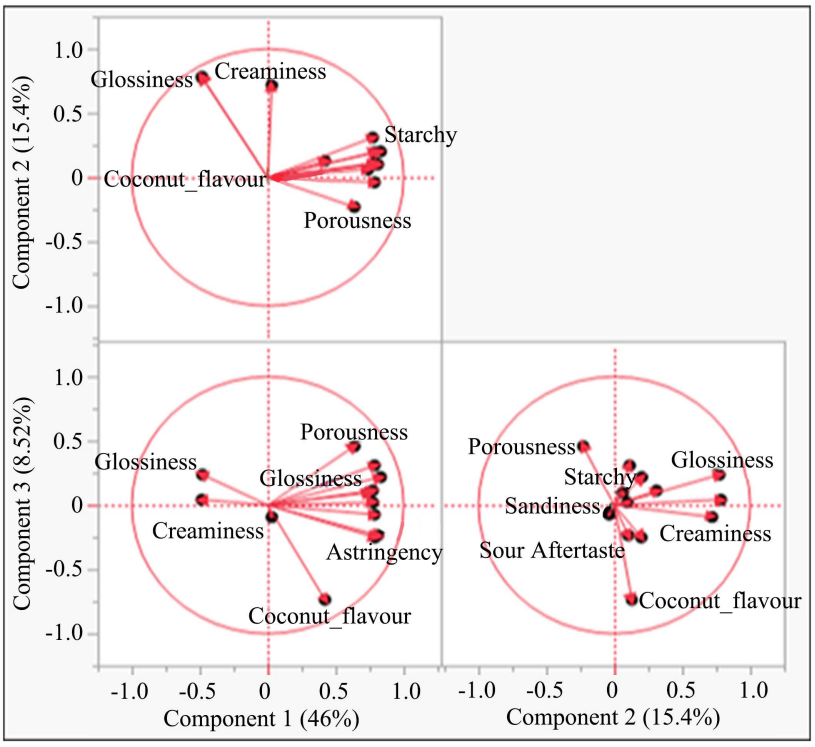

Figure 4. Loading of descriptive attributes on principal components.

On the other hand, the effect of adding gum Arabic at the different levels was not significant ($p < 0.05$) for all attributes. This observation could be attributed to the fact that gum Arabic dissolves easily in water resulting into an odorless and colorless solution [31]. However, the effect due to interaction between gum Arabic and soursop puree at the different levels was significant for colour, flavour and texture but not significant for taste and overall acceptability. Stabilizers and emulsifiers play an important role in the texture of ice creams [32]. According to [33], gum possesses an emulsifying property that causes fat destabilization hence improving textural properties of the ice cream [11]. These results were in line with those reported by [34] where using stabilizers and emulsifiers at 0.5% and 0.7% respectively gave the best outcome in ice cream. Therefore using the right stabilizers and emulsifiers is important.

Table 6 represents the correlation coefficients for the different sensory parameters. All attributes had a positive correlation to overall acceptability. This implies that an increase in the intensity of any of the parameters would consequently cause an increase in the overall acceptability of the ice cream and vice versa. The strongest correlation existed between taste and overall acceptability ($r = 0.78$). The high intensities for sweetness contributed to this strong correlation.

Table 5. Mean square table for the effect of soursop puree and gum Arabic and their interaction effect on sensory properties of the ice cream.

Source of Variation	Degrees of Freedom	Colour	Flavour	Texture	Taste	Overall Acceptability
Soursop	3	16.75***	11.06***	8.05**	11.87***	7.22**
Gum	3	1.95^{ns}	1.94^{ns}	3.27^{ns}	3.54^{ns}	1.21^{ns}
Soursop* Gum	9	2.57**	3.75*	3.79*	3.47^{ns}	3.07^{ns}
Panelists	29	6.82***	10.70***	8.77***	10.65***	5.55***
Error	435	0.96***	1.56***	1.61***	2.14***	1.68***
Coefficient of variation	-	18.41	24.62	25.77	29.16	26.34

Key: ***significant at $p < 0.001$, **significant at $p < 0.01$, *significant at $p < 0.05$, ns: Not significant at $p < 0.05$.

Table 6. Correlation coefficients for the different sensory properties.

	Colour	Flavour	Texture	Taste	Overall Acceptability
Colour	1	0.41***	0.35***	0.38***	0.39***
Flavour		1	0.51***	0.71***	0.68***
Texture			1	0.54***	0.58***
Taste				1	0.78***
Overall Acceptability					1

Key: ***Significant at $p < 0.001$.

The correlation between colour and overall acceptability (r = 0.39) was the weakest implying that consumers may not have focused more on the colour of the product but on the taste, flavour and texture. The strong positive correlation between flavour and taste (r = 0.71) can be attributed to addition of soursop fruit which has a characteristic strong fruity flavour due to the presence of volatile aroma compounds such as esters [27].

4. Conclusion and Recommendations

Addition of soursop puree and gum Arabic in the ice cream mix caused perceivable changes in the intensities of the different sensory parameters. The PCA indicated strong positive coefficients for consistency and glossiness and a strong negative coefficient for coconut aroma categorized into the three different principal components. Consumer preference leaned towards taste and flavour properties of the ice cream due to the presence of sugars and volatile flavour compounds in soursop respectively. Furthermore, the ability of gum Arabic to provide emulsifying and stabilizing properties resulted in ice cream with high intensities in terms of textural properties and consequently high preference by consumers. Treatments with combinations of 10% to 20% soursop puree and 0.5% to 1.0% gum Arabic were most preferred by consumers. Soursop and gum Arabic utilization in non-dairy coconut milk-based ice cream is an innovation that gives an ice cream with improved sensory properties. Therefore, soursop puree and gum Arabic have the potential to be used in coconut milk-based ice cream.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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