Plant Archives Vol. 25, No. 2, 2025 pp. 2805-2815 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org

DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.404

EFFECT OF PACKAGING AND STORAGE ON QUALITY ATTRIBUTES OF CASHEW APPLE BLENDED FRUIT JUICE RTS BEVERAGE

R. Kamalraj[1]*, K. Umamaheswara Rao[2], B. Prasanna Kumar[3] and K. Aruna Kumari[1]

[1]Dr. Y.S.R. Horticultural University, COH- Venkataramannagudem, West Godavari District - 534 101, Andhra Pradesh, India.

[2]Dr. Y.S.R. Horticultural University, Cashew Research Station- Bapatla, Andhra Pradesh, India.

[3]Controller of Examinations, Dr. Y.S.R Horticultural University, Venkataramannagudem, West Godavari District-534101, A.P., India

*Corresponding author E-mail : kamalhortz@gmail.com

(Date of Receiving-16-07-2025; Date of Acceptance-21-09-2025)

ABSTRACT

The present study evaluated the effect of three packaging materials (glass bottles, foodgrade plastic bottles and spouted standup pouches) on the physicochemical stability of Ready to Serve (RTS) beverage prepared from cashew apple and pineapple blends (75:25, 50:50, 25:75 and 100:0)with addition of sugandhi root extract (2.5%). Prepared cashew apple juice blended RTS were stored at ambient temperature (~28 ± 2°C) and analyzed at 0, 30, 60 and 90 days for pH, total soluble solids (°Brix), titratable acidity (%), TSS/acid ratio, ascorbic acid (mg/100 mL) and tannins (mg/mL). Data were analyzed using a factorial completely randomized design.Over period of 90 days, TSS, TSS/Acid ratio increased, while pH, titrable acidity, ascorbic acid and tannins content were found decreased. Among blended juice combinations, B_3(25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded highest TSS, titrable acidity and lowest pH and tannins content, while B_4 (100% cashew apple juice) recorded highest ascorbic acid content. Among packaging materials, P_3(Spouted standup pouches) recorded the highest TSS and lowest pH, titrable acidity and tannins content.This highlights an important opportunity to transform cashew apple into a marketable and profitable product with both nutritional and economic significance.

Key words : Quality attributes, Cashew apple, Blended fruit juice, RTS beverage.

Introduction

Cashew (*Anacardium occidentale* L.) stands as a prominent plantation crop in India, cultivated for several centuries, known as the “Gold Mine of Wasteland”. This tropical tree was introduced to the Indian subcontinent by the Portuguese in the 16th century, primarily to combat soil erosion. The cashew tree thrives in hot, humid climates and is predominantly grown across 13 Indian states including Kerala, Tamil Nadu, Andhra Pradesh, Maharashtra and Goa. With an annual production exceeding 7.82 lakh tonnes, these nuts are cultivated over an area of 11.92 lakh hectares, yielding an average of 766 kg/ha. Andhra Pradesh, as a leading cashew-producing state, cultivates 1.99 lakh hectares and produces approximately 1.27 lakh tonnes of cashew nuts annually (DCCD, 2023).

The cashew fruit have a unique botanical composition comprising two distinct parts: the fleshy, pear shaped cashew apple and the kidney shaped nut. The cashew apple is fibrous and juicy, typically weighing six to eight times more than the nut. For every tonne of cashew nuts harvested, approximately 10 to 15 tonnes of cashew apples are produced. Despite the widespread consumption and export of the cashew nut, the cashew apple often goes to waste. It is typically left to spoil under the trees in orchards, primarily due to its limited utilization. However, the cashew apple is rich in polyphenols, minerals and vitamins, particularly vitamin C (Chempakam, 1983).

The cashew apple, is characterized by its significant nutritional profile, encompassing sugars, minerals and vitamins. Notably, it exhibits a high concentration of ascorbic acid (260 mg/100 ml) and a moisture content of 87.8% as reported by Augustin (1984). The fruit also

contains quantifiable amounts of protein, fat, carbohydrates, crude fiber and various minerals, including calcium, phosphorus and iron. The cashew apple is very rich in vitamin C and contains five times more vitamin C than an orange. Furthermore, cashew apples are abundant in various antioxidants, including polyphenols, flavonoids, carotenoids and tannins.

Cashew apple juice possesses numerous medicinal properties and has been traditionally used to treat various ailments, including scurvy, diarrhea, uterine complaints, dropsy, cholera and rheumatism (Vijayakumar, 1991). The potential of the cashew apple remains largely untapped due to its highly astringent taste, attributed to phenolic compounds like leucoanthocyanidins, which reduce its direct consumption and processing. The astringency, coupled with the acrid taste and tannin content, originates from a waxy layer on the skin that cause irritation to the tongue and throat upon consumption. While tannins contribute to the astringent taste, the diverse nutrient profile of the cashew apple is associated with numerous potential health benefits. However, the presence of tannins in the cashew apple necessitates consideration during processing and consumption. Therefore, effective processing methods are essential to reduce or remove these tannins and to improve the overall sensory quality and palatability of beverages derived from cashew apples.

