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Impact of storage on chemical properties of custard apple (*Annona squamosa* L) pulp

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Abstract
The present investigation was undertaken to evaluate the extraction methods, packaging material and its effect of storage on the chemical properties of custard apple pulp. Eight treatment combinations were evaluated using a completely randomised block design in three replications on local genotypes of Satpuda Hills. The treatments involved three parameters: the extraction method (manual and mechanical), the packaging material (200 and 300 gauge LDPE), and the storage temperature (3 to 5 ^{0}C and -18 ^{0}C). Research on the physical, chemical, and organoleptic characteristics of custard apple pulp was carried out in the winter of 2023, with observations being made every fifteen days for up to six months. The research was conducted during winter-2023 and observations were recorded at intervals of fifteen days up to six months on the chemical properties of custard apple pulp. It was observed that the TSS, total sugars, and reducing sugars rose during storage. The pH and acidity decreased during storage at a differential rate. Compared to cold storage (-18 ^{0}C), ambient storage (3-5 ^{0}C) showed a faster rate of change.

Keywords: Custard apple, storage, TSS, acidity, reducing sugar, pH, chemical properties, pulp

Introduction

Custard apples are often consumed fresh after ripening, with a very short shelf life of two to three days. Because the biochemical alterations in custard apples are climacteric in nature, they happen more quickly after harvest. After being harvested, the mature fruits ripen quickly, get overly soft in 2-3 days at room temperature, and are therefore unfit for human consumption. Consequently, the growers would benefit from the custard apples' longer shelf life (Gohlani and Bisen, 2012) [5].

Because of its excellent flavour and high nutritional content, the custard apple (*Annona squamosa* L.) is mostly eaten as a dessert fruit. With an overall area of 40,000 hectares, it is widely grown in India's states of Maharashtra, Gujarat, Madhya Pradesh, Chhattisgarh, Assam, Uttar Pradesh, Bihar, Rajasthan, Andhra Pradesh, and Tamil Nadu (Sundaramahalingam *et al*., 2021) [18]. 70.5% moisture, 23.5% carbs, 1.6% proteins, 0.4% fat, 0.9% mineral matter, 1.0% iron, 0.2% calcium, 0.4% phosphorus, and 104 Kcal/100g of edible part are all present in this fruit (Gopalan *et al*., 1974) [6]. Fruits of *A. squamosa* have a limited shelf life due to their perishable nature. Pulp has a relatively limited shelf life—just a few hours at room temperature—but it may be kept frozen for up to six months.

The market offers the pulp in a frozen state. Processing requires the availability of high-quality pulp nearly all year round. It has a little sweetness and acidity. The primary processing limitations for custard apples are the appearance, which gradually turns bitter after pulp extraction due to limonin, and the enzymatic browning reaction, which is catalysed by polyphenol oxidase (PPO). To keep the pulp fresh for a long time, different treatments are given to them. In the present study, the effect of different treatments on the chemical properties of custard apple pulp is discussed.

Materials and Methods

The present research was conducted at the Department of Horticulture Laboratory, Govt. College of Agriculture, Nandurbar, Maharashtra State, India during the year 2022- 23. For the research work, the multilayered pouches made up of LDPE, of 200 gauge and 300 gauge;

of 500 ml capacity were used. The best quality riped fruits with firm texture were selected for pulp separation. The pulp was separated by brush type extractor from peel and seeds. Pulp can be extracted by two different methods *viz*., manual method and mechanical method.

The content of total soluble solids in the pulp was measured with the help of Erma Hand Refractometer (0-32^{0}Brix). The prism of refractometer was washed with distilled water and wiped by muslin cloth after recording each observation (A.O.A.C., 1990). Acidity of the pulp was determined by titration with 0.01 N sodium hydroxide prescribed by Ranganna, 1986 [16]. The pH of the products was determined by using a pH meter. The pH is a scale used to measure how acidic or basic a water-based solution is. Reducing sugars were determined by the method suggested by Lane and Eynon (1960) [10] and as modified by Ranganna (1986) [16]. Total sugars was determined by method of Lane and Eynon (1923) [10] as modified by Ranganna (1986) [16]. All experiments were carried out by using Completely Randomized Design (CRD). The data obtained in the present investigation was analyzed for the statistical significance according to the procedure given by Panse and Sukhatme (1985) [13].

Results and Discussion

On the initial count, observations for all the parameters recorded higher readings for the mechanical method of extraction over manual methods. The initial readings for total soluble solids were 23.30^{0}Brix and 23.70^{0}Brix for manual and mechanical methods respectively. The acidity was 0.39 per cent and 0.42 per cent and TSS: acidity ratio was 59.74 to 60.00 respectively for manual and mechanical methods of pulp extraction. The pH of manual extraction was 5.65 and that of mechanical was 5.70. Total sugar content was also slightly higher for mechanical extraction which was 20.60 per cent over manual extraction which was 19.40 per cent. Reducing sugar content for manual extraction was 16.70 per cent and that of mechanical was 16.90 per cent. The results are discussed under the following separate sections of chemical properties.

