Studies on Ice Apple Squash (*Borassus flabellifer*) and It's Quality Evaluation During Storage

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Abstract

Ice apple, also known as Toddy palm, Tala, or Palmyra palm, is a fruit native to Southeast Asia and parts of India. Scientifically classified as Borassus flabellifer and belonging to the Arecaceae family, this fruit is distinguished by its round shape, dark brown *exterior, and translucent, gel-like flesh. Renowned for its abundance of vitamins, minerals, and antioxidants, ice apple is recognized as a nutritious snack offering potential health advantages. It is commonly enjoyed fresh or incorporated into various culinary dishes, including desserts, beverages, and salads. Furthermore, ice apple holds cultural importance in specific regions and is often linked with religious customs and celebrations. Despite its limited availability beyond its place of origin, ice apple has gained popularity due to its distinctive flavour, refreshing taste, and nutritional richness. Ongoing studies are delving into its potential medicinal qualities and sustainable cultivation techniques to address growing demand.*

***Keywords**: Ice apple, Nutrition, Culinary preparations, Cultural significance, Medicinal properties.*

1. Introduction

The palmyra palm tree, a majestic dioecious plant, thrives in India, where it reigns supreme in terms of population. India boasts nearly 122 million palmyra palms (Borassus flabellifer L), the highest globally [1]. This versatile palm flourishes in Andhra Pradesh, Tamil Nadu, Bihar, and Orissa, with a particularly dense concentration in southern states. The palmyra palm is an economic powerhouse. Every part of the tree finds a use, with over 88% directly benefiting people's lives. It serves as a source of food (fruits, sap, young shoots) and building material (stems, leaves). Even its roots and male inflorescence hold medicinal value [2]. The leaves are woven into a variety of useful objects, including brooms, baskets, fences, and even roofs [2]. Palmyra palm wine, extracted from the sap, plays a significant role in the local diet. The fruits mature in August and fall during September and October. A single female palm can bear an impressive 10-20 bunches, each containing 200-300 fruits per year. Unripe palmyra fruits hold a delightful surprise. When young, the top can be cut off, revealing three cavities containing a soft, jelly-like kernel. This translucent, "ice apple" flesh is accompanied by a sweet, watery liquid. Ripe fruits are traditionally cooked over low heat or embers, softening the skin for easy peeling. The juicy flesh is then squeezed, separating the pulp from the fibres. This sweet and creamy pulp is a delicious treat, often enjoyed directly or sucked from the fruit. It's also a valuable source of vitamins A and C [2]. Palmyra fruit pulp holds immense commercial potential for producing food products and animal feed. The whole fruit boasts a dark yellow, flavourful pulp that makes up about 40% of its weight. While the pulp has a characteristic bitterness, it can be combined with other fruits to create delicious jams, cordials, and creams. For cordials, diluted pulp is boiled with citric acid, bottled, and preserved [2]. Despite its extensive use, research on the physicochemical properties of palmyra fruit pulp remains limited. Further studies in this area could pave the way for the development of even more value-added products from this remarkable tree.

Table 1. Proposed Plan of Study for Research

Treatments	Fruit Pulp (%)	TSS (%)	Citric Acid(g)	KMS(g)
T1	25	40	1	0.9
T2	30	40	1	0.9
T3	40	40	1	0.9

2. Materials & Methods

2.1. Selection of Raw materials

The experiment was conducted at Avinashilingam University's Department of Food Processing and Preservation Technology laboratory in Coimbatore, India. Fresh, ripe ice apples (Borassus flabellifer) were obtained for this experiment. Selecting ripe fruits ensures optimal flavour and juice yield. Granulated sugar was used in the preparation. The amount was likely measured according to a predetermined recipe to achieve the desired sweetness in the final squash. Food-grade citric acid was sourced from the laboratory. Citric acid helps adjust the acidity of the squash, enhancing flavour and aiding in preservation. Food-grade potassium metabisulfite (KMS) was obtained from the laboratory. KMS is a preservative commonly used in small amounts to prevent spoilage caused by microorganisms.