To harness the full potential of cashew apple, processed products like juices and beverages are gaining popularity across different sections of society due to their pleasing aroma, taste and superior nutritional qualities. These fruit based beverages are highly refreshing, thirst quenching, appetizing, easily digestible and far superior to synthetic drinks. Further, the practice of juice blending represents a viable method for enhancing nutritional quality and palatability in fruit based beverages. This technique facilitates the enhancement of vitamins and mineral concentrations, with the choice of fruits and vegetables.Hence, keeping in view of the above facts regarding importance and scope of cashew apple utilization, cashew apple juice blended with pineapple juice a study was undertaken by preparation of RTS.

Materials and Methods

Extraction of cashew apple juice

Disease free fully ripened, undamaged cashew apple fruits were cut into pieces and then processed using a mechanical screw type extractor. This machine pressed the fruits to separate the juice and pomace and the juice collected in a clean, stainless steel container and utilized for clarification.

Clarification of cashew apple juice

Due to its high perishability, fresh cashew apple juice is susceptible to rapid degradation, typically within a 24 hour period. The presence of tannins imparts an undesirable astringency, necessitating a clarification procedure to enhance product quality. In this process, the juice was initially subjected to filtration through muslin cloth and collected in a sterile, wide mouthed stainless steel vessel. Subsequently, a clarifying agent, comprising 2 grams of cooked sago and 2.5 grams of citric acid per liter of cashew apple juice. Clarifying agent was introduced and thoroughly incorporated via continuous circular and stirring agitation, inducing the formation of a flocculent precipitate. Following an 16 hour sedimentation period, the clarified supernatant was carefully decanted, minimizing disturbance of the residual precipitate. The resultant clarified juice was further subjected to a secondary filtration through muslin cloth prior to its utilization in subsequent preparation of cashew apple juice blends and its evaluation in the present experimentation.

Extraction of pineapple juice

The fully mature, ripened pineapple fruits were washed and manually peeled using a sterile stainless steel knife. The crown, rind, eyes and core were removed. Subsequently, the remaining fruit pulp was sectioned into smaller pieces and introduced into a high speed blender and juice was extracted. The resulting juice was then subjected to filtration through a double layered muslin cloth and the clarified juice was collected in a sterile stainless steel container and utilized for preparation of juice blends in the present experimentation.

Preparation of sugandhi root extract

After a thorough cleaning, the central white part of root was removed and the dark outer layers of 250 g were sun dried for a day. These dried roots were then steeped in 2 liters of water overnight, resulting in a dark coloured liquid. The next day, this mixture was boiled down to half its initial volume and then filtered through a double cheesecloth to remove any solids. The strained liquid was transferred to a clean, heavy bottomed vessel, where one kilogram of sugar was added. This was heated until it thickened and became sticky (about 15 minutes on low-medium heat), then cooled and stored in a clean bottle.

Treatment details

Factor I: Blended juice combination for RTS (B)

B_1- Cashew apple juice (75%) + Pineapple juice (25%) + Sugandhi (2.5%)

B_2 - Cashew apple juice (50%) + Pineapplejuice

(50%) + Sugandhi (2.5%)

B_3 - Cashew apple juice (25%) + Pineapple juice (75%) + Sugandhi (2.5%)

B_4 - Cashew apple juice (100%)

Factor II: Packaging material (P)

P_1-Glass bottles

P_2-Food grade plastic bottles

P_3-Spouted standup pouches

Treatment combinations	Treatment details
T_1: B_1P_1	Cashew Apple Juice (75%) + Pineapple Juice (25%) + Sugandhi (2.5%) RTS in Glass Bottles
T_2: B_1P_2	Cashew Apple Juice (75%) + Pineapple Juice (25%) + Sugandhi (2.5%) RTS in Food Grade Plastic Bottles
T_3: B_1P_3	Cashew Apple Juice (75%) + Pineapple Juice (25%) + Sugandhi (2.5%) RTS in Spouted Standup Pouches
T_4: B_2P_1	Cashew Apple Juice (50%) + Pineapple Juice (50%) + Sugandhi (2.5%) RTS in Glass Bottles
T_5: B_2P_2	Cashew Apple Juice (50%) + Pineapple Juice (50%) + Sugandhi (2.5%) RTS in Food Grade Plastic Bottles
T_6: B_2P_3	Cashew Apple Juice (50%) + Pineapple Juice (50%) + Sugandhi (2.5%) RTS in Spouted Standup Pouches
T_7:B_3P_1	Cashew Apple Juice (25%) +Pineapple Juice (75%) + Sugandhi (2.5%) RTS in Glass Bottles
T_8: B_3P_2	Cashew Apple Juice (25%) + Pineapple Juice (75%) + Sugandhi (2.5%) RTS in Food Grade Plastic Bottles
T_9: B_3P_3	Cashew Apple Juice (25%) + Pineapple Juice (75%) + Sugandhi (2.5%) RTS in Spouted Standup Pouches
T_{10}: B_4P_1	Cashew Apple Juice (100%) RTS in Glass Bottles
T_{11}: B_4P_2	Cashew Apple Juice (100%) RTS in Food Grade Plastic Bottles
T_{12}: B_4P_3	Cashew Apple Juice (100%) RTS in Spouted Standup Pouches

