


Prospects of Cashew Apple
- A Compilation Report

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PERFACE

Cashew is an introduced crop to India from Brazil during 16th century by Portuguese sailors. This crop was initially noticed for their attractive fleshy receptacle popularly called as cashew apple (misunderstood as fruit). Cashew apple juice is able to supply energy and minerals instantly to the consumer. But somehow the peculiar physiological behaviour and thin skin hamper the cashew apple storage and subsequently reduce their marketing value. In addition, the acrid sense in throat while consuming cashew apple juice and certain pre and post-harvest factors *i.e.,* fruit cracking, pest and disease attack, nut and apple drying also hinder the cashew apple usage. Hence, in most of the plantations, cashew apples are left over as a waste after nut separation.

Cashew apples are rich source of minerals, vitamins especially vitamin C and sugars infused with water. Keeping the nutritional qualities in view, several approaches like low temperature storage, modified and control atmospheric storage, edible coating, use of botanicals and chemicals have been attempted and optimised to increase the storage life and transportation. Valorization or value addition is one of the approaches to improve the market horizon of cashew apple products and thereby the livelihood of cashew farmers and processors. Preparation of alcoholic and non-alcoholic beverages, pickles, candies, probiotics, enzymes, emulsan, surfactants and cattle feed from cashew apple pomace have already been standardised. ICAR-Directorate of Cashew Research has developed cashew apple RTS fortified with lemon juice, cashew apple cider, cashew apple jam and jelly. This technical bulletin provides a detailed description of botany, biochemical attributes, preservation and value addition of cashew apple.

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Technical Bulletin on
Prospects of Cashew Apple - A Compilation Report

1. Introduction

The initial introduction of Cashew (*Anacardium occidentale* L.) in India was in the Goan coast during the 16th century by Portuguese sailors. Though the crop is well known for its tasty roasted nuts in the recent past, it had been utilized to mitigate soil erosion in coastal India during its initial periods of introduction. Initially, the cashew apple was given priority over cashew kernel because the ready consumption of cashew apple was known as the best thirst quencher and instant energy supplier to the exhausted travellers. Whereas, cashew nuts are obstructed with several processing steps and skills to obtain the edible produce "cashew kernel".

The attractive cashew apple which holds cashew nut is a reservoir of minerals and vitamins especially vitamin C and polysaccharides. But there are certain constraints that limits the transportation, extensive utilization and commercialization of cashew apple, such as (i) formation of abscission layer in pedicel and abrupt increase in apple size at the end phase of maturity which reduces the pulling force, consequently encouraging the natural fall of apple and nut (ii) the thin skin of cashew apples make it susceptible to bruises and (iii) very short storage life. The usual practice during harvest is that the cashew nuts are detached from the fallen cashew apples and the cashew apples are left in the field. These leftover cashew apples along with other recyclable cashew biomass undergo decomposition and contribute to the improvement of soil fertility. Though the leftover cashew apples improves the soil physico-chemical and biological properties, the *in-situ* decomposition emits unpleasant odour in the plantation and hence, proper disposal or value addition of cashew apple is essential. This technical bulletin provides details on proper utilization and valorization of cashew apple at the industrial and household level.

2. Botany of cashew apple

Cashew belongs to the family Anacardiaceae having drupe fruit type (Fig. 1). The drupaceous kidney-shaped fruit is exclusively surrounded by a greyish hard coat and attached outwardly to a swollen fruit stalk (cashew apple) which is mis-conceptualized as fruit. Cashew apples are derived from a tissue called thalamus or receptacle or stalk present outside the ovary. Hence, the distinct layers like exocarp, meso and endocarp are absent in cashew apple and therefore considered

as pseudocarp or false fruit. The fleshy thalamus is attached to the pedicel at dorsal side and astylar end of the actual fruit (derived from the ovary) with a sunken spot (apex groove). The development and maturity of cashew apple are coherent with the nut maturation. The cashew apple can reach up to an average length x breadth of 11 x 5 cm which is 8 to 10 times more than that of respective nut size. The matured cashew apples are spherical or cylindrical in shape without (Fig. 2a) or with (Fig. 2b) medial depression and look like a pyriform shaped hypocarp. During maturation and ripening, the firm, fragile and green, immature cashew apples are turned to soft and juicy with the different outer spectrum (red, orange and yellow) depending on the varieties.