Total Soluble Solids (TSS)

The effect of the storage of custard apple pulp on its TSS had showed an increase in the value upon storage. Table 2 shows the combined impact of extraction techniques, packing materials, and storage circumstances on the custard apple pulp on periodic TSS contents. The data showed statistically significant variations in the TSS concentrations of custard apple pulp as a result of different treatments. The more increase in TSS (^{0}Brix) is not acceptable for custard apple pulp during storage. The lesser the increase in TSS content, the better the quality of pulp is considered.

On the 15th day of the custard apple pulp storage, the maximum TSS recorded by treatment T_5 (24.11 ^{0}Brix) followed by T_7 (24.04 ^{0}Brix) and T_1 (23.98 ^{0}Brix). On the 30th day of the storage, the slowest increase in TSS content was recorded by T_4 (23.51 ^{0}Brix) which was at par with T_2 (23.64 ^{0}Brix) which was favourable. The highest TSS was shown by treatment T_7 (24.91 ^{0}Brix) followed by T_5 (24.42 ^{0}Brix), T_6 (24.22 ^{0}Brix) and T_1 (24.18 ^{0}Brix). The highest TSS observed by treatment T_6 (25.37 ^{0}Brix) on the 45th day of custard apple pulp storage was followed by T_7 (25.10 ^{0}Brix) and T_5 (25.07 ^{0}Brix). T_4 (23.59 ^{0}Brix) showed the slowest increase in TSS content on the 60th day of storage and it was at par with T_2 (23.84 ^{0}Brix), which was beneficial.

The slowest increase in TSS on 75th day was observed in the treatment T_4 (23.68 ^{0}Brix) which is at par with T_2 (24.02 ^{0}Brix) and followed by T_3 (24.53 ^{0}Brix) and T_1 (25.41 ^{0}Brix). The highest TSS on the same day of storage was recorded by the treatment T_5 (27.06 ^{0}Brix) followed by T_7 (27.04 ^{0}Brix), T_8 (26.13 ^{0}Brix) and T_5 (26.05 ^{0}Brix). On the 90th day of storage, the maximum TSS (27.64 ^{0}Brix) was recorded in the treatment T_5. It was followed by treatments T_7 (27.32 ^{0}Brix), T_8 (26.15 ^{0}Brix) and $T_{6,}$ (26.10 ^{0}Brix). The minimum TSS (23.86 ^{0}Brix) was recorded in the treatment T_4. Among the eight treatments, T_4 recorded the slowest increase in TSS at the 105th day, which was (23.93 ^{0}Brix), followed by T_2 (24.47 ^{0}Brix) and T_3 (24.76 ^{0}Brix). On the 135th day of custard apple pulp storage, treatment T_5 had the highest TSS (29.24 ^{0}Brix), followed by T_7 (27.81 ^{0}Brix) and T_6 (26.37 ^{0}Brix). With a TSS of 24.25^{0}Brix, treatment T4 had the lowest reported TSS, trailed by treatment T_2's 24.93 ^{0}Brix and treatment T_3's 25.07 ^{0}Brix.

On the 150th day of storage, T_4 (24.39 ^{0}Brix) exhibited the slowest increase in TSS content, which was advantageous because it was comparable to T_2 (25.01 ^{0}Brix). The treatments with the greatest TSS were T_5 (29.95 ^{0}Brix), T_7 (28.06 ^{0}Brix), T_6 (26.41 ^{0}Brix), and T_8 (26.34 ^{0}Brix). On the 165th day, the treatment T_4 (24.50 ^{0}Brix) showed the slowest increase in TSS, followed by T_2 (25.07 ^{0}Brix), T_3 (25.70 ^{0}Brix), and T_8 (26.36 ^{0}Brix). The treatment T_5 recorded the maximal TSS (30.83 ^{0}Brix) on the 180th day of storage. Treatments T_7 (28.46 ^{0}Brix), T_6 (26.69 ^{0}Brix), and T_8 (26.41 ^{0}Brix) came after it. In treatment T_4, the lowest TSS (24.58 ^{0}Brix) was observed. The mechanical extraction method revealed a small rise in TSS concentrations in both packaging materials and under various storage conditions. This could result from the pulp being fully extracted using another inert substance.

After six months of storage, Mohite (2002) [11] found that the TSS of custard apple pulp increased from 26.86 to 28.20^{0}Brix. Comparable outcomes were also noted for custard apple pulp by Geeta (2000) [4], Aggarwal and Saini (2002) [2], Pareek (2011) [14], Kumhar (2014) [8] and Kachhadiya and Jethva (2017) [7], mango pulp (Patil, 1990; Sethi, 1995) [15, 17], guava pulp (Tondon and Kalra, 1984) [19], sapota pulp (Kute *et al*., 2000) [9]. It was discovered that the rate at which the TSS levels of pulp grew during storage was higher in 3-5 °C storage than in -18^{0}C storage.

