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Studies on storability of tamarind pulp and preparation of squash from tamarind pulp

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Abstract
The study on "Value Addition in Tamarind" was conducted at the Post Harvest Technology Laboratory, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (2023-24). For storage of tamarind pulp at long period is a problem as many physico-chemical changes take place during storage. Therefore tamarind pulp was analysed for various physiological characteristics in different packaging material like polyethylene pouches, Aluminium pouches, porcelain container and glass bottles stored at room temperature (25 °C) and to develop tamarind-based product (squash).The objectives were to assess the chemical properties of tamarind pulp, and monitor changes in tamarind squash during storage.
Chemical analysis showed that the TSS, titratable acidity, reducing sugars increased and pH, ascorbic acid decreased in all packaging material during 120 days of storage. Porcelain containers were the most effective, minimizing microbial growth and nutrient loss over 120 days. Glass bottles and polyethylene bags also performed well, but aluminum pouches led to the most quality deterioration.
An attempt was made to use tamarind squash by using different treatment. Changes in chemical constituents during storage upto 120 days at ambient temperature were studied. Results showed that in the stored products, TSS, total sugars increased whereas ascorbic acid content, titratable acidity decreased. Tamarind squash retained their characteristics colour, flavour, taste and were microbiologically safe upto 3 months of storage at room temperature.

Keywords: Tamarind pulp, packaging material, squash, storability

Introduction
Tamarind (*Tamarindus indica* L.), a tropical drought hardy tree can be grown in dryland areas and on degraded, eroded, gravelly, saline and sodic wastelands. The origin of tamarind hails from Madagascar in Eastern Africa.
India stands as the world's leading tamarind producer of 162,000 metric tonnes in the year 2023. Tamil Nadu has production of 44,000 metric tonnes followed by Karnataka and Kerala. Maharashtra has production of 8,000 metric tonnes, Telangana, and Andhra Pradesh are some of the other states that produce tamarind (Annon, 2023) [2]. Tamarind is a rich source of minerals such as iron, phosphorus, potassium, calcium. The pulp of ripe tamarind fruit is particularly high in potassium, ranging from 62 to 570 mg per 100 grams, and phosphorus, ranging from 86 to 190 mg per 100 grams (Manjula *et al*. 2017) [15]. The TSS of the pulp can vary from 54 - 69.9^{O} Brix (Bonero *et al*., 1974) [8]. Due to perishable nature of fruits, these require immediate processing to avoid post harvest losses (Ramakumar *et al*., 1997) [22] and changes in colour from brown to black due to phenolics, and non -enzymatic browning during storage. Storing of tamarind pulp at room temperature it was found that the moisture content, titratable acidity and reducing sugar increased in all packaging materials while pH decreased. In aluminium foil box and polyethylene the extent of increase was found less (Agrawal *et al*., 2014) [1]. Therefore, these investigation was carried out for storage of tamarind pulp and preparation of value added products (squash) from tamarind pulp.

Materials and Methods
The experiment with four treatment was conducted and replicated thrice. For the storage of tamarind four different packaging material were used i.e. polyethylene, aluminium pouches, porcelain container and glass bottles.

About 250 g of sample was stored in each packaging material in triplicate. The packages were stored at room temperature at 25 °C. Changes in physicochemical parameters were recorded at 30 days interval.
For preparation of tamarind squash, the experiment with twelve treatment was conducted and replicated thrice.

Collection of fruits
Well matured and clean tamarind was used during this study. The tamarind was procured from gudadhi block, Dr. PDKV Akola.

Extraction of pulp
The pulp was extracted of ripe fruits by removing fruit rind, fiber and seed. The pulp was extracted by soaking in the required amount of water and pulp ratio. The materials thus obtained were used for squash preparation**.**

Methodology for preparing tamarind squash
Tamarind pulp was soaked in water. The tamarind pulp was then extracted through filtration with muslin cloth. The sugar syrup was prepared in a separate vessel and blended with pulp. The obtained squash was filled in glass bottles and subjected to storage at room temperature (Archana and Laxman, 2015, Pattar *et al.* 2013) [4, 20].

Ripen fruits
↓
Washing and cleaning
↓
Juice extraction
↓
Straining
↓
Juice measuring
↓
Preparation of syrup
↓
(Sugar (150 g)+ Water (50 ml) +heating just to dissolve)
↓
Straining
↓
Mixing with juice (100 ml)
↓
Adding of preservative
↓
Bottling
↓
Storage

Flow chart for tamarind squash preparation

Physicochemical characteristics
Total soluble solids (TSS)
TSS of tamarind pulp and squash were analysed by digital refractometer and expressed as degree Brix (°B).

Titratable acidity
The titratable acidity of tamarind pulp and squash was determined as per the procedure of Ranganna (2009) [23] by using 0.1 N sodium hydroxide phenolphthalein as an indicator.

$$\text{Titratable Acidity (\%)} = \frac{\text{Titrate value} \times \text{normality of NaOH} \times \text{equivalent weight of citric acid}}{\text{Juice taken (ml)}} \times 1000 \times 100$$

pH
The pH of each sample of tamarind was recorded by digital pH meter. pH meter was used to measure the pH of product samples. Temperature was kept constant while taking observations for all the samples.