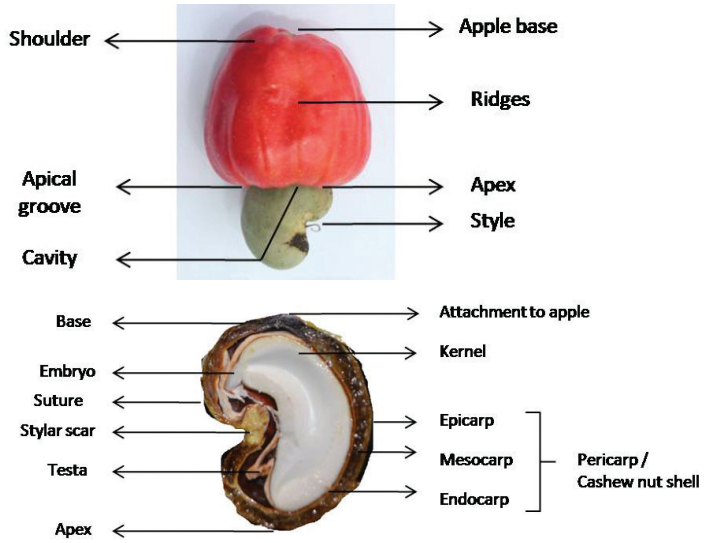


Fig. 1. Botany of cashew apple and nut

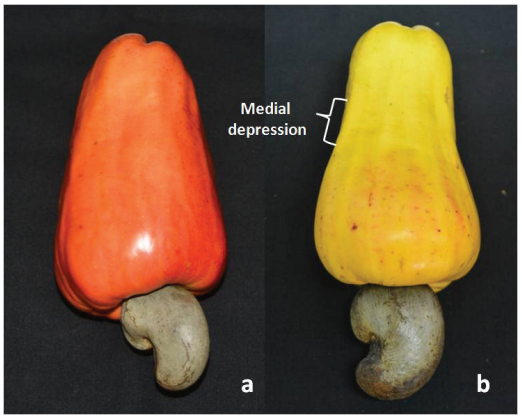


Fig. 2. Cashew apple without (a) and with (b) medial depression

3. Biochemical and physical attributes of cashew apple

In cashew apple, the essential minerals, vitamins and sugars are permeated in the water matrix (juice) whereas the leftover fibre matrix (pomace) is a composite of cellulose, hemicelluloses, pectin and protein. Total sugars in the form of fructose, glucose and sucrose are one of the major components present in cashew apple. The vitamin C in cashew apple ranges from 200 to 300 mg / 100 g of pulp, which is found to be four times greater than in citrus fruits and ten times higher than in pineapple juice. Cashew apple contains 0.099% vitamin B2, 0.041% calcium, 0.011% phosphorous and 0.003% iron. The biochemical constituents *i.e.,* total soluble solids (TSS), acidity, phenols, tannins, anti-oxidants and minerals such as potassium, phosphorous, calcium, magnesium, zinc and iron are varied among varieties and growing conditions. However, yellow apples tend to be bigger, less firm and less astringent than scarlet or orange apples. Biochemical factors determine their suitability for different industrial purposes.

4. Volatile compounds and essential oils

Cashew apples emit pleasant and foul smell during ripening and spoilage respectively. The volatile components in freshly ripen cashew apple are mainly composed of esters, terpenes and hydrocarbons. So far, 29 esters, 16 terpenes, 9 hydrocarbons, 7 carboxylic acids, 7 aldehydes, 3 alcohols, 2 ketones, 2 lactones and 1 norisoprenoids, and are characterized and quantified by different extraction and analysis methods. The sweet and fruity aroma in well-ripened cashew apple is due to substances like methyl 3-methyl butanoate, ethyl 3-methyl butanoate, methyl butanoate, ethyl butanoate, ethyl-trans-2-butenoate and methyl 3-methyl pentanoate. The green odour is due to the presence of six and five carbon aldehyde components such as cis-3-hexenol, hexanal and 2-methyl-2-pentenal. The most common unpleasant and stinky odour experienced during the spoilage of cashew apple is due to 2-methyl butanoic acid. Apart from olfactory substances, few essential oils have also been identified from cashew apple. The essential oil profile distinguishes between red and yellow cashew apples. Palmitic acid and oleic acids are two major constituents of red apples. While palmitic acid, furfural, 4-hydroxydodecanoic acid, lactone, (*E*)-hex-2-enal, (*Z*)-hex-3-enol and hexadecanol are the principal oil components in yellow cashew apples.