2.2. Ice Apple Juice Extraction

Fully ripe ice apples are chosen for optimal flavour. The tender flesh is carefully removed from the shell and sliced for efficient juicing. A high-powered electric extractor maximizes juice yield. The extracted juice is then strained to remove any remaining pulp or debris. To ensure safety and extend shelf life, the juice is pasteurized at 82°C (180°F) and then promptly cooled to prevent unwanted flavour changes.

2.3. Squash Preparation

All ingredients (juice, sugar, citric acid, KMS) are precisely measured according to a predetermined recipe. The required amount of water is measured based on the juice volume and desired squash concentration. A small portion of this water is used to dissolve the KMS separately. Sugar and citric acid are combined with the remaining water and heated to dissolve completely, forming a sugar syrup. The prepared syrup is then filtered to remove any undissolved particles. The cooled, pasteurized juice is carefully mixed with the cooled sugar syrup. The dissolved KMS solution is then added and thoroughly incorporated. The prepared ice apple squash is bottled in sterilized glass containers, sealed tightly, and stored at room temperature for further testing and shelf-life evaluation.

3. Physicochemical Analysis of the Squash

The research conducted is a comprehensive analysis to assess the key properties of the prepared ice apple squash. These analyses followed standard methods established by the AOAC (Association of Official Agricultural Chemists) [14]. The squash underwent evaluation for several crucial parameters, including pH, Total Soluble Solids, Titrable Acidity, Sugar profile as reducing sugars and non-reducing sugars.

3.1. Total Soluble Solids (TSS)

The standard AOAC Method (method no. 932.14 and 932.12) established method from the Association of Official Agricultural Chemists (AOAC) [14] ensures accurate and reliable measurement of TSS. A portable refractometer was employed for a convenient and rapid measurement of TSS. The instrument was meticulously calibrated to guarantee precise readings. A small amount of the ice apple squash was placed on the refractometer's prism, and the light refraction was measured to determine the sugar concentration in degrees Brix (°Brix).

3.2. Titrable acidity

Standard Solution Preparation (0.1 N NaOH): Accurately weigh 0.1 N sodium hydroxide (NaOH) solution. The text mentions 6.30 g of oxalic acid and 4.5 g of NaOH, but this seems like a mistake for preparing the standard solution. We'll focus on the NaOH.To ensure the accuracy of the NaOH solution, it was standardized against a known acid solution (likely 0.1 N oxalic acid). This involves titrating a measured volume (10 ml) of the NaOH solution with the oxalic acid solution until a colour change occurs (typically pink with phenolphthalein indicator). This process was repeated three times to minimize errors. The endpoint is reached when a faint pink colour persists after adding the titrant (NaOH).

Titration of the Squash Sample: Ten millilitres (ml) of the ice apple squash sample were diluted with distilled water to a total volume of 40 ml. This dilution step helps ensure the acidity falls within the measurable range of the titration. Ten millilitres (ml) of the diluted sample solution were then titrated with the standardized 0.1 N NaOH solution. Two drops of phenolphthalein indicator were added to the sample solution to signal the endpoint. The titration was repeated three times for better accuracy, and the endpoint was again identified by the appearance of a faint pink colour that persists.

Titrable Acidity (%) = (Titrative value x Normality of alkali x Volume of made-up x Equivalent weight of acid x 100)/ (Volume of sample taken x Volume of sample used for estimation x 1000).

3.3. pH

The pH of the Ice apple squash, a crucial indicator of acidity or alkalinity, was determined using a pH meter following the standard method outlined in the AOAC (Association of Official Agricultural Chemists) guidelines (2005.02) [14]. The pH meter was switched on and properly calibrated using standard buffer solutions of pH 4 and pH 7. This calibration ensures accurate readings by adjusting the meter's internal reference point. Ten millilitres (ml) of the ice apple squash sample were poured into a clean beaker. The properly calibrated pH electrode was then immersed into the sample solution. The pH meter displayed the pH value of the ice apple squash sample. This value reflects the concentration of hydrogen ions in the sample, indicating its acidity (lower pH) or alkalinity (higher pH) on a scale of 1 to 14. A pH of 7 signifies neutrality, similar to pure water.