Ascorbic acid
Ascorbic acid of tamarind juice was determined by 2, 6-dichlorophenol indophenols visual titration method (Ranganna 1997) [22].

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre x Dye equivalent x Volume made up}}{\text{Aliquot taken for estimation x weight of sample}} \times 100$$

Reducing sugars (%)
For reducing sugars estimation, the method given by Nelson Smogyi was used. In this method DNS reagent, prepared by dissolving 1 g dinitro salicylic acid, 200 mg crystaline phenol and 50 mg sodium sulphate In 100 ml of 1% NaOH and was used immediately after preparation and absorbance was noted at 510 nm and accordingly graph plotted by standard glucose solution.

$$\text{\% Reducing sugars} = \text{Reading from graph (ugml}^{-1}\text{)} \times \frac{1}{1000000} \times \frac{100}{1} \times \frac{100}{\text{weight of sample}}$$

Total sugars
"Dubois method" was employed for determination of total sugars. In this method 5 per cent phenol and 96 per cent conc, H_2SO_4 was used to carry out analysis. Absorbance of the sample was noted at 490 nm and graph values were put in the following formula to estimate the final value of total sugars.

% Total sugars = Reading from graph (ugml^{-1}) × (1/10000000) × (100 × 50/1) × (100/1) × (1/ weight of juice in gram)

Non-reducing sugars
The non-reducing sugar contents of the tamarind juice samples were determined by method of difference as

Non-reducing sugars = Total sugars - Reducing sugars.

Sensory evaluation of tamarind squash
Squash prepared from tamarind fruits was evaluated for sensory qualities viz. colour, taste, at an interval of 30 days. Each attribute was given a separate score of 9 point hedonic scale according to the method reported by Amerine *et al.*, (1965) [3]. Sensory panel consisted of 5 trained panelists evaluated the experimental samples as per the hedonic scale. The mean values of score for sensory evaluation were calculated and reported.

Microbial analysis
The microbial count was taken from tamarind beverages after storage as per methods described by of Harrigan and Mccance (1966) [10].

Statistical Analysis
The data were subjected to statistical analysis as per the procedure described by Panse and Sukhatme (1985) [19]. The experiment design was conducted in Randomized Block Design.

Results and Discussion

Table 1: Physical and chemical composition of tamarind fruit.

Sr. No	Parameter	Mean value
1	Fruit weight (g)	16.65
2	Pulp weight pod^{-1} (g)	7.5
3	Peel weight pod^{-1} (g)	4.25
4	No of seeds pod^{-1} (g)	7.60
5	Pulp recovery (%)	45.05
7	TSS (^{0}B)	24.2
8	Acidity (%)	3.90
9	Reducing sugars (%)	24.7
10	Non Reducing Sugars (%)	6.3
11	Total Sugars (%)	31
12	Ascorbic acid (mg / 100 g)	3.8
13	pH	2.8

Experiment I. Effect of storage period on physico-chemical characteristics of tamarind pulp storage at room temperature

Table 2: Effect of storage period on TSS of tamarind pulp during storage at room temperature

Treatment	Treatment	TSS (^{O} Brix)				
		Storage period (days)				
		Initial	30th	60th	90th	120th
T_1	Polyethylene bag	24.70	27.63	27.91	28.83	29.29
T_2	Aluminium pouch	24.70	27.13	27.38	28.40	28.95
T_3	Porcelain container	24.70	27.94	28.18	29.11	29.43
T_4	Glass bottle	24.70	27.42	27.65	28.71	29.18
F Test		NS	Sig	Sig	Sig	Sig
SE (m)±		0.30	0.07	0.09	0.12	0.05
CD at 5%		NS	0.26	0.31	0.42	0.16

From table 2, it was observed that, the TSS of tamarind pulp increases in storage period. Significantly, treatment (T_3) porcelain containers demonstrated the maximum TSS increasing from 24.70° Brix to 29.43° Brix upto 120 days. followed by polyethylene bags (T_1) and glass bottles (T4) performed similarly with final TSS values of 29.29° Brix and 29.18° Brix, respectively which were statistically at par with the superior treatment. Treatment (T_2) i.e. aluminium pouches significantly had the minimum TSS (28.95° Brix) at the end of the storage period, suggesting they were less effective in preserving moisture and increasing sugar concentration.