5. Medicinal uses and anti-nutrients of cashew apple

5.1. Nutritional and medicinal qualities

The cashew tree is classified under medicinal trees in its place of origin and South American continent. The cashew apple is a fleshy fruit containing 65 to 80%

moisture which can be extracted as minerals, sugars, polyphenols and tannins rich juice. Cashew apple juice and their byproducts have potential medicinal value for treatment against various ailments and also can be used as refreshment drink. Cashew apple juice is consumed freshly to get better relief against chronic dysentery, sore throat and bone demineralization. Owing to the unique astringent property, the external rubbing of fresh or distilled cashew apple juice is reported to provide relief from rheumatism and neuralgia. Cashew apple can be very well used as an energy booster to revitalize the body because of high calorific value. Fructose in cashew apple regulates the insulin and stabilizes the blood sugar, whereas glucose in cashew apple acts as an instant energy supplier. The copper in cashew apple facilitates the flexibility of blood vessels and augments the oxygen-carrying capacity. The calcium present in cashew apple helps in bone and joint wellness. The fresh and fermented beverage helps to prevent muscle cramp, macular degeneration and insomnia in old age. Cashew apple is known as a potent antioxidant and oral cleanser. It helps to strengthen the gums, maintain oral freshness and overall dental health. According to the Indian Council of Medical Research, the average requirement of vitamin C for Indians ranges from 40 to 80 mg, and this can be fulfilled by consuming 100 ml of cashew apple juice. The fibre rich cashew apple increases the level of fat oxidation in adipose tissue and cholesterol hence recommended at a moderate level for those looking for weight reduction.

5.2. Anti-microbial and anti-proliferation properties

The cashew apple is used for stomach and intestine ailments such as ulcer and gastrointestinal problems. The anacardic acid in cashew apple has an acute lethal action on *Helicobacter pylori* – peptic ulcer causing bacteria and reduces infection. Cashew apple juice potentially reduces the activity of *Salmonella typhimurium* which causes liver ailments. Soaking fresh meet in cashew apple juice drastically reduce the spoilage caused by *Escherichia coli* and *Salmonella aureus.* It is also said to have anti-cancerous properties. Various forms of antioxidants in cashew apple acts on the tumor cell and prohibit their proliferation rate. The volatile components isolated from cashew apple exhibited a lethal effect on growth and survival of certain microorganisms of genus Bacillus (*B. subtilis* and *B. ammoniagenes*), Salmonella (*S. aureus, S. cerevisiae* and *S. mutans*), Escherichia (*E. coli* and *E. aerogenes*), Pseudomonas (*P. acnes, P. aeruginosa, P. vulgaris, P. chrysogenum* and *P. ovule*), *Trichophyton mentagrophytes* and *Calathea utilis.* Volatile compounds pertaining to inhibitory action against microorganisms are car-3-ene, limonene, furfural, benzaldehyde, nonanal, 2-methylpentan-1-ol, α-terpinene and 8-caryophyllene.

5.3. Anti-nutritional factors

Cashew apple contains a countable amount of anti-nutritional substance like cyanoglycosides (20.65 to 26.61 mg HCN /100g) and oxalic acid (1.2 to 1.7%). Hence, excess consumption may cause an adverse effect on humans. The symptoms of cutaneous manifestation has occurred in women having IgE-mediated anaphylactic reactions due to the residual effect of cardol and anacardic acid. Similar kind of allergic symptoms was noticed by over consumption of mango fruit– an anacardic counterpart of cashew.

6. Preservation of cashew apple and juice

6.1. Low temperature and modified atmosphere storage

Cashew apples can be stored up to a maximum of only one day at ambient conditions. Low temperature (1 to 5°C temperature and 85 to 90% relative humidity) relatively extend the shelf life of cashew apples up to 25 days without spoilage and minimum physiological loss in weight (22%). Cashew apples sealed with plastic film flushed with carbon dioxide in combination with low temperature storage (5°C) can extend the shelf life up to 15 days.

6.2. Chemical preservatives

The colour, flavour, appearance, texture of cashew apple and nutritive quality can be well preserved without microbial spoilage by using chemical preservatives. Sodium benzoate, sodium metabisulphite, potassium metabisulphite, citric acid, sorbates and benzoic acids have been used as preservatives for improving the shelf life of the cashew apple juice. The benzoates and sorbates inhibit the yeast and mould growth whereas the sodium and potassium metabisulphite reduce the enzymatic browning and use of citric acid decreases polyphenol oxidase activity. Any one of the following chemical combinations *viz.,* sodium benzoate and sodium metabisulphite at 0.01% each or sodium benzoate and citric acid at 0.01% each or sodium metabisulphite and potassium metabisulphite at 0.05% each can extend the shelf life of juice up to 20 days under ambient condition. Coating fresh cashew apple with vegetable oils such as mustard or neem oil is the best preservative for shelf life extension of the cashew apple up to 12 days.