Preparation of blended cashew apple fruit juice RTS

The cashew apple blended RTS (200ml) was prepared by mixing of cashew apple and pineapple fruit juices, in various proportions (75:25, 50:50, 25:75 and 100:0 ratio) with addition of Sugandhi extract (2.5%). Treatment T_1, T_2 and T_3 were prepared by 15ml of cashew apple juice with 5ml of pineapple juice and addition of 5ml of sugandhi extract, 20g of sugar,0.6g of citric acid, 0.1g of sodium benzoate, 160ml of water and packed in glass bottles, food grade plastic bottles and spouted standup pouches respectively. T_4, T_5 and T_6 madeup by 10ml of cashew apple juice with 10ml of pineapple juice and addition of 5ml of sugandhi extract, 20g of sugar,0.6g of citric acid, 0.1g of sodium benzoate, 160ml of water and packed in glass bottles, food grade plastic bottles and spouted standup pouches, respectively. T_7, T_8 and T_9 were prepared by 5ml of cashew apple juice with 15ml of pineapple juice and addition of 5ml of sugandhi extract, 20g of sugar,0.6g of citric acid, 0.1g of sodium benzoate, 160ml of water and packed in glass bottles, food grade plastic bottles and spouted standup pouches respectively. T_{10}, T_{11} and T_{12} were prepared by 20ml of cashew apple juice and 20g of sugar,0.6g of citric acid, 0.1g of sodium benzoate, 160ml of water and packed in glass bottles, food grade plastic bottles and spouted standup pouches respectively. The glass bottles were crown corked, pasteurized at about 90ºc for 25min and all the bottles are cooled, labelled and stored at room temperature and analyzed for various parameters during the storage period.

Physicochemical analysis

The prepared cashew apple blended fruit juice RTS were analyzed for various parameters like pH, TSS, Titrable acidity, TSS/Acid ratio, Ascorbic acid and Tannins at the interval of 30 days upto 3 months of storage period.

pH was measured by using digital pHmeter (Systronics model:362) and Total Soluble Solids (TSS) was recorded by using digital pocket refractometer (Atago) and expressed in ºBrix. Titrable acidity (%) and Ascorbic acid (mg/100ml) was determined by titrimetric method. TSS/Acid was calculated by dividing TSS and titrable acidity. Tannin content (mg/ml) of prepared RTS was determined byFolin Denis reagent method.

The prepared cashew apple blended fruit juice RTS were stored in respective packaging material at ambient storage temperature (28±2). The data collected on the physicochemical parameters were analyzed statistically for Factorial Completely Randomized Design (FCRD).

Results and Discussion

pH

At initial day of storage, the blended juice combinations were found only significant. Among blended juice combinations, B_4 (100% cashew apple juice) was recorded the highest pH (3.813) followed by B_1 (75%

cashew apple juice and 25% pineapple juice with 2.5% sugandhi) was recorded the pH of 3.662 and B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi was recorded the lowest pH (3.338). The influence of packaging was not observed, as all the samples were freshly prepared and packaged. The non significant results were recorded for both packaging materials and their interaction effects (Table 1).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP).At 90 days of storage, among blended juice combinations, B_4 (100% cashew apple juice) recorded the highest pH (3.446) followed by B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) with a pH of 3.226,while B_3(25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the lowest pH (2.848). Among packaging materials, P_1 (Glass bottles) recorded the highest pH (3.204) followed by P_2 (Food grade plastic bottles) with a pH of 3.126, while P_3 (Spouted standup pouches) recorded the lowest pH (3.057). Among treatment combination,B_4P_1(100% cashew apple juice and stored in glass bottles) recorded the highest pH (3.478) followed by B_4P_2 (100% cashew apple juice and stored in food grade plastic bottles) with a pH of 3.463, while B_3P_3(25% cashew apple juice and 75% pineapple juice and stored in spouted standup pouches) recorded the lowest pH (2.723).

Among blended juice combinations, cashew apple juice dominant blends (B_4 and B_1) maintained higher pH than pineapple juice dominant blend (B_3). These differences are due to the inherent acidity of the fruit juices used in the RTS beverages(Akinwale, 2000). Among different packaging materials used, both P_1 (Glass bottles) and P_2 (Food grade plastic bottles) were more effective in retaining higher pH levels compared to P_3 (Spouted standup pouches). Among treatment combinations, B_4P_1 and B_4P_2, which is made up of 100% cashew apple juice and were stored in respective glass bottles and food grade plastic bottles, consistently recorded the highest pH across all intervals. Whereas B_3P_3 made up of25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in spouted standup pouches, exhibited the lowest pH across all intervals of storage.

The declined trend of pH during storage of cashew apple blended RTS is mainly due to increased levels of sugars by hydrolysis and decreased levels of acidity as reported in Amla with Mango blends by Rustagi and Kumar (2013). Similar findings also reported by Priyanka*et al*. (2015) in Jamun blended RTS.

TSS (ºBrix)

During the initial day of storage, the blended juice combinations were found only significant. Among blended juice combinations, B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the highest TSS (11.753 ºBrix) followed by B_2(50% cashew apple juice and 50% pineapple juice with 2.5% sugandhi) with a TSS of 11.353 ºBrix, whereas B_4 (100% cashew apple juice) recorded the lowest TSS of 10.350 ºBrix. The influence of packaging was not observed, as all the samples were freshly prepared and packaged. The non significant results were recorded for both packaging materials and their interaction effects (Table 2).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). Among blended juice combinations, B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the highest TSS (13.425 ºBrix) followed by B_2 (50% cashew apple juice and 50% pineapple juice with 2.5% sugandhi) with a TSS of 12.938 ºBrix, whereas B_4 (100% cashew apple juice) recorded the lowest TSS (11.652ºBrix). Among packaging materials, P_3 (Spouted standup pouches)recorded the highest TSS (12.795ºBrix) and in contrast P_1(Glass bottles) showed the lowest TSS (12.375 ºBrix). Among interactions, the treatment combination B_3P_3(25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in spouted standup pouches) recorded the highest TSS (13.575 ºBrix) followed by B_3P_2 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in food grade plastic bottles) with a TSS of 13.425 ºBrix, whereas B_4P_1 (100% cashew apple juice and stored in glass bottles) recorded the lowest TSS (11.325 ºBrix).