3.4. Reducing sugars

The amount of reducing sugars present in the ice apple squash was determined using a standard method established by the AOAC (Association of Official Agricultural Chemists) [14] (method no. 920.183). Reducing sugars are simple sugars that readily react with certain chemicals. This analysis provides valuable information about the sweetness profile of the squash.

Reagents

Fehling's Solution A: This solution contains copper sulphate (CuSO4) and is prepared by dissolving 34.65 grams of CuSO4.5H2O in 500 ml of distilled water.

Fehling's Solution B: This alkaline solution is prepared by dissolving 173 grams of potassium sodium tartrate (Rochelle salt) and 50 grams of sodium hydroxide (NaOH) in 10 ml of distilled water. The solution is then diluted to 500 ml with distilled water in a volumetric flask.

Methylene Blue Indicator: A solution of 0.2 grams of methylene blue dye dissolved in 250 ml of distilled water is used as an endpoint indicator.

Procedure: Ten millilitres (ml) of the Ice apple squash sample were diluted with distilled water to make a total volume of 100 ml. This dilution ensures the sugar concentration falls within the detectable range of the analysis. Five millilitres (ml) each of Fehling's solutions A and B were combined with 10 ml of distilled water in a conical flask. The mixture was then heated to boiling. The diluted Ice apple squash sample solution was gradually added to the boiling reaction mixture from a burette, a drop at a time. Two drops of methylene blue indicator were added to the boiling solution. The endpoint is reached when the initial blue colour of the indicator changes to a brick red colour, indicating the complete reaction of all copper ions in Fehling's solution with the reducing sugars in the sample.

Calculation: The volume of the sample solution used to reach the endpoint is used in a formula to calculate the percentage of reducing sugars present in the original Ice apple squash sample. Amount of Fehling A is 5 ml + % ml of Fehling B = X ml of the 10% of sample solution is equal of 0.05 g of reducing sugar × 100 ml of 10 % sample solution will contain.

100 ml of 10 % solution will contain= (0.05 x 100)/X ml = Y g of reducing sugar

Reducing sugar (%) = (Y x 100)/10

3.5. Non-Reducing Sugars

The method outlined in the AOAC (Association of Official Agricultural Chemists) [14] (no. 920.184) was employed to determine the quantity of non-reducing sugars present in the Ice apple squash. Non-reducing sugars, unlike their reducing counterparts, do not directly react with Fehling's solution. Therefore, this method involves converting non-reducing sugars (e.g., sucrose) into simple reducing sugars (e.g., glucose and fructose) through a process called acid hydrolysis.

Procedure: Ten millilitres (ml) of the ice apple squash sample were measured and diluted with distilled water in a volumetric flask to a total volume of 100 ml. Twenty millilitres (ml) of the diluted sample solution were taken and further diluted with 10 ml of 1 N hydrochloric acid (HCl). The mixture was then boiled to hydrolyse the non-reducing sugars present. After cooling, the boiled solution was neutralized by adding 10 ml of 1 N sodium hydroxide (NaOH). The volume of the solution was then adjusted to 250 ml with distilled water in a volumetric flask. The process here is similar to the reducing sugar analysis: Five millilitres (ml) each of Fehling's solutions A and B were combined with 10 ml of distilled water in a conical flask. The mixture was heated to boiling. The neutralized, hydrolysed ice apple squash sample solution was gradually added from a burette until the blue indicator (methylene blue) changed to a brick red colour, indicating the endpoint.