6.3. Use of osmolytes

Osmolytes such as sugar and salt can significantly reduce the moisture content from cashew apple (48 to 70%). The subsequent drying time at the final step of processing can be reduced due to osmolyte intake in this pre-drying process.

The cashew apple cubes of 1cm^3 immersed in sugar solution of 40 to 60°Brix under 30 to 50°C for 2-4 hrs followed by air drying was found suitable for developing dehydrated cashew apple products. After pre-drying with the osmolytes, further preservation can be done using air or vacuum drying.

Advantages

- Prevents enzymatic browning and microbial growth
- A suitable method at industrial and homestead level
- Reduces the astringency of cashew apple juice.

Disadvantages

- Leaching of nutrients especially vitamin C and biochemical characters

6.4. Thermal processing

This method is common for the preservation of juice and pulp of any fruit. The liquid or semi-solid substance are homogenized, de-aerated and exposed to heat (90°C) for one hour followed by immediate bottling (hot filling) or heated – cooled – filled in aseptic filling in glass or tetra pack pouches (polythene-aluminum-foil layered). Both these processes are found to be effective in maintaining the physico-chemical characteristics of the treated juice for up to 12 months. The combined approach of chemical preservatives and pasteurization (high temperature short time or low temperature long time) enhances the shelf life of cashew juice.

Advantages

- Prevent microbial growth and ensures safe consumption
- Reduces the astringency of cashew apple juice

Disadvantages

- Degrades vitamins especially vitamin C (vitamin C is sensitive to high temperature) and other nutrients
- Inactivates enzyme activity
- Non-enzymatic browning
- The loss in sensory qualities

6.5. High-pressure processing technique

Pressure and temperature are the main components of this method. The pressure and temperature applied over the surface of solid or semi-solid or liquid phase are uniformly transmitted to the inner part to achieve desirable effect of texture, colour, flavour, microbiologically safe and stable food products. The exposure time for pressure and temperature application depends on the product and the target microorganisms. Cashew apple juice can be well preserved under 350 MPa pressure for 7 min or 400 MPa for 3 min at room temperature (28±3°C) for a maximum of 8 weeks under refrigerated conditions. The nutritional quality, vitamin C, total soluble solids and acidity of the cashew apple juice are maintained in this method.

Advantages

- Prevents microbial growth and ensures safe consumption
- Maximum retention of nutritional and biochemical properties

Disadvantages

- Expensive method of preservation
- Standardization of pressure, temperature and time combination is required for every horticultural crop and food products

6.6. Irradiation technique

Electromagnetic waves of different wavelength especially gamma rays and X-rays are mainly used in the field of food preservation. Irradiation using gamma rays with doses of 0.5 and1.0 k Gy can be used for an extended shelf life of cashew apple juice.

Advantages

- Maximum preservation of nutritional and biochemical properties
- Prevents microbial growth and ensures safe consumption
- Feasible technology in the field of food preservation

Disadvantages

- The higher dose of radiation leads to substantial loss of vitamin C

7. De-tanning of cashew apple juice

Tannins present in cashew apple are responsible for astringency of the juice (3 to 5 mg/ml). It binds with proteins and minerals and interferes with their assimilation in the body, resulting in a nutritional deficiency. Tannin reduction has a vital role to make cashew apple juice palatable like other fruits.

7.1. De-tannification using bio-products

Bio-products available in nature are the cheapest and safest source of de-tannification. Cassava starch is readily available and effectively reduces tannin at the rate of 39.8%, but requires more than 8 hr for clarification which leads to fermentation. Hence, refrigeration with clarification is recommended in this method to avoid fermentation. Rice gruel is a rapid (20 to 40 min) and effective clarifying agent but the quantity of gruel to be added at the rate of 1:2 (Juice: Gruel) leads to dilution of fruit juice and alter the taste. Some recently identified de-tanning agents such as defatted soybean meal, dried potato starch and bajra starch (rich in starch and iron) were tested for their efficiency in tannin reduction at ICAR-Directorate of Cashew Research, Puttur and found to be more efficient to reduce tannin at the rate of 34.3%, 28.6% and 24.0%, respectively.