Acidity

The findings pertaining to acidity contents, as displayed in Table 3, indicated statistically significant variations resulting from different treatment combinations. The highest acidity observed by treatment T_6 and T_8 (0.42) on the 15th day of custard apple pulp storage and was at par with T_5 and T_7 (0.41). T_6 (0.41) showed the slowest decrease in acidity content on the 30th day of storage and it was at par with T_5 and T_8 (0.40), which was beneficial. On the 45th day of custard apple pulp storage, treatment T_6 had the highest acidity (0.40) which was at par with T_5 and T_8 (0.39). On the 60th day of storage, T_6 (0.39) exhibited the slowest decrease in acidity content, which was advantageous because it was at par to T_5 and T_8 (0.38).

The treatments with the more reduced acidity were T_1 (0.34), T_3 (0.34), and T_2 (0.35). The slowest decrease in acidity on 75th day was observed in the treatment T_5, T_6 and

T_8 (0.37) which was at par with T_7 (0.36). The most reduced acidity on the same day of storage was recorded by the treatment T_3 (0.33) followed by T_1 (0.34), and T_2 (0.35). On 90th day of storage the maximum acidity (0.36) was recorded in the treatment T_6 and T_8. It was at par with treatments T_5 (0.35). The minimum acidity (0.32) was recorded in the treatment T_3. Out of all the eight treatments, T_8 had the slowest decrease in acidity at day 105, measuring 0.35. It was at par with T_6 and T_7 was next to it with 0.34 and 0.33 respectively.

Treatments T_8 and T_7 had the greatest acidity (0.32) on the 135th day of custard apple pulp storage, at par with T_6 (0.31) and followed by T_5 (0.30). T_1 (0.25) showed the most decrease in acidity content on the 150th day of storage. T_8 (0.31) is good because it was similar to T_7 (0.30) and T_6 (0.30) were the treatments with lowest acidity decrease than initial readings. The treatment T_6 and T_8 (0.29) had the slowest decrease in acidity on day 165 which was at par with T_7 (0.28). On the final day of storage, the treatment T_6 and T_8 (0.28) had the highest acidity which was at par with T_7 (0.27). On the 180th day of storage, the treatment T_1 reported the maximum decrease in acidity (0.23). It was followed by treatments T_3 (0.24), T_4 and T_2 (0.25). The acidity concentrations in packing materials and under different storage settings showed a slight increase, according to the mechanical extraction method. This can happen if another inert material is used to entirely remove the pulp. It was discovered that as the period increased, titrable acidity dropped. This may result from raising the storage temperature during storage and deactivating metabolic enzymes that break down polysachharides to produce acids (Kumhar *et al*., 2014) [8].

TSS: acidity ratio

Table 4 shows the observations of the TSS: acidity ratio of custard apple pulp stored at various conditions. On the 15th day of the custard apple pulp storage, the maximum TSS: acidity ratio was recorded by treatment T_1 (64.81) followed by T_3 (64.43) and T_5 (62.65). The slowest increase in TSS: acidity ratio content of the pulp was recorded by treatment T_8 which was at par with treatment T_6 and T_4. On the 30th day of the storage, the slowest increase in TSS: acidity ratio content was recorded by T_6 (62.80) which was at par with T_4 (63.53) and T_2 (63.32) which was favourable.

The highest TSS observed by treatment T_1 (72.27) on the 45th day of custard apple pulp storage was followed by T_7 (69.92) and T_3 (69.17). T_6 (67.22) showed the slowest increase in ratio on the 60th day of storage and it was comparable to T_4 (65.53), which was beneficial. Treatment T_1 (73.53) reported the highest ratio, followed by T_3 (71.86), T_6 (69.97) and T_2 (67.47). The slowest increase in ratio on 75th day was observed in the treatment T_4 (67.65) which was at par with T_2 (67.97), and followed by T_6 (70.41) and T_8 (70.62). On 90th day of storage the maximum ratio (80.35) was recorded in the treatment T_7. It was followed by treatments T_5 (78.98), T_1 (77.61), T_3 (77.05) and T_8 (72.63). The minimum ratio (70.17) was recorded in the treatment T_4. Among the eight treatments, T_4 recorded the slowest increase in ratio at 105th day, which was (74.79), at par with T_8 (74.76) and followed by T_2 (76.47).

On 120th day, minimum increase in ratio was observed in T_4 (77.58) and the maximum ratio observed was 92.90 by the treatment T_5 followed by T_1 (92.06), T_7 (86.52) and T_3 (85.76). On the 135th day of custard apple pulp storage, treatment T_1 had the highest ratio (100.85), followed by T_5 (97.48) and T_3 (92.84). On the 150th day of storage, T_8 (84.98) exhibited the slowest increase in ratio content, which was advantageous because it was comparable to T_4 (87.10). On the 165th day, the treatment T_8 (90.91) showed the minimum increase in ratio which was at par with T_6 (91.79), followed by T_4 (94.23), and T_2 (100.28). The treatment T_1 (117.72) had the greatest ratio on the day of storage, followed by T_5 (112.04), T_3 (102.81), and T_7 (101.43). The treatment T_1 recorded the maximal ratio (124.54) on the 180th day of storage. Treatments T_5 (118.56), T_3 (107.72), and T_7 (105.42) came after it.