Table 3: Effect of storage period on titratable acidity of tamarind during storage at room temperature

Treatment	Treatment	Titratable acidity (%)				
		Storage period (days)				
		Initial	30th	60th	90th	120th
T_1	Polyethylene bag	3.90	3.47	4.06	4.43	4.67
T_2	Aluminium pouch	3.90	3.23	3.49	4.00	4.18
T_3	Porcelain container	3.90	3.56	4.27	4.63	4.86
T_4	Glass bottle	3.90	3.28	3.68	4.17	4.34
F Test		Ns	Sig	Sig	Sig	Sig
SE (m)±		0.02	0.01	0.08	0.06	0.03
CD at 5%		Ns	0.06	0.27	0.21	0.13

From table 3.it was observed that as the storage period extended, the acidity of the tamarind rise in all treatments, which is a normal reaction to the decomposition of organic matter and the production of organic acids as a result of enzymatic processes.
Significantly at 120 days, porcelain container (T_3) showed maximum acidity level of 4.86% during the storage period. It appears that, porcelain is the best storage material for maintaining acidity. Whereas, treatment (T_1) polyethylene bag and (T_4) glass bottle showed comparable performance, with acidity values of 4.67% and 4.34%, respectively which were at par with the highest value, since the acidity levels of these treatments did not differ noticeably from one another and the significantly minimum acidity level was observed in the aluminium pouch (T_2) at 4.18%.
All treatments had a small decline in acidity from 3.90% at day initial to 30 days during storage. However, starting on day 60, all storage materials acidity levels steadily increased, indicating the ongoing production of acids. The aluminium bag remained the least efficient by days 90 and 120, whereas the porcelain container kept the greatest levels of acidity better than the others. The gradual rises in acidity demonstrate how the rate of acid preservation in tamarind is influenced by various storage materials. The results mentioned above are in conformity with the findings of Agrawal *et al.* (2014) [1] in storage of tamarind in different packaging material.

Table 4: Effect of storage period on reducing sugars of tamarind pulp during storage at room temperature

Treatment	Treatment	Reducing sugar (%)				
		Storage period (days)				
		Initial	30	60	90	120
T_1	Polyethylene bag	19.10	21.10	21.18	21.54	21.78
T_2	Aluminium pouch	19.10	20.92	21.00	21.39	21.58
T_3	Porcelain container	19.10	21.33	21.41	21.61	21.86
T_4	Glass bottle	19.10	21.01	21.09	21.45	21.68
F Test		NS	Sig	Sig	Sig	Sig
SE (m)±		0.11	0.04	0.07	0.02	0.01
CD at 5%		NS	0.15	0.25	0.09	0.03

From table 4. it was found that**,** the effect of storage period on the reducing sugar of tamarind was found to be significant in all packaging materials.

During the storage period, the porcelain container (T_3) significantly showed the maximum increase in reducing sugar percentage, rising from 19.10% at 0 days to 21.86% at 120 days. The polyethylene bag (T_1) and the glass bottle (T_4) was closely at par with the superior value, with final reducing sugar percentages of 21.78% and 21.68%, respectively. The significantly minimum content of reducing sugar obtained was aluminium pouch (T_2) with 21.58%. The results mentioned above are in conformity with the findings of Agrawal *et al.* (2014) [1] in storage of tamarind in different packaging material,

Table 5: Effect of storage period on pH of tamarind pulp during storage at room temperature.

Treatment	Treatment	pH				
		Storage period (days)				
		Initial	**30**	**60**	**90**	**120**
T_1	Polyethylene bag	2.78	2.75	2.67	2.54	2.49
T_2	Aluminium pouch	2.78	2.58	2.51	2.43	2.39
T_3	Porcelain container	2.78	2.69	2.58	2.50	2.47
T_4	Glass bottle	2.78	2.65	2.55	2.47	2.46
F Test		NS	Sig	Sig	Sig	Sig
SE (m)±		0.10	0.02	0.01	0.02	0.01
CD at 5%		NS	0.07	0.04	0.07	0.05

From table 5. It was found that, all treatments show a progressive reduction in pH values, with eventually rise in acidity%. Significantly, treatments T_1 showed the maximum pH content of 2.49. Glass bottle (T_4) is the most stable with pH decreases from 2.78 to 2.46. Porcelain container (T_3) of 2.47, is at par with the superior treatment. Aluminum pouches significantly showed the minimum pH due to exposure to moisture and external gases, accelerating acidity i.e. 2.39.

When it comes to maintaining the acidity levels of tamarind, glass bottles and porcelain containers are a superior selection because both treatments show greater stability than polyethylene bags and aluminium pouches

Table 6: Effect of storage period on ascorbic acid content of tamarind pulp during storage at room temperature

Treatment	Treatment	Ascorbic acid(mg /100 g)				
		Storage period (days)				
		Initial	**30**	**60**	**90**	**120**
T_1	Polyethylene bag	3.83	3.67	3.58	3.43	3.35
T_2	Aluminium pouch	3.83	3.33	3.20	3.11	3.03
T_3	Porcelain container	3.83	3.80	3.77	3.52	3.48
T_4	Glass bottle	3.83	3.53	3.37	3.23	3.16
F Test		NS	Sig	Sig	Sig	Sig
SE (m)±		0.23	0.03	0.08	0.07	0.07
CD at 5%		NS	0.11	0.28	0.23	0.24

From table 6. It was observed that ascorbic acid content decreases over time in all treatments. Significantly, results indicate that the porcelain container (T_3) was the best treatment in terms of maintaining ascorbic acid. At the end of the storage period, the initial value of 3.83 mg/100 g had gradually decreased to 3.48 mg/100 g upto 120 days of storage. T_1 (Polyethylene bag - 3.35 mg/100 g) and T_4 (Glass bottle - 3.16 mg/100 g) were statistically at par with the superior treatment. The minimum content of ascorbic acid was retained in the aluminium pouch (T_2), with decreasing level to 3.03 mg/100 g by 120 days.