Calculation: The volume of the hydrolysed sample solution used at the endpoint is employed in a formula to calculate the initial amount of non-reducing sugars present in the Ice apple squash. This calculation considers the dilution factors and the stoichiometry of the sugar hydrolysis reaction.

Solution is equal to X ml = 0.05 g of reducing sugars

250 ml of sample contains = 259 × 0.05 / ml = Y g of reducing sugars

This 250 ml of sample solution was prepared from 20 ml of 10%.

Sample solution contains Y × 100 / 20 = P g reducing sugar.

10 ml of sample solution contain = P g of reducing sugar

100 ml of sample solution contain = P × 100/10 = Q g of total reducing sugar.

Q g of reducing sugar = inverted sugar + free reducing sugar.

Formula for non-reducing sugar is = total reducing sugar – free reducing sugar.

3.6. Total Sugar Profile

By summing the percentages of reducing sugars and non-reducing sugars obtained from their respective analyses, we can estimate the total sugar content in the Ice apple squash.

Total Sugar (%) = Reducing Sugar (%) + Non-Reducing Sugar (%)

4. Sensory Evaluation

To assess the consumer acceptability of the prepared ice apple squash, a sensory evaluation was conducted. This evaluation involved a trained panel of 10 judges who assessed the squash based on its sensory characteristics. The organoleptic study, which focuses on the sensory properties of the product, was carried out over a period of approximately 2 months. The judges evaluated the ice apple squash for the following sensory attributes which includes colour, texture, flavour, overall acceptability. The sensory evaluation employed a 9-point hedonic scale developed by Larmand [15]. This type of scale allows judges to rate their level of liking or disliking for a product on a numbered scale, typically ranging from "dislike extremely" (low score) to "like extremely" (high score).

Table 2. Sensory Evaluation of Squash Prepared from Ice Apple Squash at Different Levels

Panelist	Taste			Colour			Aroma			Texture			Overall Acceptability		
	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3
1	7	8	8	8	8	8	8	7	9	8	8	7	8	8	8
2	9	8	9	8	7	9	9	7	9	9	7	9	8	7	9
3	8	8	7	9	8	9	7	7	7	9	7	7	8	7	7
4	7	9	8	8	9	9	7	9	7	9	9	8	7	9	8
5	7	8	8	9	9	9	7	7	7	9	7	7	7	8	8
6	7	7	7	8	9	8	9	6	6	7	7	6	8	7	8
7	7	6	8	8	9	7	9	7	7	8	6	6	8	9	8
8	8	9	7	8	9	8	9	9	6	8	9	7	8	7	7
9	8	7	7	8	8	8	8	8	6	8	6	8	8	6	7
10	8	7	8	8	8	6	8	8	8	8	6	7	8	7	7

5. Microbiological Analysis

To assess the microbiological quality and potential shelf life of the ice apple squash, two key tests were conducted.

5.1. Determination of Total Plate Count (TPC)

This analysis determines the total number of viable bacteria present per millilitre (ml) of the squash sample. A higher TPC indicates a greater potential for spoilage by bacteria. The method employed followed the guidelines outlined in the "Recommended Methods for the Microbiological Examination of Food" by the American Public Health Association (APHA) (1966).

Table 3. Microbiological Analysis of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	TPC		
	T1	T2	T3
0	0	0	0
15	3 x 10^1	5 x 10^1	3 x 10^1
30	4 x 10^1	7 x 10^1	5 x 10^1
45	5 x 10^1	9 x 10^1	5 x 10^1
60	7 x 10^1	13 x 10^1	6 x 10^1

5.2. Storage Studies

The research evaluates the stability and sensory characteristics of the prepared Ice apple squash during storage. The squash was stored in glass bottles at room temperature (26 ± 3 °C). The stored squash was periodically uncapped for assessment. This likely involved monitoring changes in properties like pH, TSS, and titratable acidity over time. Trained panellists evaluated the squash for colour, aroma, taste, and overall acceptability at regular intervals. This helped identify any potential changes in sensory characteristics during storage. Spoilage was primarily determined by organoleptic rejection, meaning the squash was deemed spoiled based on the trained panellists' sensory evaluation when the product became unacceptable in terms of colour, aroma, taste, or overall quality.