Among blended juice combinations, B_3(25% cashew apple and 75% pineapple juice with 2.5% sugandhi) consistently exhibited the highest TSS values at each storage interval, while the blend B_4(100% cashew apple juice) recorded comparatively lower TSS values during the storage. Among packaging materials, spouted standup pouches (P_3) showed higher increase in TSS levels from initial day to 90 days of storage. The glass bottles (P_1) most effectively maintained the TSS levels with minor increase in values thorough out the storage period (Robertson, 2013). The treatment combination B_3P_3(25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in spouted standup pouches)recorded the highest TSS across all intervals. Whereas B_4P_1

Table 1 : Effect of packaging materials on the pH of cashew apple blended RTS beverage during storage.

pH																			
Days of storage																			
Initial day					30th day					60th day					90th day				
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	3.665	3.660	3.660	3.662	B_1	3.375	3.300	3.268	3.314	B_1	3.320	3.250	3.210	3.260	B_1	3.293	3.213	3.173	3.226
B_2	3.450	3.450	3.450	3.450	B_2	3.173	3.077	3.035	3.095	B_2	3.112	3.027	2.980	3.040	B_2	3.073	2.983	2.933	2.996
B_3	3.340	3.340	3.335	3.338	B_3	3.058	2.938	2.824	2.940	B_3	3.007	2.886	2.767	2.887	B_3	2.973	2.848	2.723	2.848
B_4	3.815	3.815	3.810	3.813	B_4	3.548	3.529	3.481	3.519	B_4	3.512	3.502	3.442	3.485	B_4	3.478	3.463	3.399	3.446
Mean	3.568	3.566	3.564		Mean	3.289	3.211	3.152		Mean	3.238	3.166	3.100		Mean	3.204	3.126	3.057	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.002		0.005		B	0.002		0.007		B	0.002		0.005		B	0.001		0.004	
P	0.001		NS		P	0.002		0.006		P	0.001		0.004		P	0.001		0.004	
BxP	0.003		NS		BxP	0.004		0.012		BxP	0.003		0.009		BxP	0.002		0.007	

Table 2 : Effect of packaging materials on the TSS (°B) of cashew apple blended RTS beverage during storage.

TSS(°B)																			
Days of storage																			
Initial day					30th day					60th day					90th day				
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	10.750	10.760	10.750	10.753	B_1	11.325	11.475	11.675	11.492	B_1	11.725	11.925	12.175	11.942	B_1	12.025	12.275	12.555	12.285
B_2	11.350	11.360	11.350	11.353	B_2	11.975	12.025	12.125	12.042	B_2	12.500	12.525	12.655	12.560	B_2	12.875	12.915	13.025	12.938
B_3	11.760	11.750	11.750	11.753	B_3	12.425	12.575	12.655	12.552	B_3	12.925	13.055	13.205	13.062	B_3	13.275	13.425	13.575	13.425
B_4	10.350	10.350	10.350	10.350	B_4	10.675	10.885	11.175	10.912	B_4	11.025	11.275	11.655	11.318	B_4	11.325	11.605	12.025	11.652
Mean	11.053	11.055	11.050		Mean	11.600	11.740	11.908		Mean	12.044	12.195	12.423		Mean	12.375	12.555	12.795	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.023		0.069		B	0.013		0.041		B	0.014		0.044		B	0.014		0.043	
P	0.020		NS		P	0.012		0.036		P	0.012		0.038		P	0.012		0.037	
BxP	0.039		NS		BxP	0.023		0.072		BxP	0.025		0.076		BxP	0.024		0.075	

(100%cashew apple juice and stored in glass bottles), exhibited the lowest TSS across all intervals of storage.

'The steady increase in TSS over time might be due to moisture loss, polysaccharide breakdown and continued hydrolysis of sugars during storage, as observed by Karnale (2017) in bael RTS. Similar results were also reported by Vaishnavi (2016) in blended RTS made up with Aonla with grapes.

Titrable acidity (%)

During the initial day of storage, blended juice combinations were only found significant. Among blended juice combinations, B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the highest acidity (0.543%) followed by B_2 (50% cashew apple juice and 50% pineapple juice with 2.5% sugandhi) with a acidity of 0.473%, whereas B_4 (100% cashew apple juice) recorded the lowest acidity of 0.383 %.The influence of packaging was not observed, as all the samples were freshly prepared and packaged. The non significant results were recorded for both packaging materials and their interaction effects (Table 3).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). At 90 days of storage, among blended juice combinations, B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the highest acidity (0.362 %) followed by B_2 (50% cashew apple juice and 50% pineapple juice with 2.5% sugandhi)with a acidity of 0.290% and B_4 (100% cashew apple juice) recorded the lowest acidity (0.180%). Among packaging materials, P_1 (Glass bottles) showed the highest acidity (0.310 %) and in contrast P_3(Spouted standup pouches) showed the lowest acidity (0.226%). Among interactions, the treatment combination B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles) showed the highest acidity (0.406%) followed by B_3P_2 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in food grade plastic bottles) with a acidity of 0.370 %, whereas B_4P_3 (100% cashew apple juice and stored in spouted standup pouches) showed the lowest acidity (0.143%).