7.2. De-tannification using chemicals

Poly vinyl pyrolidone (PVP) is one of the most effective chemicals that precipitates tannin in cashew apple juice (34 to 35%). But PVP is very expensive and not readily available in the market. Gelatin powder is the most common and readily available de-tanning agent (35 to 36%). It works well even within the range of 3 to 10g for one litre of cashew apple juice. Enzymes like tannase can also be used as best tannin precipitant but its sourcing and affordability is a dispute.

7.3. Steaming and blanching

These are the integral operations in processing for the inactivation of enzymes and sterilization of apple surface. Steaming of cashew apples (0.4 N/m^2) for 5 to 15 min or boiling in salt water (40 to 50°C) for 15 min reduces the tannin content in cashew apples.

7.4. Microfiltration

This method is also in practice but requires tedious pre-treatments like the use of clarifying agents prior to filtration and is expensive as well.

8. Packaging and transportation

Selection of ripe, firm and undamaged apples plays a vital role in deciding the quality of processed products. Cashew apples should be plucked from the tree or the picked apples should be firm enough and free from spoilage to develop edible products. These apples are advised to reach processing units within 24 hours of collection. If the nuts are separated from apples, the shelf life of fresh apple is reduced to six hours. In India, cashew apples are transported in cardboard boxes. The studies on packaging materials and transportation with respect to cashew apples are meagre. In countries like Brazil, facilities such as perforated carton boxes and refrigerated wagons (Temperature: 5°C; Relative Humidity: 85 to 90%) are made to promote safe reach of cashew apples to the processing units.

9. Cashew apple valorization

9.1. Agricultural uses

9.1.1. *In-situ* and *ex-situ* biocompost

Usually, the cashew apples are left behind in the plantation sites after the nut separation. In biodiversity rich sites, the beneficial soil microorganisms enhance the rate of decomposition and hence improve the soil biological and physical properties. Leftover cashew apples along with other recyclable cashew biomass can be used for making compost *in-situ* or *ex-situ*. The nutrient composition and microbial properties of cashew apple compost are as follows:

pH	6.45
Organic carbon	31.53%
Total nitrogen	0.80%
Total phosphorous	0.46%
Total potassium	0.81%
Carbon: Nitrogen	38.43
Total calcium	1275 mg/kg
Total magnesium	1134 mg/kg
Total iron	166 mg/kg
Total manganese	157.8 mg/kg

Total zinc	27.8 mg/kg
Total copper	4.0 mg/kg
Bacteria	9.00 x 10^{-6}cfu/g
Fungi	139.6 x 10^{-4}cfu/g)
Actinomycetes	8.66 x 10^{-5}cfu/g

9.2. Industrial by-products

9.2.1. Non-alcoholic beverages and products

9.2.1.1. Cashew apple juice

Freshly harvested cashew apples are washed in running water and ensured to be free from soil debris or microbial spoilage. The juice extraction can be achieved through basket press, screw press or hydraulic press. Poly Vinyl Pyrollidone is added at the rate of 10 g or defatted soy-meal 180-200 g per 8 to 10 lit of cashew juice and passed through muslin cloth for clarification. After 20 to 40 min the clear supernatant is added with sugar at the rate of 0.5 kg per litre of juice and preservatives such as sodium benzoate and citric acid 6 g each.

9.2.1.2. Cashew apple squash

The procedure for preparation of juice and squash is similar. But the consistency of squash can be achieved by adding more sugar and citric acid. Freshly harvested cashew apples are washed in running water and ensured to be free from soil debris or microbial spoilage. The juice extraction can be achieved through basket press, screw press or hydraulic press. Poly Vinyl Pyrollidone is added at the rate of 10 g per 8 to 10 lit of cashew juice and passed through muslin cloth for clarification. After 20 to 40 min the clear supernatant is added with sugar at the rate of 3 kg per litre of juice and preservatives *viz.,* 6 g of sodium benzoate and 100 g of citric acid. The squash can be diluted with three times of water and serve.

9.2.1.3. Cashew apple syrup

The clarified cashew apple juice is added with 2 kg of sugar per 1 lit of juice and kept under moderate heat. The mixture is frequently stirred till the sugar completely dissolves. Dissolve 15 g of citric acid in a small quantity of the above syrup. Add this to the large quantity with continuous stirring. The syrup can be diluted with five times of water and serve.

9.2.1.4. Ready to serve beverage (RTS)

The required amount of water with sugar (200 g sugar / 1 L water) and citric acid (5g) are boiled with continuous stirring. Amount of 200 ml clarified cashew apple juice and 100 ml of any fruit juice are added after switching off the flame. The content is cooled and packed in aseptic condition.