The porcelain container (T_3) performs better than other containers because of its inertness and impermeability, which reduces the tamarind pulp exposure to air and light two major variables that cause ascorbic acid to degrade. Comparably, the non-reactive and airtight qualities of the glass bottle (T_4) provided good protection as well, but marginally less so than porcelain in this particular situation whereas polyethylene bag (T_1) offered a reasonable level of protection, the increased gas permeability probably increased the oxidative deterioration of vitamin C.

Experiment II. Preparation and storage of tamarind squash

Table 7: Effect of different treatment on TSS of tamarind squash during storage.

Treatment	Treatment details	Pulp: Water	TSS (^{0} Brix) Storage period (Days)				
			Initial	**30**	**60**	**90**	**120**
T_1	Cold water Treatment	(1:2)	54.00	54.19	54.36	54.63	54.78
T_2	Cold water Treatment	(1:3)	54.00	54.14	54.29	54.58	54.75
T_3	Cold water Treatment	(1:4)	54.00	54.10	54.24	54.57	54.72
T_4	Hot water Treatment	(1:2)	54.00	54.21	54.40	54.69	55.02
T_5	Hot water Treatment	(1:3)	54.00	54.18	54.37	54.65	54.98
T_6	Hot water Treatment	(1:4)	54.00	54.15	54.33	54.62	54.95
T_7	Cold water + Pectinase 0.25%	(1:2)	54.00	54.26	54.49	54.78	55.06
T_8	Cold water + Pectinase 0.25%	(1:3)	54.00	54.23	54.45	54.74	55.04
T_9	Cold water + Pectinase 0.25%	(1:4)	54.00	54.21	54.41	54.73	55.02
T_{10}	Hot water + Pectinase 0.25%	(1:2)	54.00	54.37	54.58	54.83	55.13
T_{11}	Hot water + Pectinase 0.25%	(1:3)	54.00	54.29	54.55	54.80	55.10
T_{12}	Hot water + Pectinase 0.25%	(1:4)	54.00	54.27	54.50	54.78	55.08
F Test			NS	Sig	Sig	Sig	Sig
SE (m)±			0.16	0.04	0.02	0.03	0.04
CD at 5%			NS	0.12	0.07	0.09	0.12

From the table 7. It was found that, during storage under several conditions comprising cold water, hot water and the enzyme pectinase, tamarind squash showed a gradual increase in total soluble solids. Every treatment started out with a fixed initial TSS value of 54.00° Brix for the course of the 120 days of storage. However, the changes of TSS values varied depending on the specific treatment applied.

Significantly, treatment T_{10} (hot water treatment with pectinase 0.25%, 1:2 pulp to water ratio) showed the maximum TSS content, reaching 55.13° Brix after 120 days of storage, followed by T_{11} (Hot water + Pectinase 0.25%, 1:3), with TSS content of 55.10° Brix, respectively. Treatment T_9 (55.02) and T_6 (54.95) was at par with the superior treatment T_{10} at 120 days. Whereas significantly minimum TSS was recorded in T_3 (54.10, 54.24, 54.57 and 54.72 ° Brix) respectively at 30, 60, 90 and 120 days after storage.

In general, pectinase treatments seem to produce the highest TSS values when used in conjunction with hot water treatments, which makes them more useful for boosting soluble solids during squash long-term storage. The similar results were also been observed in blended squash by (Nath *et al.* 2005) [16], Kayshar *et al.* (2014) [11] in mixed fruit squash and in aonla squash by Chikkasubbanna *et al.* (2008) [9]. Kinh *et al*. (2001) [12] stated that, the slight increase in total soluble solid might also be due to chemical preservative as in apple juice.

Table 8: Effect of different treatment on titratable acidity of tamarind squash during storage

Treatment	Treatment details	Pulp : Water	Titratable Acidity (%) Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	1.30	1.28	1.27	1.24	1.21
T_2	Cold water Treatment	(1:3)	1.31	1.29	1.28	1.26	1.23
T_3	Cold water Treatment	(1:4)	1.31	1.30	1.29	1.26	1.24
T_4	Hot water Treatment	(1:2)	1.28	1.25	1.23	1.22	1.17
T_5	Hot water Treatment	(1:3)	1.27	1.26	1.25	1.23	1.20
T_6	Hot water Treatment	(1:4)	1.29	1.27	1.26	1.24	1.21
T_7	Cold water + Pectinase 0.25%	(1:2)	1.22	1.21	1.18	1.16	1.15
T_8	Cold water + Pectinase 0.25%	(1:3)	1.24	1.22	1.20	1.19	1.17
T_9	Cold water + Pectinase 0.25%	(1:4)	1.25	1.24	1.22	1.21	1.19
T_{10}	Hot water + Pectinase 0.25%	(1:2)	0.91	0.89	0.85	0.84	0.83
T_{11}	Hot water + Pectinase 0.25%	(1:3)	0.95	0.92	0.88	0.87	0.86
T_{12}	Hot water + Pectinase 0.25%	(1:4)	0.97	0.95	0.93	0.91	0.88
F Test			NS	Sig	Sig	Sig	Sig
SE (m)±			0.26	0.02	0.01	0.03	0.04
CD at 5%			NS	0.06	0.04	0.09	0.12

From the table 8.it was found that, the titratable acidity of the squash shows a declining trend with time across all treatments, which is a common during lengthy storage because of chemical reactions that lower the organic acid concentration.