Among blended juice combinations, B_3(25% cashew apple and 75% pineapple juice with 2.5% sugandhi) consistently exhibited the highest acidity values at each storage interval, while the blend B_4(100% cashew apple juice) recorded comparatively lower acidity values during the storage. Among packaging materials, glass bottles (P_1) showed higher acidity levels from initial day to 90th day of storage. In contrast spouted standup pouches (P_3)

Table 3 : Effect of packaging materials on the Titrable acidity (%) of cashew apple blended RTS beverage during storage.

Titrable acidity(%)																				
Days of storage																				
Initial day					30th day				60th day					90th day						
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	0.442	0.440	0.441	0.441	B_1	0.408	0.371	0.331	0.370	B_1	0.323	0.298	0.258	0.293	B_1	0.277	0.237	0.213	0.242
B_2	0.474	0.472	0.473	0.473	B_2	0.448	0.404	0.354	0.402	B_2	0.383	0.343	0.278	0.334	B_2	0.343	0.288	0.239	0.290
B_3	0.544	0.542	0.543	0.543	B_3	0.508	0.460	0.396	0.455	B_3	0.453	0.408	0.333	0.398	B_3	0.406	0.370	0.310	0.362
B_4	0.384	0.382	0.383	0.383	B_4	0.315	0.280	0.260	0.285	B_4	0.263	0.233	0.198	0.231	B_4	0.217	0.182	0.143	0.180
Mean	0.461	0.459	0.460		Mean	0.420	0.379	0.335		Mean	0.355	0.320	0.266		Mean	0.310	0.269	0.226	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.001		0.002		B	0.002		0.007		B	0.001		0.004		B	0.002		0.007	
P	0.001		NS		P	0.002		0.006		P	0.001		0.004		P	0.002		0.006	
BxP	0.001		NS		BxP	0.004		0.012		BxP	0.003		0.008		BxP	0.004		0.012	

showed lower acidity levels thorough out the storage period (Deka and Sethi, 2001). The treatment combination B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles) recorded the highest acidity across all intervals. Whereas B_4P_3 (100%cashew apple juice and stored in spouted standup pouches), exhibited the lowest acidity across all intervals of storage.

This decreasing trend of acidity was due to increased level of sugars by hydrolysis and release of acid by decomposition, hydrolysis or oxidation (which modifies the hydrogen ion concentration), results in changed acidity of the cashew apple blended fruit juice RTS beverage (Thakur *et al*., 2018). Similar results were reported by Roy *et al*. (2016) in blended cashew apple RTS.

TSS/acid ratio

During the initial day of storage, blended juice combinations were only found significant. Among blended juice combinations,the highest TSS / Acid ratio of 27.024 found in B_4 (100% cashew apple juice) followed by 24.385 in B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) and the lowest TSS / Acid ratio of 21.645 was found in B_3 (25% cashew apple juice and 75% pineapple with 2.5% sugandhi). The influence of packaging was not observed, as all the samples were freshly prepared and packaged. The non significant results were recorded for both packaging materials and their interaction effects (Table 4).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). At 90days of storage,among blended juice combination, B_4 (100% cashew apple juice) recorded the highest TSS / Acid ratio (66.891) followed by B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) with a TSS/Acid ratio of 51.461, whereas B_3 (25% cashew apple juice and 75% pineapple juice) was recorded the lowest TSS/Acid ratio (37.605). Among packaging materials, P_3 (Spouted standup pouches)showed the highest TSS / Acid ratio (60.477) and in contrast P_1 (Glass bottles) showed the lowest TSS / Acid ratio (41.520). Among interactions, the treatment combination B_4P_3 (100% cashew apple juice and stored in spouted standup pouches) recorded the highest TSS / Acid ratio (84.415) followed by B_4P_2 (100% cashew apple juice and stored in food grade plastic pouches) with TSS/ Acid ratio of 63.945, whereas B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles) recorded the lowest TSS / Acid ratio (32.738).

Table 4 : Effect of packaging materials on the TSS/Acid ratio of cashew apple blended RTS beverage during storage.

TSS/Acid Ratio																				
Days of storage																				
Initial day					30th day				60th day					90th day						
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	24.322	24.455	24.377	24.385	B_1	27.793	30.896	35.226	31.305	B_1	36.359	40.088	47.287	41.245	B_1	43.492	51.798	59.092	51.461
B_2	23.946	24.068	23.996	24.003	B_2	26.702	29.770	34.302	30.258	B_2	32.681	36.572	45.608	38.287	B_2	37.537	44.925	54.609	45.690
B_3	21.618	21.679	21.639	21.645	B_3	24.459	27.310	31.923	27.897	B_3	28.565	32.038	39.717	33.440	B_3	32.738	36.285	43.793	37.605
B_4	26.954	27.095	27.024	27.024	B_4	33.838	38.807	42.903	38.516	B_4	42.005	48.501	59.024	49.843	B_4	52.313	63.945	84.415	66.891
Mean	24.210	24.324	24.259		Mean	28.198	31.696	36.089		Mean	34.903	39.300	47.909		Mean	41.520	49.238	60.477	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.087		0.269		B	0.222		0.683		B	0.274		0.845		B	0.002		0.007	
P	0.075		NS		P	0.192		0.592		P	0.238		0.732		P	0.002		0.006	
BxP	0.151		NS		BxP	0.384		1.143		BxP	0.475		1.464		BxP	0.004		0.012	