After six months of storage, Mohite (2002) [11] found that the ratio of custard apple pulp increased from 26.86 to 28.20^{0}Brix. Comparable outcomes were also noted for custard apple pulp by Geeta (2000) [4], Aggarwal and Saini (2002) [2].

pH

The highest pH observed by treatment T_6 and T_8 (5.35) on the 15th day of custard apple pulp storage and was at par with T_5 (5.34) and followed by T_7 (5.33). T_6 and T_8 (5.34) showed the slowest decrease in pH content on the 30th day of storage and it was at par with T_5 (5.32), which was beneficial. Treatment T_1 (5.24) reported the highest pH decreased from initial reading, followed by T_3 (5.26) and T_2 (5.27). On the 45th day of custard apple pulp storage, treatment T_8 had the highest pH (5.33), which was at par with T_6 (5.32) and followed by T_5 (5.29) and T_7 (5.28).

On the 60th day of storage, T_8 (5.32) exhibited the slowest decrease in pH content, which was advantageous because it was comparable to T_6 (5.30), T_5 and T_7 (5.26). The treatments with the more reduced pH were T_1 (5.20), T_3 (5.21), and T_2 (5.22). The slowest decrease in pH on 75th day was observed in the treatment T_8 (5.31) followed by T_6 (5.29) and T_5, T_7 (5.24). On 90th day of storage the maximum pH (5.30) was recorded in the treatment T_8. It was followed by treatment T_6 (5.28), T_7 and T_4 (5.22).

T_8 had the slowest decrease in pH at day 105, measuring 5.28. T_6 and T_4 were in second and third, respectively, with 5.25 and 5.21. T_1 (5.09) had the lowest pH at day 105, followed by T_3 (5.11), T_2 (5.17), and T_5 (5.19). The treatment T_8 had the highest pH detected on day 120, at 5.26, followed by T_6 at 5.23, and T_4 (5.19) was at par with T_7 (5.18). Treatment T_8 had the greatest pH (5.24) on the 135th day of custard apple pulp storage, followed by T_6 (5.21) and T_7 (5.17). T_1 (4.95) showed the most decrease in pH content on the 150th day of storage. T_8 (5.22) is good because it was similar to T_6 (5.20) and T_7 (5.15) were the treatments with lowest pH decrease than initial readings.

The treatment T_8 (5.21) had the slowest decrease in pH on day 165 followed by T_6 (5.18), and T_7 (5.14). On the final day of storage, the treatment T_8 (5.20) had the highest pH, followed by T_6 (5.16), and T_7 (5.13). On the 180th day of storage, the treatment T_1 reported the maximum decrease in pH (4.82). It was followed by treatments T_3 (4.95), T_2 (5.03) and T_4 (5.06). The pH concentrations in packing materials and under different storage settings showed a slight increase, according to the mechanical extraction method. This can happen if another inert material is used to entirely remove the pulp. Low storage temperature during storage could be the reason for this. Custard apple pulp's pH generally dropped while it was being stored. The breakdown of pectin in organic acid was the cause of the pH fall in the samples. Muhammad *et al.* (2011) [12] in apple pulp, Wisal *et al.* (2013) [20] in strawberry juice, and Bakane *et al.* (2015) [3] in custard apple pulp all observed similar pH drops with storage time.

Total sugars

On the 15th day of the storage of custard apple pulp, the slowest increase in total sugar content was reported by the treatment T_4 which was 19.43% (26.15) and at par with T_2, 19.51% (26.21); followed by T_8, 20.68% (27.05) and T_6, 20.81% (27.14). The highest total sugar recorded was 21.14% (27.38) by treatment T_5. On the 30th day, the highest total sugar content was observed with treatment T_5 22.06% (28.01) and the lowest was recorded in treatment T_4 19.61% (26.28), at par with treatment T_2, 19.74% (26.38); followed by T_3, 20.39% (26.85) and T_8, 20.73% (27.08). On the 45th day of custard apple pulp storage, treatment T_4 reported the slowest increase in total sugar content, with a value of 19.66% (26.32); T_2, 19.87% (26.47); T_3, 20.54% (26.95) and T_8, 20.74% (27.09). The results show that on day 60, the maximum total sugar level was 22.93% (28.61) by treatment T_5, while the lowest was 19.79% (26.41) by treatment T_4.

After 75 days of custard apple pulp storage, treatment T_4, 19.97% (26.54), T_2, 20.24% (26.73), T_8, 20.84% (27.16), and T_3, 21.68% (27.75) showed the least rate of increase in total sugar content. According to the data, the highest total sugar level recorded on day 90 was 24.55% (29.70) by treatment T_5, while the lowest was 20.04% (26.59) by treatment T_4. Treatments T_4, 20.14% (26.67), T_2, 20.48% (26.90), T_8, 21.06% (27.31) and T_3, 22.27% (28.16) exhibited the least rate of growth in total sugar content after 105 days of custard apple pulp storage. The lowest recorded total sugar level on day 120 was 20.22% (26.72), while the maximum was 25.37% (30.24) based on the data. Following in the observational sequence were treatment T_2, 20.57% (26.97); T_8, 21.25% (27.45) and T_3, 22.63% (28.41).