9.2.1.5. Cashew apple - mango mixed fruit jam

Freshly harvested cashew apples and ripe mango fruits are washed, sliced and made into pulp using a mixer or pulper. Potassium meta-bisulphate (KMS) is added @ 2.5 g and citric acid @ 5 g per kg of pulp for storage. The stored pulp and sugar with equal quantity (1:1 ratio) are mixed well under low flame. When it reaches the appropriate consistency of jam, cooling and packing under the aseptic condition is recommended.

9.2.1.6. Cashew apple pickle

Matured de-tanned cashew apple slices	:	500 g
Gingelly oil	:	75 ml
Chilli powder	:	75 g
Fenugreek powder	:	20 g
Curry leaf and mustard powder	:	5 g
Asafoetida powder	:	10 g
Turmeric powder	:	5 g
Mustard	:	10 g
Vinegar	:	100 ml
Sodium benzoate	:	0.75 g
Salt	:	to taste

Preparation method

Marinate the sliced cashew apple in the salt solution for at least 24 hr. Gingelly oil is added to the preheated vessel, and mustard, fenugreek powder, turmeric powder, chilli powder, curry leaf and mustard powder are added to the boiling gingelly oil in sequence. The de-tanned cashew apple slices are added to the boiling spice mixture and cooked for 5-10 min. Salt and vinegar is gradually added by thorough stirring. At last a pinch of sodium benzoate is mixed thoroughly with the end product. The product can be cooled before serving.

9.2.2. Alcoholic beverages

9.2.2.1. Cashew apple feni

The cashew apple feni is prepared through fermentation and distillation process. Matured and ripened cashew apples are collected, juice extracted, fermented and subjected to the distillation process. By distillation method, the concentration of alcohol can be adjusted to the required level. Cashew feni has been awarded the Geographical Indication registration in 2009 as a special alcoholic beverage from Goa. The hydrocarbons, volatile and mineral constituents of cashew feni are ethanol (42.85%), acetic acid (12.28%), ethyl acetate (55.97%), acetaldehyde (18.28%), furfural (3.22%) and copper (1.04%).

9.2.2.2. Cashew apple wine

The required quantity of cashew apples is cleaned in running water for removal of debris and immersed in 5% salt solution for 2-3 days for tannin reduction. The apples are then exposed to steam of 15 lb for 15 min. This can be done using a pressure cooker or autoclave. The steamed apples are crushed using squeezer or grinder to collect juice and filtered through muslin cloth. The preservative sodium metabisulfite is added at 1g/litre juice to arrest the microbial growth. Sugar @ l kg and tartaric acid @ 6g are added to the juice with continuous stirring till it reaches 17°Brix. The bacterial culture *Saccharomyces cerevisiae var. bayanus* is added to the prepared mixture at the rate of 2% (v/v) and the fermentation process is to be carried out at room temperature (28±3°C) for 6 days. The TSS of final product stage is 2–3°Brix. **Wine clarification:** The wine can be clarified with the addition of 0.04% bentonite after racking. The estimated chemical composition of cashew wine is as follows.

pH	2.92
TSS	2°Brix
Reducing sugar	0.9%
Titrable acidity	1.21%
Phenols	0.12 g/100 mL
Tannin	1.9 mg/100 mL
Ethanol	5-6%