Among blended juice combinations, B_4(100% cashew apple juice) consistently exhibited the highest TSS / Acid ratio values at each storage interval, while the blend B_3(25% cashew apple and 75% pineapple juice with 2.5% sugandhi) recorded comparatively lower TSS / Acid ratio values during the storage. Among packaging materials, spouted standup pouches (P_3) showed higher level of increase in TSS / Acid ratio levels from initial day to 90th day of storage. In contrast glass bottles (P_1) most effectively maintained the TSS / Acid ratio levels with minor increase in values thorough out the storage period.The treatment combination B_4P_3(100%cashew apple juice and stored in spouted standup pouches) recorded the highest TSS / Acid ratio across all intervals. Whereas B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles), exhibited the lowest TSS / Acid ratio across all intervals of storage.

The results revealed that there was increase in TSS/ Acid ratio of different cashew apple blended juice RTS throughout the storage period of 90 days irrespective of the treatments. These results were aligned with Kannan *et al*. (2025), reported that the ratio of Total Soluble Solids (TSS) to acidity increased consistently across all treatments as TSS levels rose and acidity decreased during storage in cashew apple blended RTS. Similar findings were also reported by Roy *et al*. (2016) in blended cashew apple juice RTS and Umamaheswara Rao *et al*. (2020) in reconstituted cashew apple juice powder RTS.

Ascorbic acid (mg/100ml)

At initial days of storage, blended juice combinations and packaging materials and its interactions showed significant effects on the ascorbic acid content of cashew apple blended juice RTS. Among blended juice combinations, the highest ascorbic acid of 35.021 mg/ 100 ml found in B_4 (100% cashew apple juice) followed by 29.373 mg/100 ml in B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) and the lowest ascorbic acid of 19.888 mg/100 ml was found in B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi). Among packaging materials, the maximum ascorbic acid content of 27.821 mg/100ml was found in P_2 (Food grade plastic bottles) was on par with 27.818 mg/100ml in P_3 (Spouted standup pouches) where as the minimum ascorbic acid content of 25.933mg/100ml was found in P_1 (Glass bottles). Among interaction, the highest ascorbic acid content of 35.600 mg/100ml was observed in B_4P_2 (100% cashew apple juice and stored in food grade plastic bottles), which was on par with B_4P_3 (100% cashew apple juice and stored in spouted standup pouches) with a ascorbic acid content of 35.593 mg/100ml followed by B_4P_1 (100% cashew apple juice and stored in glass bottles) with a ascorbic acid content of 33.870 mg/100ml. The lowest ascorbic acid content of 18.960 mg/100ml was found in B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles) (Table 5).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). At 90days of storage, among blended juice combinations, B_4 (100% cashew apple juice) recorded the highest ascorbic acid (32.423 mg/100 ml) followed by B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) with a ascorbic acid content of 26.890 mg/100ml, whereas B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the lowest ascorbic acid content of 17.707 mg/ 100 ml. Among packaging materials, P_2 (Food grade plastic bottles)showed the highest ascorbic acid content (25.515 mg/100 ml) and in contrast P_1(Glass bottles) showed the lowest ascorbic acid content (23.665 mg/ 100 ml). Among interactions, the treatment combinations B_4P_2 (100% cashew apple juice and stored in food grade plastic bottles) recorded the highest ascorbic acid content of 32.990 mg/100 ml followed by B_4P_3 (100% cashew apple juice and stored in spouted standup pouches) with a ascorbic content of 32.940 mg/100 ml, whereas B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the lowest ascorbic acid content (16.940 mg/100 ml).

Among blended juice combinations, B_4(100 % cashew apple juice) consistently exhibited the highest ascorbic acid values at each storage interval, while the blend B_3(25% cashew apple juice and 75% Pineapple juice with 2.5% sugandhi) recorded comparatively lower ascorbic acid values during the storage(Akinwale, 2000). Among packaging materials, food grade plastic bottles (P_2) showed higher ascorbic acid levels from initial day to 90th day of storage. In contrast glass bottles (P_1) maintained lower ascorbic acid content thorough out the storage period due to pasteurization of glass bottles.The treatment combination B_4P_2 (100% cashew apple juice and stored in food grade plastic bottles)recorded the highest ascorbic acid across all intervals. Whereas B_3P_1 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in glass bottles), exhibited the lowest ascorbic acid across all intervals of storage.

The results revealed that there was decrease in ascorbic content of different cashew apple blended fruit

Table 5 : Effect of packaging materials on the Ascorbic acid (mg/100ml) of cashew apple blended RTS beverage during storage.