On the 135th, 150th and 165th day of the custard apple pulp storage, the slowest increase in total sugar content was reported by the treatment T_4 which was 20.44% (26.88), 20.63% (27.02) and 20.73% (27.08). Treatment T_5 recorded the highest increase in total sugar content of 25.92% (30.61), 26.81% (31.18) and 27.35% (31.53) on the 135th, 150th and 165th day respectively. On the final 180th day of the storage of pulp, treatment T_4 recorded the slowest increase in total sugar content which was 20.89% (27.19) while the highest increase was 27.85% (31.85) by treatment T_5. The rapid breakdown of polysaccharides such as pectin, cellulose, starch, etc. and their conversion into simple sugars at room temperature, while it was slower at low temperature, maybe the cause of the increase in total sugars in the pulp held under varied circumstances. Similar findings were reported by Geeta (2000) [4].

Reducing sugars

On the 15th day of the storage of custard apple pulp, the slowest increase in reducing sugar content was reported by the treatment T_4 which was 16.80% (24.20) followed by T_2, 16.95% (24.31); T_8, 16.97% (24.33) and T_6, 17.22% (24.52). On the 30th day, the highest reducing sugar content observed was 18.76% (25.67) and the lowest recorded was 17.04% (24.38) by treatment T_4 followed by treatment T_2, 17.18% (24.49); T_8, 17.37% (24.63) and T_6, 17.81% (24.96). On the 45th day of custard apple pulp storage, treatment T_4 reported the slowest increase in decreasing sugar content, with a value of 17.10% (24.43); T_2, 17.32% (24.59); T_8, 17.62% (24.82), T_6, 17.95% (25.06) and T_5, 19.23% (26.01) was the largest reduced sugar content that was reported by treatment T_5.

The results show that on day 60, the maximum reducing sugar level was 20.66% (27.03) by treatment T_5, while the lowest was 17.24% (24.54) by treatment T_4. After 75 days of custard apple pulp storage, treatment T_4, 17.45% (24.69), T_2, 17.67% (24.86), T_8, 18.15% (25.21) and T_6, 19.14% (25.94) showed the least rate of increase in reduced sugar content. According to the data, the highest decreasing sugar level recorded on day 90 was 22.31% (28.18) by treatment T_5, while the lowest was 17.52% (24.74) by treatment T_4. Treatments T_4, 17.65% (24.84), T_2, 17.93% (25.05), T_8, 18.56% (25.52) and T_6, 19.74% (26.38) exhibited the least rate of growth in reduced sugar content after 105 days of custard apple pulp storage.

The lowest recorded lowering sugar level on day 120 was 17.71% (24.88), while the maximum was 23.14% (28.75) based on the data. Following in the observational sequence were treatment T_2, 18.04% (25.13); T_8, 18.73% (25.64) and T_6, 20.10% (26.64). On the 135th, 150th and 165th day of the custard apple pulp storage, the slowest increase in reducing sugar content was reported by the treatment T_4 which was 17.93% (25.05), 17.94% (25.06) and 18.26% (25.27). Treatment T_5 recorded the highest increase in reducing sugar content of 23.67% (29.11), 23.94% (29.29) and 25.12% (30.06) on 135th, 150th and 165th day respectively. On the final 180th day of the storage of pulp, treatment T_4 recorded the slowest increase in reducing sugar content which was 18.44% (25.43) while the highest increased was 25.63% (30.42) by treatment T_5.

Over the course of six months, Mohite (2002) [11] also documented an increase in the reducing sugar content in custard apple pulp, going from 16.15 to 17.57 percent. The possible causes of this could include heightened activity of various enzymes that break down stored starch, cellulose, pectin, etc. in pulp that has been stored, as well as the conversion of sugars into acid during processing at room temperature.

Table 1: Initial chemical composition of custard apple pulp before the storage

Sr. No.	Chemical composition of pulp	Method of extraction of pulp	
		Manual method	Mechanical method
1	TSS (^{0}Brix)	23.30	23.70
2	Acidity (%)	0.39	0.42
3	TSS: Acidity ratio	59.74	60.00
3	Reducing sugars (%)	16.70	16.90
4	Non-reducing sugars (%)	2.70	3.70
5	Total sugars (%)	19.40	20.60
6	pH	5.65	5.70