Treatment T_{10} (hot water treatment with 0.25% pectinase, 1:2 pulp to water ratio) significantly, showed the minimum acidity % after 120 days, decreasing from 0.91 initially to 0.83 followed with the treatment T_{12} (Hot water + Pectinase 0.25%, 1:4), which dropped to 0.88 after 120 days.

However, maximum change i.e. 1.24% in titratable acidity was noticed with the treatment T_3 (Cold water treatment 1:4 ratio) and it was followed by treatment T_2 (Cold water treatment 1:3 ratio) i.e. 1.23%. According to Yadav *et al.* (2009) [23] decrease in acidity during 3 months of storage of pummelo and orange blended nectar. Acidity showed decreasing trend because of the co- polymerization of organic acids with amino acids and sugar by Malav *et al.* (2014) [14]

Table 8: Effect of different treatment on ascorbic acid content of tamarind squash during storage

Treatment	Treatment details	Pulp : Water	Ascorbic Acid (mg /100 g) Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	3.61	3.58	3.53	3.49	3.47
T_2	Cold water Treatment	(1:3)	3.52	3.52	3.45	3.386	3.37
T_3	Cold water Treatment	(1:4)	3.55	3.36	3.28	3.26	3.24
T_4	Hot water Treatment	(1:2)	3.67	3.64	3.60	3.57	3.55
T_5	Hot water Treatment	(1:3)	3.57	3.57	3.50	3.49	3.47
T_6	Hot water Treatment	(1:4)	3.53	3.50	3.42	3.39	3.38
T_7	Cold water + Pectinase 0.25%	(1:2)	3.75	3.75	3.70	3.65	3.63
T_8	Cold water + Pectinase 0.25%	(1:3)	3.67	3.67	3.62	3.597	3.60
T_9	Cold water + Pectinase 0.25%	(1:4)	3.60	3.60	3.51	3.49	3.51
T_{10}	Hot water + Pectinase 0.25%	(1:2)	3.87	3.84	3.81	3.78	3.76
T_{11}	Hot water + Pectinase 0.25%	(1:3)	3.87	3.77	3.73	3.707	3.68
T_{12}	Hot water + Pectinase 0.25%	(1:4)	3.67	3.67	3.63	3.59	3.56
F Test			NS	Sig	Sig	Sig	Sig
SE (m)±			0.55	0.04	0.03	0.02	0.02
CD at 5%			NS	0.12	0.08	0.06	0.06

From table 8. It was observed that All treatments result in a progressive drop in ascorbic acid levels over time, although the rate of decline varies according to the treatment. Since ascorbic acid is susceptible to changes in temperature and enzymatic activity, whether it is retained or lost during storage affects the nutritional value of squash products.

Significantly, the maximum ascorbic content was obtained in treatment T_{10} (hot water + pectinase 0.25%, 1:2 pulp to water ratio) with 3.87 mg/100 g at the beginning and after 30 days it declined to 3.84, after 60 days to 3.81 and after 90 days to 3.78. It continued to have a comparatively high value of 3.76 mg/100 g after 120 days.T_{11} (Hot water +

Pectinase 0.25%, 1:3 pulp to water ratio), initially at 3.87 mg/100 g and continues to maintain 3.68 mg/100 g after 120 days.

However the minimum ascorbic acid content was seen in treatment T_3 (Cold water treatment 1:4 ratio) decreases from 3.55 mg/100 g to 3.24 mg/100 ml upto 120 days of storage. This shows that, ascorbic acid content is less effectively preserved by cold water treatments, perhaps due to the absence of enzymes or heat treatments that could aid in lowering ascorbic acid's oxidative degradation during storage.

Similar results were also recorded by Attri *et al.* (1998) [5] in blended juice of pear, apple, & apricot, in blended juice of kinnow by Bhardwaj *et al.* (2011) [7]. Hence, It is concluded that, content of ascorbic acid was reduce during storage duration.

Table 9: Effect of different treatment on reducing sugars of tamarind squash during storage