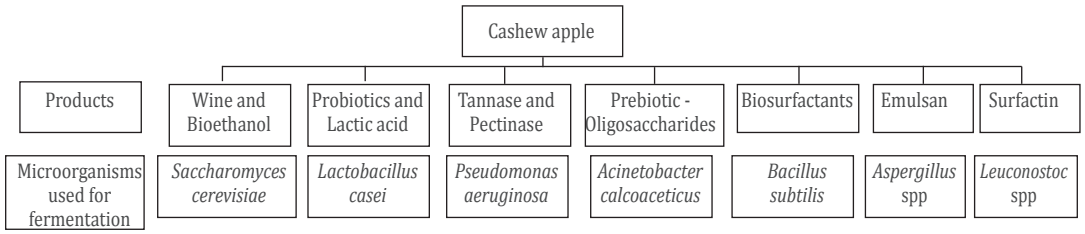
9.2.2.3. Cashew apple vinegar

Cashew apple vinegar preparation consists of two stages a) alcoholic fermentation, b) acidic fermentation. Yeast @ 2.0 g in 20 ml coconut water is added and kept for 12 hours to make starter solution. To clarify the cashew apple juice, cooked and cooled sago gruel @ 5g is added along with starter solution into 1 lit of extracted unclarified cashew apple juice. This solution is kept for twelve days for alcoholic fermentation in narrow-mouthed plastic bottles, with cotton plugging. After twelve days, the fermented supernatant juice is separated through filtration (to obtain alcoholic ferment) into a wide mouth glass container or clay pot and added with thrice the quantity of mother vinegar for acidic fermentation. This container is kept tied with a muslin cloth, allowing air passage, for 15 days. The clear juice portion is filtered to a clean stainless steel vessel and pasteurized by keeping in boiling water for 10 minutes, cooled and bottled on the 16th day to get vinegar with 5 to 6% acidity. For continuous vinegar production, the filtrate can be used as mother vinegar. The estimated chemical composition of cashew vinegar is as below:

pH	4.6
TSS	17°Brix
Reducing sugar	6.44%
Titrable acidity	0.36%
Phenols	0.12 g/100 mL
Tannin	2.2 mg/100 mL

9.3. Other industrial by-products

The polysaccharides and nutrients present in cashew apple make it a potential substrate to develop diverse alcoholic and non-alcoholic beverages at the industrial level. The gist of fermented products and co-products of cashew apple juice and microorganisms used are furnished below:



9.4. Bio-fortified cashew apple juice

Though cashew apple is highly nutritious, blending with other fruit juice improves its nutritive quality and palatability. Cashew apple juice can be blended with the sap of fruits depending on the availability of seasons and locations. The biochemical qualities of cashew apple juice blended with other fruit juices are furnished in Table 1. ICAR-Directorate of Cashew Research, Puttur has developed a product called "CashLime" which is cashew apple and lemon juice blend/ RTS/ nectar prepared using cashew apple juice. The nutrient-rich drink can be stored under the refrigerated conditions for five months with maximum retention of nutrients. The leading PepsiCo Corporation had a tie-up with the Clinton Foundation to look about the sustainability and utility of cashew apple juice with other popular juices in villages of Maharashtra.

Table 1. Biochemical qualities of cashew apple juice blended with other fruit juices

	Cashew apple juice : other juice	Acidity (%)	TSS (° Brix)	vitamin C (mg/100 ml)
Cashew apple juice	-	0.55	11.31	97.77
Cashew apple juice + Lime juice	72:25	1.80	13.62	72
Cashew apple juice + Pineapple juice	75:25	0.26	11.25	57.44
Cashew apple juice + Passion fruit juice	50:50	0.61	14.50	79.73
Cashew apple juice + Amla juice	50:50	0.66	14.92	79.29
Cashew apple juice + Papaya juice	50:50	0.52	14.61	75.19
Cashew apple juice + Coconut water	12.5:87.5	0.24	10.6	19.3

9.4. Osmo-dehydrated products

9.4.1. Cashew apple sweet candy

Whole cashew apples or cashew apple slices are soaked overnight (10-14 hr) in sucrose solution of concentrations ranging from 50-70°Brix, enriched with 2%

calcium chloride and 0.6% potassium metabisulphate (KMS) at ambient conditions. The apple slices in solution should be frequently turned upside down manually or through agitator to ensure complete immerse, which will otherwise lead to microbial infection. The sugar solution concentration can be maintained at 60°Brix for 3-4 days. The cashew apple slices are separated from sugar solution and spread over a clean dry stainless steel tray for air drying. Dehydration using cabinet dryer at 50°C for 3-4 hr is advisable for rapid dehydration process. When whole apples are used, slits on four sides can be made using bamboo splints to encourage osmosis.

9.4.2. Cashew apple spice candy

Whole cashew apples or cashew apple slices are soaked overnight (10-14 hr) in salt mixed with turmeric powder, chilli powder, pepper powder, 2% calcium chloride and 0.6% potassium metabisulphate (KMS) at ambient conditions. The apple slices in solution should be frequently turned upside down manually or through agitator to ensure complete coating of spice mixture, which will otherwise lead to microbial infection. The slices should be retained in spice mixture for at least 2 days. The cashew apple slices are spread over a clean dry stainless steel tray for air drying. Dehydration using cabinet dryer at 50°C for 3-4 hr is advisable for rapid dehydration process. Cashew apples slices are more preferred for this method than whole apple processing.