Ascorbic acid (mg/100ml)																			
Days of storage																			
Initial day					30th day					60th day					90th day				
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	27.880	30.115	30.125	29.373	B_1	26.955	29.310	28.890	28.385	B_1	25.935	28.185	27.835	27.318	B_1	25.440	27.790	27.440	26.890
B_2	23.020	25.215	25.205	24.480	B_2	22.355	24.610	24.270	23.745	B_2	21.335	23.485	23.085	22.635	B_2	20.940	23.040	22.690	22.223
B_3	18.960	20.355	20.350	19.888	B_3	18.390	19.760	19.340	19.163	B_3	17.435	18.685	18.335	18.152	B_3	16.940	18.240	17.940	17.707
B_4	33.870	35.600	35.593	35.021	B_4	32.960	34.610	34.540	34.037	B_4	31.835	33.385	33.335	32.852	B_4	31.340	32.990	32.940	32.423
Mean	25.933	27.821	27.818		Mean	25.165	27.073	26.760		Mean	24.135	25.935	25.648		Mean	23.665	25.515	25.253	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.009		0.029		B	0.005		0.017		B	0.009		0.027		B	0.010		0.031	
P	0.008		0.025		P	0.005		0.014		P	0.007		0.023		P	0.009		0.027	
BxP	0.016		0.050		BxP	0.009		0.029		BxP	0.015		0.046		BxP	0.017		0.053	

Table 6 : Effect of packaging materials on the Tannins (mg/ml) of cashew apple blended RTS beverage during storage.

Tannins (mg/ml)																			
Days of storage																			
Initial day					30th day					60th day					90th day				
Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean	Factors	P_1	P_2	P_3	Mean
B_1	0.570	0.575	0.565	0.570	B_1	0.545	0.549	0.519	0.537	B_1	0.536	0.529	0.507	0.524	B_1	0.524	0.512	0.498	0.511
B_2	0.490	0.475	0.475	0.480	B_2	0.482	0.442	0.451	0.458	B_2	0.471	0.436	0.434	0.447	B_2	0.462	0.424	0.419	0.435
B_3	0.435	0.435	0.445	0.438	B_3	0.422	0.409	0.408	0.413	B_3	0.415	0.400	0.391	0.402	B_3	0.404	0.392	0.377	0.391
B_4	0.705	0.695	0.685	0.695	B_4	0.698	0.650	0.607	0.652	B_4	0.680	0.640	0.586	0.635	B_4	0.664	0.631	0.568	0.621
Mean	0.550	0.545	0.543		Mean	0.536	0.513	0.496		Mean	0.525	0.501	0.479		Mean	0.513	0.490	0.465	
	SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%			SEm±		CD@5%	
B	0.003		0.008		B	0.006		0.017		B	0.006		0.017		B	0.005		0.015	
P	0.002		NS		P	0.005		0.015		P	0.005		0.015		P	0.004		0.013	
BxP	0.005		NS		BxP	0.010		0.030		BxP	0.010		0.030		BxP	0.008		0.026	

juice RTS throughout the storage period of 90 days irrespective of the treatments. Decrease in ascorbic acid due to oxidative degradation of ascorbic acid into dehydroascorbic acid.Similar trend was reported by Vaishnavi (2016) in aonla blended RTS, that the ascorbic acid content in the Ready-to-Serve (RTS) beverages declined significantly during storage and Kannan *et al*. (2025) in cashew apple blended RTS.

Tannins (mg/ml)

During the initial day of storage, there is a significant difference among the blended juice combination. Among blended juice combinations, B_4 (100% cashew apple juice) recorded the highest tannins (0.695 mg/ml) followed by B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) with a tannin content of 0.570 mg/ml, while B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the lowest tannins (0.438 mg/ml). The influence of packaging was not observed, as all the samples were freshly prepared and packaged. The non significant results were recorded for both packaging materials and their interaction effects (Table 6).

From 30 days of storage to 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). At 90 days of storage,the significant differences were recorded for blended juice combinations (B), packaging materials (P) and their interactions (BxP). Among blended juice combinations, B_4 (100% cashew apple juice) recorded the highest tannins content (0.621 mg/ml) followed by B_1 (75% cashew apple juice and 25% pineapple juice with 2.5% sugandhi) with a tannins content of 0.511 mg/100ml, whereas B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) recorded the lowest tannins content (0.391mg/ml). Among packaging materials, P_1 (Glass bottles) showed the highest tannins content (0.513 mg/ml) and in contrast P_3(Spouted standup pouches) showed the lowest tannins content (0.465 mg/ml). Among interactions, B_4P_1 (100% cashew apple juice and stored in glass bottles) recorded the highest tannins content (0.664 mg/ml) followed by B_4P_2 (100% cashew apple juice and stored in food grade plastic bottles) with a tannins content of 0.631 mg/ml, whereas the lowest tannins content of 0.377 mg/ml was found in B_3P_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in spouted standup pouches).

Among all blended juice combinations, B_4(100% cashew apple juice) consistently exhibited the highest tannins values at each storage interval, while the blend B_3 (25% cashew apple and 75% pineapple juice with 2.5% sugandhi) recorded comparatively lower tannins values during the storage (Anand *et al*., 2014). Among packaging materials, glass bottles (P_1) showed higher in tannins levels from initial day to 90th day of storage. In contrast, spouted standup pouches (P_3) showed sharp decline in values thorough out the storage period (Harendra and Bhagwan Deen, 2022). The treatment combination B_4P_1 (100%cashew apple juice and stored in glass bottles) recorded the highest tanninscontent across all intervals. Whereas B_3P_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi and stored in spouted standup pouches), exhibited the lowest tannins across all intervals of storage.