Table 2: Effect of extraction methods and packaging materials on TSS (0Brix) of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	23.30	23.98	24.18	24.57	25.00	25.41	25.87	26.46	26.70	27.23	27.79	28.25	28.64
T_2	M1P1C2	23.30	23.58	23.64	23.73	23.84	24.02	24.29	24.47	24.81	24.93	25.01	25.07	25.18
T_3	M1P2C1	23.30	23.84	23.89	24.21	24.43	24.53	24.66	24.76	24.87	25.07	25.45	25.70	25.85
T_4	M1P2C2	23.30	23.42	23.51	23.54	23.59	23.68	23.86	23.93	24.05	24.25	24.39	24.50	24.58
T_5	M2P1C1	23.70	24.11	24.42	25.07	26.82	27.06	27.64	28.16	28.80	29.24	29.95	30.25	30.83
T_6	M2P1C2	23.70	23.85	24.22	25.37	25.99	26.05	26.10	26.22	26.33	26.37	26.41	26.62	26.69
T_7	M2P2C1	23.70	24.04	24.91	25.10	26.89	27.04	27.32	27.42	27.69	27.81	28.06	28.40	28.46
T_8	M2P2C2	23.70	23.82	24.14	24.95	25.57	26.13	26.15	26.17	26.28	26.31	26.34	26.36	26.41
	SE ±		0.061	0.049	0.040	0.070	0.069	0.050	0.080	0.080	0.070	0.061	0.123	0.050
	CD (5%)		0.170	0.150	0.120	0.222	0.200	0.160	0.229	0.240	0.220	0.172	0.350	0.160

Note:

$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18^{0}C temperature

Table 3: Effect of extraction methods and packaging materials on acidity of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	0.39	0.37	0.35	0.34	0.34	0.34	0.33	0.31	0.29	0.27	0.25	0.24	0.23
T_2	M1P1C2	0.39	0.38	0.37	0.36	0.35	0.35	0.34	0.32	0.30	0.28	0.26	0.25	0.25
T_3	M1P2C1	0.39	0.37	0.36	0.35	0.34	0.33	0.32	0.31	0.29	0.27	0.26	0.25	0.24
T_4	M1P2C2	0.39	0.38	0.37	0.36	0.36	0.35	0.34	0.32	0.31	0.29	0.28	0.26	0.25
T_5	M2P1C1	0.42	0.41	0.40	0.39	0.38	0.37	0.35	0.33	0.31	0.30	0.28	0.27	0.26
T_6	M2P1C2	0.42	0.42	0.41	0.40	0.39	0.37	0.36	0.34	0.33	0.31	0.30	0.29	0.28
T_7	M2P2C1	0.42	0.41	0.39	0.38	0.37	0.36	0.34	0.33	0.32	0.32	0.30	0.28	0.27
T_8	M2P2C2	0.42	0.42	0.40	0.39	0.38	0.37	0.36	0.35	0.33	0.32	0.31	0.29	0.28
	SE ±		0.007	0.006	0.006	0.006	0.005	0.004	0.003	0.004	0.006	0.007	0.005	0.004
	CD (5%)		0.020	0.018	0.017	0.017	0.015	0.011	0.009	0.011	0.018	0.022	0.014	0.013

Note:

$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18 ^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18 ^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18 ^{0}C temperature
$M_2P_2C_1$: Mechanical method + 300 gauge pouch + 3-5 ^{0} C temperature
$M_2P_2C_2$: Mechanical method + 300 gauge pouch + -18 ^{0}C temperature

Table 4: Effect of extraction methods and packaging materials on TSS : acidity ratio of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	59.74	64.81	69.10	72.27	73.53	75.49	77.61	85.35	92.06	100.85	111.17	117.72	124.54
T_2	M1P1C2	59.74	62.04	63.32	65.31	67.47	67.97	71.45	76.47	82.70	89.02	96.18	100.28	100.71
T_3	M1P2C1	59.74	64.43	65.74	69.17	71.86	74.34	77.05	79.87	85.76	92.84	97.87	102.81	107.72
T_4	M1P2C2	59.74	61.09	63.53	65.40	65.53	67.65	70.17	74.79	77.58	83.61	87.10	94.23	98.31
T_5	M2P1C1	60.00	62.65	64.90	67.69	69.97	72.49	78.98	85.33	92.90	97.48	106.95	112.04	118.56
T_6	M2P1C2	60.00	61.24	62.80	65.24	67.22	70.41	72.51	77.12	79.78	85.05	88.02	91.79	95.33
T_7	M2P2C1	60.00	63.89	67.36	69.92	72.67	75.11	80.35	83.10	86.52	86.92	93.52	101.43	105.42
T_8	M2P2C2	60.00	61.20	64.57	66.55	68.61	70.62	72.63	74.76	79.65	82.22	84.98	90.91	94.31
	SE ±		1.156	1.019	0.975	1.095	0.998	0.755	0.573	0.726	1.184	1.477	1.045	1.014
	CD (5%)		3.466	3.056	2.924	3.283	2.992	2.263	1.719	2.176	3.549	4.429	3.134	3.041

Note:

$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18^{0}C temperature
$M_2P_2C_1$: Mechanical method + 300 gauge pouch + 3-5^{0}C temperature
$M_2P_2C_2$: Mechanical method + 300 gauge pouch + -18^{0}C temperature