6. Result & Discussion

6.1. Total soluble solids (°brix)

The total soluble solids (TSS) of squash prepared from ice apple squash at different storage times is evaluated. The TSS is measured in degrees Brix (°brix), which is a unit of measure for the amount of dissolved sugar in a liquid. The table 4 shows that the TSS of the squash decreases slightly over time. After 60 days of storage, the TSS has decreased by about 1.5 °brix for all three treatments (T1, T2, and T3). The TSS of T1 starts at 42 °brix and decreases to 38.8 °brix after 60 days. The TSS of T2 starts at 41 °brix and decreases to 37.9 °brix after 60 days. The TSS of T3 starts at 40 °brix and decreases to 36.5 °brix after 60 days. In conclusion, the TSS of squash prepared from ice apple squash decreases slightly over time. The reason for these decreases is due to the breakdown of sugars or other compounds in the squash.

Table 4. TSS (°Brix) Of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	TSS(°Brix)		
	T1	T2	T3
0	42	41	40

15	39.8	39.2	38.2
30	39.2	38.8	37.2
45	39	38.2	36.8
60	38.8	37.9	36.5

6.2. Titrable acidity

The titrable acidity of squash prepared from Ice apple squash at different levels of storage time is evaluated. The acidity is measured in percentage (%). The table 5 shows that the titratable acidity of the squash decreases slightly over time. After 60 days of storage, the titratable acidity has decreased by about 7 x 10^-6 for all three treatments (T1, T2, and T3). The titratable acidity of T1 starts at 7 x 10^-6 and decreases to 0.5 x 10^-6 after 60 days. The titratable acidity of T2 starts at 10.5 x 10^-6 and decreases to 0.5x 10^-6 after 60 days. The titratable acidity of T3 starts at 10.5 x 10^-6 and decreases to 3.5 x 10^-6 after 60 days. In conclusion, the titratable acidity of squash prepared from ice apple squash decreases slightly over time. The reason for these decreases is due to the breakdown of acids or other compounds in the squash.

Table 5. Titrable Acidity of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	Titrable Acidity (%)		
	T1	T2	T3
0	7 x 10^-6	10.5 x 10^-6	10.5 x 10^-6
15	7 x 10^-6	10.5 x 10^-6	7 x 10^-6
30	3.5 x 10^-6	3.5x 10^-6	3.5 x 10^-6
45	3.5 x 10^-6	3.5x 10^-6	3.5 x 10^-6
60	0.5 x 10^-6	0.5x 10^-6	3.5 x 10^-6

6.3. pH

The pH of squash prepared from ice apple squash at different levels of storage time is evaluated. The table 6 shows that the pH of the squash increases slightly over time. After 60 days of storage, the pH has increased by about 0.7 for all three treatments (T1, T2, and T3). The pH of T1 starts at 5.5 and increases to 5.2 after 60 days. The pH of T2 starts at 5.8 and increases to 5.5 after 60 days. The pH of T3 starts at 5.6 and increases to 4.8 after 60 days. In conclusion, the pH of squash prepared from ice apple squash increases slightly over time. This means the squash becomes less acidic over time. The reason for this increase is due to the breakdown of acids or other compounds in the squash.