Treatment	Treatment details	Pulp : Water	Reducing sugars (%) Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	22.17	23.78	25.24	26.58	28.42
T_2	Cold water Treatment	(1:3)	22.10	23.68	25.35	26.19	27.76
T_3	Cold water Treatment	(1:4)	20.88	23.58	24.73	25.59	26.86
T_4	Hot water Treatment	(1:2)	22.86	24.3	25.55	27.55	29.68
T_5	Hot water Treatment	(1:3)	22.81	24.2	25.50	27.02	28.83
T_6	Hot water Treatment	(1:4)	21.99	24.15	25.42	26.64	28.13
T_7	Cold water + Pectinase 0.25%	(1:2)	23.34	24.83	25.88	28.20	30.86
T_8	Cold water + Pectinase 0.25%	(1:3)	23.26	24.72	25.79	27.75	30.16
T_9	Cold water + Pectinase 0.25%	(1:4)	23.16	24.65	25.72	27.37	29.47
T_{10}	Hot water + Pectinase 0.25%	(1:2)	23.65	25.63	26.20	29.32	32.32
T_{11}	Hot water + Pectinase 0.25%	(1:3)	23.53	25.53	26.08	28.76	31.57
T_{12}	Hot water + Pectinase 0.25%	(1:4)	22.70	25.35	25.99	28.34	30.93
F Test			NS	Sig	Sig	Sig	Sig
SE (m)±			0.58	0.31	0.19	0.70	0.69
CD at 5%			NS	0.91	0.57	2.07	2.03

From table 9. The results indicate that, there were significant differences between the treatments with respect to days after storage of tamarind squash. There was a general increase in reducing sugars over time in all treatment, most likely because complex carbohydrates hydrolyse into simpler ones like fructose and glucose. The efficacy of the treatments in raising the reducing sugar content over time varies greatly.

Significantly,T_{10} (Hot water + Pectinase 0.25%) was the best treatment it showed the maximum increase in reducing sugars content reaching 32.32% by 120 days. This is explained by pectinase's enzymatic degradation of polysaccharides, which quickens the release of reducing sugars followed by T_{11} (Hot water + Pectinase 0.25% 1: 3) and T_{12} (Hot water + Pectinase 0.25% 1: 4) with final reducing sugars levels of 31.57% and 30.93% respectively. Treatment T_8 and T_6 with (30.16%) and (28.13%) were at par with the superior treatment.

However, treatment T_3 (Cold water treatment, 1:4 ratio) was observed with minimum content of reducing sugar with a final sugar content of 26.86%. This implies that increased dilution in cold water on its own may not be as successful in encouraging sugar breakdown in storage. In the tamarind syrup reducing and total sugar% was raised and non reducing sugar decreased as observed by Kotecha *et al.* (2003) [13] and Tiwari (2000) [21] found that there was increase in reducing sugar content during storage of the RTS beverages prepared from guava and papaya. This finding was supported by Nidhi *et al.* (2008) [17].

Table 10: Effect of different treatment on non reducing sugars of tamarind squash during storage

Treatment	Treatment details	Pulp : Water	Non Reducing sugars (%) Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	12.57	12.17	11.92	11.50	11.44
T_2	Cold water Treatment	(1:3)	12.16	11.99	11.23	10.70	10.56
T_3	Cold water Treatment	(1:4)	11.82	11.55	10.57	10.10	10.02
T_4	Hot water Treatment	(1:2)	13.05	12.92	12.31	12.10	11.97
T_5	Hot water Treatment	(1:3)	12.35	11.75	11.57	11.30	11.23
T_6	Hot water Treatment	(1:4)	11.91	11.31	11.00	10.47	10.40
T_7	Cold water + Pectinase 0.25%	(1:2)	13.42	13.35	12.84	12.43	12.37
T_8	Cold water + Pectinase 0.25%	(1:3)	13.06	12.41	11.96	11.70	11.63
T_9	Cold water + Pectinase 0.25%	(1:4)	12.45	12.12	11.23	10.63	10.00
T_{10}	Hot water + Pectinase 0.25%	(1:2)	13.66	13.42	12.93	12.71	12.53
T_{11}	Hot water + Pectinase 0.25%	(1:3)	13.13	12.90	12.00	11.75	11.65
T_{12}	Hot water + Pectinase 0.25%	(1:4)	12.83	12.17	11.53	11.27	11.10
F Test			Sig	Sig	Sig	Sig	Sig
SE (m)±			0.33	0.28	0.22	0.24	0.25
CD at 5%			0.96	0.81	0.65	0.72	0.74

From table 10. It was observed that, over the course of the storage period, a decline in non-reducing sugars was seen in all treatments combined and it was clear from the prior analysis's increasing trend of reducing sugars, this drop is caused by the hydrolysis of non-reducing sugars (like sucrose) into reducing sugars like glucose and fructose.

Treatment T_{10} (Hot water + Pectinase 0.25%) significantly was the best in terms of non-reducing sugars with 12.53% after 120 days. It appears that, the combination of hot water and pectinase helps retain some level of non-reducing sugars for a longer amount of time, presumably due to regulated hydrolysis of complex sugars, as this treatment demonstrated a reasonably moderate fall in non-reducing sugars throughout storage.T_{11} and T_{12} was at par with the superior treatment. Whereas, treatment T_3 (cold water treatment, 1:4 ratio) significantly had the lowest non-reducing sugar content. Palinswamy *et al.* (1984) [18] obtained similar results in mango squash and Kayshar *et al.* (2014) [11] in mixed fruit squash.