Table 5: Effect of extraction methods and packaging materials on pH of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	5.30	5.27	5.24	5.22	5.20	5.18	5.14	5.09	5.02	4.97	4.95	4.89	4.82
T_2	M1P1C2	5.30	5.28	5.27	5.25	5.22	5.20	5.19	5.17	5.15	5.12	5.10	5.08	5.03
T_3	M1P2C1	5.30	5.28	5.26	5.23	5.21	5.19	5.16	5.11	5.08	5.03	5.00	4.98	4.95
T_4	M1P2C2	5.30	5.29	5.28	5.27	5.25	5.24	5.22	5.21	5.19	5.15	5.12	5.08	5.06
T_5	M2P1C1	5.36	5.34	5.32	5.29	5.26	5.24	5.21	5.19	5.17	5.16	5.14	5.12	5.11
T_6	M2P1C2	5.36	5.35	5.34	5.32	5.30	5.29	5.28	5.25	5.23	5.21	5.20	5.18	5.16
T_7	M2P2C1	5.36	5.33	5.30	5.28	5.26	5.24	5.22	5.20	5.18	5.17	5.15	5.14	5.13
T_8	M2P2C2	5.36	5.35	5.34	5.33	5.32	5.31	5.30	5.28	5.26	5.24	5.22	5.21	5.20
	SE ±		0.003	0.004	0.004	0.005	0.004	0.005	0.005	0.004	0.003	0.003	0.003	0.003
	CD (5%)		0.009	0.012	0.012	0.014	0.012	0.016	0.014	0.012	0.010	0.009	0.009	0.008

Note

$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18 ^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18 ^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18 ^{0}C temperature
$M_2P_2C_1$: Mechanical method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_2P_2C_2$: Mechanical method + 300 gauge pouch + -18 ^{0}C temperature

Table 6: Effect of extraction methods and packaging materials on total sugar of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	19.40	20.04 (26.59)	20.86 (27.18)	21.66 (27.74)	22.44 (28.28)	23.16 (28.77)	23.47 (28.98)	23.89 (29.26)	24.12 (29.41)	24.60 (29.73)	25.33 (30.22)	25.74 (30.49)	26.03 (30.68)
T_2	M1P1C2	19.40	19.51 (26.21)	19.74 (26.38)	19.87 (26.47)	20.03 (26.58)	20.24 (26.73)	20.34 (26.81)	20.48 (26.90)	20.57 (26.97)	20.71 (27.07)	20.91 (27.21)	21.01 (27.28)	21.17 (27.39)
T_3	M1P2C1	19.40	19.85 (26.46)	20.39 (26.85)	20.54 (26.95)	20.96 (27.25)	21.68 (27.75)	21.87 (27.88)	22.27 (28.16)	22.63 (28.41)	22.96 (28.63)	23.56 (29.04)	23.92 (29.28)	24.28 (29.52)
T_4	M1P2C2	19.40	19.43 (26.15)	19.61 (26.28)	19.66 (26.32)	19.79 (26.41)	19.97 (26.54)	20.04 (26.59)	20.14 (26.67)	20.22 (26.72)	20.44 (26.88)	20.63 (27.02)	20.73 (27.08)	20.89 (27.19)
T_5	M2P1C1	20.60	21.14 (27.38)	22.06 (28.01)	22.52 (28.33)	22.93 (28.61)	23.98 (29.32)	24.55 (29.70)	24.90 (29.93)	25.37 (30.24)	25.92 (30.61)	26.81 (31.18)	27.35 (31.53)	27.85 (31.85)
T_6	M2P1C2	20.60	20.81 (27.14)	21.22 (27.43)	21.55 (27.66)	21.72 (27.78)	22.18 (28.10)	22.32 (28.19)	22.65 (28.42)	22.81 (28.53)	23.17 (28.77)	23.63 (29.09)	23.84 (29.23)	24.15 (29.43)
T_7	M2P2C1	20.60	21.07 (27.32)	21.80 (27.84)	22.28 (28.17)	22.61 (28.39)	23.43 (28.95)	23.86 (29.24)	24.22 (29.48)	24.89 (29.93)	25.04 (30.02)	25.83 (30.54)	26.26 (30.83)	26.65 (31.08)
T_8	M2P2C2	20.60	20.68 (27.05)	20.73 (27.08)	20.74 (27.09)	20.83 (27.15)	20.84 (27.16)	20.94 (27.23)	21.06 (27.31)	21.25 (27.45)	21.45 (27.59)	21.83 (27.85)	21.99 (27.96)	22.24 (28.14)
	SE ±		0.050	0.040	0.029	0.029	0.039	0.030	0.030	0.030	0.030	0.030	0.029	0.020
	CD (5%)		0.139	0.130	0.100	0.100	0.110	0.079	0.080	0.090	0.090	0.080	0.089	0.060

Note: (Figures in parenthesis are arc sine transformation)

$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18 ^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18 ^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18 ^{0}C temperature
$M_2P_2C_1$: Mechanical method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_2P_2C_2$: Mechanical method + 300 gauge pouch + -18 ^{0}C temperature

Table 7: Effect of extraction methods and packaging materials on reducing sugar of custard apple pulp on the different storage conditions