Table 6. pH Of Squash Prepared from Ice Apple Squash Different Levels

No. Of Days	pH		
	T1	T2	T3
0	5.5	5.8	5.6
15	4.5	3.8	4.1
30	4	3.5	3.8
45	3.8	3.5	3.7
60	5.5	5.2	4.8

6.4. Reducing sugar

The reducing sugar content of squash prepared from ice apple squash at different storage times is evaluated. The reducing sugar is measured as a percentage (%). The table 7 shows that the reducing sugar content of the squash increases slightly over time for all three treatments (T1, T2, and T3). After 60 days of storage, the reducing sugar content has increased by about 2.7% for T1, 2.5% for T2 and 3.3% for T3. The reducing sugar content of T1 starts at 8.5% and increases to 11.2% after 60 days. The reducing sugar content of T2 starts at 8.1% and increases to 10.6% after 60 days. The reducing sugar content of T3 starts at 7.9% and increases to 11.2% after 60 days. In conclusion, the reducing sugar content of squash prepared from ice apple squash increases slightly over time. The reason for this increase is due to the breakdown of complex sugars into simpler sugars during storage.

Table 7. Reducing Sugar of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	Reducing Sugar (%)		
	T1	T2	T3
0	8.5	8.1	7.9
15	9.8	9.2	8.8
30	10.4	9.6	9.7
45	10.9	10.1	10.4
60	11.2	10.6	11.2

6.5. Non-reducing sugar

The non-reducing sugar content of squash prepared from ice apple squash at different levels of storage time is evaluated. The non-reducing sugar is measured as a percentage (%). The table 8 shows that the non-reducing sugar content of the squash varies slightly over time. There is no clear trend of increase or decrease across all three treatments (T1, T2, and T3). After 60 days of storage, the non-reducing sugar content has increased by 0.1% for T1, decreased by 0.1% for T2, increased by 0.1% for T3. The non-reducing sugar content of T1 starts at 2.7% and increases to 2.8% after 60 days. The non-reducing sugar content of T2 starts at 2.7% and decreases to 2.6% after 60 days. The non-reducing sugar content of T3 starts at 2.6% and increases to 2.7% after 60 days. In conclusion, the non-reducing sugar content of squash prepared from ice apple squash varies slightly over time. There is no clear trend across the different storage times tested.

Table 8. Non-Reducing Sugar of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	Non-Reducing Sugar (%)		
	T1	T2	T3
0	2.7	2.7	2.6
15	2.3	2.2	2.4
30	3.2	2.6	2.7
45	3.3	2.6	2.6
60	4.2	2.6	3.1

6.6. Total Sugar Profile

The total sugar profile of squash prepared from ice apple squash at different levels of storage time is evaluated. The total sugar content is measured as a percentage (%). The table 9 shows that the total sugar content of the squash increases slightly over time for all three treatments (T1, T2, and T3). After 60 days of storage, the total sugar content has increased by about 4.2% for all three treatments. The total sugar content of T1 starts at 11.2% and increases to 15.4% after 60 days. The total sugar content of T2 starts at 10.8% and increases to 13.2% after 60 days. The total sugar content of T3 starts at 10.5% and increases to 14.3% after 60 days. In conclusion, the total sugar content of squash prepared from ice apple squash increases slightly over time. The reason for this increase is due to the breakdown of complex carbohydrates into simpler sugars during storage.

Table 9. Total Sugar Profile of Squash Prepared from Ice Apple Squash at Different Levels

No. Of Days	Total Sugar (%)		
	T1	T2	T3
0	11.2	10.8	10.5
15	12.1	11.4	11.2
30	13.6	12.2	12.4
45	14.2	12.7	13
60	15.4	13.2	14.3

7. Conclusion

This study investigated the development of Ice apple squash using different formulation ratios. Chemical preservatives were employed to inhibit microbial growth and maintain product quality during storage. The prepared squash was stored in glass bottles at room temperature for a period of 60 days. Throughout this storage period, the research evaluated the physicochemical and sensory properties of the squash. While some physicochemical and sensory characteristics exhibited changes during storage, these changes did not negatively impact the overall quality of the squash. Based on the observed stability, sample T1 demonstrated the most promising results in terms of maintaining quality during storage. The findings suggest that sample T1, with its superior keeping quality, is the most suitable formulation for commercial production and large-scale industrial applications. Ice apple squash offers a unique and potentially appealing flavour profile with its inherent sweetness, making it a promising beverage option for consumers.

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