The results revealed that there was a gradual decrease in tannins of different cashew apple blended fruit juice RTS throughout the storage period of 90 days irrespective of the treatments. This reduction in tannin levels during storage can be attributed to oxidative degradation, enzymatic polymerization and interaction with other macromolecules such as proteins and pectin. The results are in line with findings of Pangotra (2016) in phalsa and pear blended beverage, Srikanth (2016) in bael blended RTS beverages, Karnale (2017) in bael RTS and Umamaheswara Rao *et al*. (2020) in reconstituted cashew apple blended RTS.

Conclusion

Among blended juice combination, B_3 (25% cashew apple juice and 75% pineapple juice with 2.5% sugandhi) with physico-chemical parameters like high TSS,titrable acidity and low pHand tannins content, while B_4(100% cashew apple juice) recorded the highest ascorbic content. Among packaging materials, P_3 (Spouted standup pouches) recorded the highest TSS, moderate ascorbic acid and lowest pH, titrable acidity and tannin content. The use of underutilized cashew apple fruit, provides unique nutritional and functional value and also helped in reducing postharvest losses. Blending with pineapple enhanced flavour balance and consumer acceptability, while packaging in glass bottles ensured better preservation of nutritional and sensory quality.This highlights an important opportunity to transform cashew apple into a marketable and profitable product with both nutritional and economic significance.

References

Akinwale, T.O. (2000). Cashew apple juice its use in fortifying the nutritional quality of some tropical fruits. *Europ. Food Res. Technol.*, **211(3)**, 205–207.

Anand, A., Sahu G.S. and Mishra H.N. (2014). Chemical composition and organoleptic evaluation of blended

cashew apple juice. *Int. J. Res. Agricult. Sci.*, **1(4)**, 23-48.

Augstin, A. (1984). Cashew apple products. *Cashew causerie*. **6(2)**, 8-9.

Chempakam, B. (1983). Distribution of ascorbic acid and ascorbic acid oxidase activity in the developing cashew apple (*Anacardium occidentale* L.). *J. Horticult. Sci*., **58(3)**, 447-448.

DCCD (2023). *Statistical data on cashew plantation area and production*. Directorate of cashewnut and cocoa development.

Deka, B.C. and Sethi V. (2001). Preparation of mixed fruit juice spiced RTS beverages. *Indian Food Packer,* **42(3)**, 58-61.

Harendra, B. and Bhagwan Deen D. (2022). Preparation and storage of Ready To Serve (RTS) beverage from Mango, Citrus lime, Aloe vera and Ginger. *Int. J. Nutr. Food Sci*.

Kannan, S., Noorjehan A.K.A.H., Baskaran A. and Raja N. (2025). Evaluation of cashew apple RTS beverages blend with mango and papaya for its physicochemical properties and storage life. *Plant Science Today*, **12(1)**, 1-7.

Karnale, S.M. (2017). Studies on preparation of ready to serve (RTS) beverage of bael (*Aegle marmelos*). *M.Sc. (Agri) Thesis*, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Pangotra, B.B. (2016). Development and evaluation of phalsa blended beverages. *M.Sc.(Agri) Thesis*, Division of Food Science and Technology, Sher e Kashmir University of Agricultural Sciences and Technology of Jammu.

Priyanka, N, Dorajeerao A.V.D. and Sudhavani V. (2015). Utilisation of jamun juice by making blended RTS beverages. *Plant Archives*, **15(2)**, 1083-1088.

Robertson, G. L. (2013). *Food Packaging: Principles and Practice* (3rd ed.). CRC Press.

Roy, A., Kumar B.P., Swami D.V. and Subbramamma P. (2016). Cashew apple juice blend with mango, pineapple and sapota for improving quality of RTS beverages and economic feasibility. *J. Horticult. Sci*., **11(1)**, 37-43.

Rustagi, S. and Kumar P. (2013). To study the storage analysis of developed amla mango blended beverage. *Adv. Biores*., **4**, 109-117.

Srikanth (2016). Standardization and evaluation of bael (*Aegle marmelos* Correa) RTS beverage and squash blended with other fruits. *M.Sc. Thesis*, Horticultural College and Research Institute, Dr. Y.S.R. Horticultural University. Venkataramannagudem, West Godavari District-534 101.

Thakur, A., Thakur N., Thakur A. and Hamid K.P. (2018). Effect of packaging and storage temperature on storage behaviour of appetizer (spiced squash) prepared from wild aonla (*Phyllanthus emblica* L.) fruits. *Chem. Sci. Rev. Lett*., **7(1)**, 310-316.

Umamaheswara Rao, K., Prasanna Kumar B., Swami D.V., Salomi Sunnetha B., Uma Krishna K. and Smith D.D. (2020). Studies on Physico-chemical Characters and Storage Behavior of Blended Cashew Apple Juice Powder for RTS Beverage. *Int. J. Curr. Microbiol. Appl. Sci.*, **9(12)**, 503-520.

Vaishnavi, S. (2016). Standardization of nutritionally enriched aonla (*Emblica officinalis*. G) based unfermented blended beverages. *M.Sc. Thesis*, Horticultural College and Research Institute, Dr. Y.S.R. Horticultural University. Venkataramannagudem, West Godavari District-534 101.

Vijayakumar, P. (1991(. Cashew apple utilization - a novel method to enhance the profit. *The Cashew*, **5**, 17-21.