Table 11: Effect of different treatment on total sugars of tamarind squash during storage

Treatment	Treatment details	Pulp : Water	Total sugars (%) Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	34.74	35.95	37.16	38.08	39.86
T_2	Cold water Treatment	(1:3)	34.26	35.67	36.69	36.89	38.32
T_3	Cold water Treatment	(1:4)	32.70	35.13	35.30	35.69	36.88
T_4	Hot water Treatment	(1:2)	35.91	37.22	37.86	39.65	41.65
T_5	Hot water Treatment	(1:3)	35.16	35.95	37.07	38.32	40.07
T_6	Hot water Treatment	(1:4)	33.90	35.46	36.42	37.11	38.53
T_7	Cold water + Pectinase 0.25%	(1:2)	36.76	38.44	38.72	40.63	43.24
T_8	Cold water + Pectinase 0.25%	(1:3)	36.32	37.38	37.75	39.45	41.78
T_9	Cold water + Pectinase 0.25%	(1:4)	35.61	36.76	36.95	38.00	40.57
T_{10}	Hot water + Pectinase 0.25%	(1:2)	37.31	38.93	39.14	42.03	44.85
T_{11}	Hot water + Pectinase 0.25%	(1:3)	36.66	38.08	38.08	40.51	43.22
T_{12}	Hot water + Pectinase 0.25%	(1:4)	33.67	37.48	37.53	39.61	40.93
F Test			NS	Sig	Sig	Sig	Sig
SE (m)±			1.64	0.45	0.37	0.43	0.55
CD at 5%			NS	1.33	1.08	1.26	1.60

From table 11. It was found that, the conversion of non-reducing sugars into reducing sugars by hydrolysis is the reason why the overall sugar concentration typically rises with time.

Significantly, with a final value of 44.85% at 120 days, treatment T_{10} (hot water + pectinase 0.25%, 1:2 ratio) was the best treatment in terms of total sugar content, showed that hot water extraction and pectinase enzyme treatment together promote optimal sugar release during storage and aid in the breakdown of complex carbohydrates. Followed by the treatment T_{11} (0.25% pectinase in hot water) 43.22% and T_{12} (40.93%) which was at par with T_{10}.

Similarly, treatment T_3 (Cold water treatment, 1:4 ratio) had the significantly minimum total sugar content, with a final sugar value of 36.88%. This treatment's high dilution and lack of enzymes probably hindered the breakdown of polysaccharides, due to which the sugar content was lowest. The observed data confirms that total sugar increase during increase in storage duration in guava nectar as reported by Baramanray *et al.* (1995) [6]. The percentage of total sugars increased from the day of preparation (39.31) to 120 days after storage (39.70) by Priyanka *et al.* (2012) [24]

Table 12: Effect of different treatment on colour of tamarind squash during storage

Treatment	Treatment details	(Pulp : Water)	Colour Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	8.7	8.5	8.2	8.1	7.8
T_2	Cold water Treatment	(1:3)	8.5	8.2	8.1	7.9	7.6
T_3	Cold water Treatment	(1:4)	8.3	8.1	7.9	7.6	7.4
T_4	Hot water Treatment	(1:2)	8.4	8.3	8.1	8.0	7.6
T_5	Hot water Treatment	(1:3)	8.3	8.1	7.9	7.5	7.2
T_6	Hot water Treatment	(1:4)	8.1	8.0	7.8	7.4	7.0
T_7	Cold water + Pectinase 0.25%	(1:2)	8.5	8.3	8.1	7.8	7.6
T_8	Cold water + Pectinase 0.25%	(1:3)	8.3	8.0	7.8	7.5	7.3
T_9	Cold water + Pectinase 0.25%	(1:4)	8.1	7.9	7.7	7.4	7.2
T_{10}	Hot water + Pectinase 0.25%	(1:2)	8.4	8..2	8.0	7.8	7.6
T_{11}	Hot water + Pectinase 0.25%	(1:3)	8.2	8.0	7.8	7.6	7.5
T_{12}	Hot water + Pectinase 0.25%	(1:4)	8.0	7.8	7.6	7.4	7.0

Table 13: Effect of different treatment on flavour of tamarind squash during storage

Treatment	Treatment details	(Pulp : Water)	Flavour Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	8.6	8.4	8.2	8.0	7.8
T_2	Cold water Treatment	(1:3)	8.4	8.2	8.0	7.8	7.6
T_3	Cold water Treatment	(1:4)	8.2	8.0	7.8	7.6	7.4
T_4	Hot water Treatment	(1:2)	8.5	8.2	8.0	7.8	7.5
T_5	Hot water Treatment	(1:3)	8.3	8.0	7.8	7.6	7.4
T_6	Hot water Treatment	(1:4)	8.1	8.0	7.8	7.5	7.2
T_7	Cold water + Pectinase 0.25%	(1:2)	8.4	8.1	7.9	7.7	7.4
T_8	Cold water + Pectinase 0.25%	(1:3)	8.2	8.0	7.8	7.6	7.3
T_9	Cold water + Pectinase 0.25%	(1:4)	8.0	7.8	7.6	7.4	7.2
T_{10}	Hot water + Pectinase 0.25%	(1:2)	8.2	8.0	7.8	7.5	7.3
T_{11}	Hot water + Pectinase 0.25%	(1:3)	8.0	7.8	7.6	7.4	7.1
T_{12}	Hot water + Pectinase 0.25%	(1:4)	7.9	7.7	7.5	7.3	7.0