Sr. No.	Treatment	Storage period (days)												
		0	15	30	45	60	75	90	105	120	135	150	165	180
T_1	M1P1C1	16.70	17.72 (24.90)	18.48 (25.46)	19.93 (26.51)	20.14 (26.67)	20.94 (27.23)	21.21 (27.42)	21.64 (27.72)	21.87 (27.88)	22.35 (28.21)	22.60 (28.39)	23.59 (29.03)	23.83 (29.22)
T_2	M1P1C2	16.70	16.95 (24.31)	17.18 (24.49)	17.32 (24.59)	17.44 (24.68)	17.67 (24.86)	17.84 (24.98)	17.93 (25.05)	18.04 (25.13)	18.15 (25.22)	18.28 (25.31)	18.55 (25.49)	18.67 (25.60)
T_3	M1P2C1	16.70	17.52 (24.74)	18.42 (25.41)	19.34 (26.09)	19.47 (26.19)	19.93 (26.51)	20.07 (26.62)	20.43 (26.87)	20.58 (26.98)	20.93 (27.22)	21.09 (27.34)	21.68 (27.72)	21.94 (27.93)
T_4	M1P2C2	16.70	16.80 (24.20)	17.04 (24.38)	17.10 (24.43)	17.24 (24.54)	17.45 (24.69)	17.52 (24.74)	17.65 (24.84)	17.71 (24.88)	17.93 (25.05)	17.94 (25.06)	18.26 (25.27)	18.44 (25.43)
T_5	M2P1C1	16.90	17.84 (24.98)	18.76 (25.67)	19.23 (26.01)	20.66 (27.03)	21.71 (27.77)	22.31 (28.18)	22.64 (28.41)	23.14 (28.75)	23.67 (29.11)	23.94 (29.29)	25.12 (30.06)	25.63 (30.42)
T_6	M2P1C2	16.90	17.22	17.81	17.95	18.44	19.14	19.31	19.74	20.10	20.43	20.59	21.4	21.77

			(24.52)	(24.96)	(25.06)	(25.43)	(25.94)	(26.07)	(26.38)	(26.64)	(26.87)	(26.99)	(27.57)	(27.81)
T_7	M2P2C1	16.90	17.74 (24.91)	18.51 (25.48)	19.17 (25.97)	20.34 (26.81)	21.15 (27.38)	21.60 (27.69)	21.96 (27.94)	22.65 (28.42)	22.79 (28.52)	23.07 (28.71)	24.06 (29.35)	24.43 (29.62)
T_8	M2P2C2	16.90	16.97 (24.33)	17.37 (24.63)	17.62 (24.82)	17.31 (24.59)	18.15 (25.21)	18.34 (25.36)	18.56 (25.52)	18.73 (25.64)	18.95 (25.81)	19.09 (25.91)	19.43 (26.18)	19.74 (26.38)
	SE ±		0.024	0.026	0.029	0.025	0.025	0.051	0.019	0.024	0.026	0.025	0.023	0.020
	CD (5%)		0.071	0.078	0.086	0.075	0.074	0.153	0.056	0.073	0.077	0.075	0.070	0.060

Note: (Figures in parenthesis are arc sine transformation)
$M_1P_1C_1$: Manual method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_1P_1C_2$: Manual method + 200 gauge pouch + -18 ^{0}C temperature
$M_1P_2C_1$: Manual method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_1P_2C_2$: Manual method + 300 gauge pouch + -18 ^{0}C temperature
$M_2P_1C_1$: Mechanical method + 200 gauge pouch + 3-5 ^{0}C temperature
$M_2P_1C_2$: Mechanical method + 200 gauge pouch + -18 ^{0}C temperature
$M_2P_2C_1$: Mechanical method + 300 gauge pouch + 3-5 ^{0}C temperature
$M_2P_2C_2$: Mechanical method + 300 gauge pouch + -18 ^{0}C temperature

Conclusion

The experiment's major objectives was to determine the ideal extraction technique for custard apple pulp and to examine the impact of different packaging materials on chemical properties of pulp during storage. It is observed that, as the storage period increases, irrespective of packaging material and storage temperature, the total soluble solids in the custard apple pulp go on increasing at variable rates. Variation in TSS could be the result of starch breaking down into simple sugars. Since one sugar molecule absorbs one water molecule during its breakdown to maintain the stable valence cell orbit of the compound, the change in total soluble solids may have resulted from the inversion of the sugar present in custard apple pulp. This ultimately lowers the amount of available moisture content and raises the relative composition of other compounds present in the products. The reducing sugar of custard apple pulp increased with an increase in storage period and storage temperatures during storage. Regardless of extraction technique, packaging material, or storage conditions, every study parameter changed with time. The pH of the custard apple pulp decreases with the increase in storage period in variable proportion. The total sugar of custard apple pulp was found to be increased with the advancement of the storage period and storage temperatures. On the basis of the findings of investigation, it can be concluded on “ad-hoc basis” that treatment having pulp of manual extraction, stored in 300 gauge LDPE bag and at -180C temperature (T4) was found to be most effective method for longer shelf life and quality upto 180 days storage.

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