Table 14: Effect of different treatment on taste score of tamarind squash during storage

Treatment	Treatment details	(Pulp : Water)	Taste Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	8.6	8.4	8.2	8.0	7.8
T_2	Cold water Treatment	(1:3)	8.5	8.3	8.1	7.9	7.6
T_3	Cold water Treatment	(1:4)	8.4	8.2	8.0	7.8	7.5
T_4	Hot water Treatment	(1:2)	8.2	8.2	7.9	7.7	7.4
T_5	Hot water Treatment	(1:3)	8.1	7.8	7.6	7.5	7.3
T_6	Hot water Treatment	(1:4)	8.0	7.6	7.5	7.4	7.1
T_7	Cold water + Pectinase 0.25%	(1:2)	8.0	7.5	7.4	7.3	7.0
T_8	Cold water + Pectinase 0.25%	(1:3)	7.9	7.7	7.6	7.5	7.3
T_9	Cold water + Pectinase 0.25%	(1:4)	7.8	7.5	7.4	7.3	7.0
T_{10}	Hot water + Pectinase 0.25%	(1:2)	8.0	7.8	7.5	7.1	6.8
T_{11}	Hot water + Pectinase 0.25%	(1:3)	7.9	7.8	7.4	7.3	6.7
T_{12}	Hot water + Pectinase 0.25%	(1:4)	7.7	7.5	7.3	7.1	6.9

From table. 12, 13 and 14. It was found that the highest colour score was recorded in T_1 (Cold water treatment, 1:2 ratio) with 8.7, At day 120, after T_1, T_2 T_7 (Cold water + Pectinase 0.25%, 1:2) has the greatest colour value (7.6), whereas T_{12} (Hot water + Pectinase 0.25%, 1:4) has the lowest score (7.0).

T_1 (Cold water, 1:2) has the highest flavour score at the beginning, 8.6, whereas T_{12} (Hot water + Pectinase 0.25%, 1:4) has the lowest initial score, 7.9. All treatments have a progressive decline in flavour scores over time as a result of natural deterioration during storage.

Significantly, maximum scores for taste (8.6, 8.4, 8.2, 8.0 and 7.8, respectively) as per hedonic scale which was recorded by treatment T_1 cold water treatment (1:2). However, minimum taste scores (7.7, 7.5, 7.3, 7.1 and 6.9 respectively) were recorded by treatment T_{12} (hot water + Pectinase 0.25% 1:4)

Table 15: Effect of different treatment on overall acceptability of tamarind squash during storage

Treatment	Treatment details	(Pulp : Water)	Overall acceptability Storage period (Days)				
			Initial	30	60	90	120
T_1	Cold water Treatment	(1:2)	8.63	8.43	8.20	8.10	7.80
T_2	Cold water Treatment	(1:3)	8.47	8.23	8.07	7.93	7.60
T_3	Cold water Treatment	(1:4)	8.30	8.10	7.90	7.73	7.43
T_4	Hot water Treatment	(1:2)	8.37	8.23	8.00	7.90	7.50
T_5	Hot water Treatment	(1:3)	8.23	7.97	7.77	7.57	7.30
T_6	Hot water Treatment	(1:4)	8.07	7.87	7.70	7.47	7.10
T_7	Cold water + Pectinase 0.25%	(1:2)	8.30	8.03	7.80	7.63	7.33
T_8	Cold water + Pectinase 0.25%	(1:3)	8.13	7.93	7.73	7.57	7.30
T_9	Cold water + Pectinase 0.25%	(1:4)	7.97	7.77	7.57	7.40	7.13
T_{10}	Hot water + Pectinase 0.25%	(1:2)	8.20	7.90	7.77	7.60	7.23
T_{11}	Hot water + Pectinase 0.25%	(1:3)	8.03	7.87	7.60	7.47	7.10
T_{12}	Hot water + Pectinase 0.25%	(1:4)	7.87	7.67	7.47	7.33	6.97

From table 15. It was found that, the maximum score for overall acceptability (8.63, 8.43, 8.20, 8.10 and 7.80, respectively) was determined during the evaluation of freshly prepared squash as well as at 30, 60, 90 and 120 days of storage condition. At the 120 day, it was adjudged as Like very much as per the hedonic scale, which was recorded by treatment combinationT_1 (cold water treatment 1: 2). However, the following minimum overall acceptability scores were noted at T_{12} (Hot water treatment + pectinase 0.25%) ranged from (7.87, 7.67, 7.47, 7.33 and 6.97 respectively).

Conclusion

In conclusion, this study highlighted the effective methods for enhancing the storability of tamarind pulp and its value-added product, tamarind squash. The results showed that porcelain containers were the most effective in preserving the quality of tamarind pulp, minimizing microbial growth and nutrient loss over 120 days, followed by glass bottles and polyethylene bags. Aluminium pouches, however, led to significant quality deterioration. Furthermore, tamarind squash, prepared using different methods, retained its sensory qualities and was safe for consumption for up to three months. The study provides valuable insights for the food processing industry regarding the optimal packaging and preparation techniques for tamarind-based products.

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