9.5. Cattle feed from cashew apple waste

Cashew apple waste is a menace in processing industries. This waste can be used as a promising feed source in dairy and piggery units. After juice extraction for human consumption, the cellulose rich processing unit residue (pomace) can be used as a nutrient rich poultry and cattle feed in wet or dry format. Because of the high dry matter (22.5%) and protein content (13.7%) and low content of crude protein (11.8%) in cashew apple, it can be ensiled as a potential poultry or cattle feed.

10. Limitations of cashew apple utility in product development

10.1. Pre-harvest factors

10.1.1. Pest infestation

The pest and disease of cashew apple have received attention in the recent past, after the realization of its commercial importance for value addition and processing. There are a few pests that infest either cashew apple or cashew nut or

both such as cashew apple and nut borer (CANB), thrips and fruit flies. The female adults of CANB lay eggs on the cavity space at apple and nut junction at tender stage and later bore and feed the tender apple and nut resulting in its premature fall. In general, one borer in apple and three to four borers in nut was observed. In both apple and nut, CANB was located near to the junction and not at the distal end of apple cavity (Fig 3a). **Thrips:** Thrips rasp the wax layer of cashew apple and suck the sap causing net like cork over the apple body. Sometimes, the cracks over the corky surface cause secondary infestation by fruit flies and microbes (Fig 3b).

10.1.2. Cashew apple cracking

The etiology for cashew apple cracking is ambiguous (Fig 3c). The reports says that cashew apple cracking is varietal specific (eg. NRC selection - 2) and inherited to progenies when this is used as one of the parents in breeding programmes. Few reports say that cashew apple oriented towards southern and western sides are more prone to cracking (70% to 80%) than the northern and eastern side. The incidence was less noticed in the apples borne in inner branches, whereas the apples in the upper branches exposed to sunlight are prone to apple cracking. The micro or macronutrients may also have a marked effect on cracking.

10.1.3. Cashew apple and nut drying

The etiology for cashew apple and nut drying is unknown (Fig 3d). Genetic inheritance or nutrient deficiency/toxicity or disease infection may be the reason for cashew apple and nut drying.

10.1.4. Microbial infection

The delicate nature of skin facilitates the entry of pathogens (Fig 3e).

10.2. Post-harvest factors

10.2.1. Physiology of cashew apple

Though cashew apple follows non-climacteric respiration pattern, high respiration rate (62 to 72 ml kg^{-1} hr^{-1}) and steady increase in ethylene expression rate was observed (200 to 400 ml kg^{-1} hr^{-1}). Drastic reduction in ethylene release rate and emission of volatile compounds at the post-harvest stage is unique to cashew apple. A sudden increase in abscisic acid at pedicel and all over the cashew apple at the later phase of development tends to reduce the retention capacity and firmness.

10.2.2. Post-harvest spoilage

Due to delicate nature of skin, cashew apples are prone to quick pre and post-harvest attack of fruit flies which facilitates the entry of fungal inoculums such as Rhizopus, Aspergillus and Colletotrichum (Fig. 3f). To avoid the pathogen entry and to disinfect apple surface, quick dip with 0.25% citric acid or 0.3% ascorbic acid or 0.1% sorbic acid is recommended before fresh consumption or product development.

10.3. Tannin content

Tannins are referred to as an anti-nutritional factor that interfere with the assimilation of proteins in the body, resulting in non-availability of nutrients. The acrid feeling while consuming fresh cashew apple or cashew apple juice is owing to the presence of tannins (35%). Hence, tannin reduction and de-tanning is an important step prior to going for any product out of cashew apple.

a. CANB infestation

b. Thrips infestation

c. Cracked apple

d. Apple and nut drying

e. Microbial infection

f. Post-harvest spoilage

Fig. 3. Pre and post-harvest factors limiting cashew apple utility

11. Exclusive cashew apple genotypes at ICAR-DCR, Puttur

Fifteen bold cashew apple accessions were identified from National Cashew Gene Bank at ICAR-DCR, Puttur (Fig. 4). Among the accessions, NRC 301 was biggest with maximum length and breadth and the average weight of 280 g/apple. The accession NRC 175 was registered for highest apple yield (36.47 kg) and nut yield (3.02 kg) with minimum pest and disease attack during 2017-2018. The cashew apple of accession NRC 120 exhibited maximum phenolics, tannins and antioxidant activities. The biochemical properties of all 15 genotypes (Table 2) and released varieties (Table 3) are furnished below.

Table 2. Important biochemical quality parameters of selected cashew apple genotypes at ICAR-DCR, Puttur

Acc. No.	Vitamin C (mg/ml)	Tannin content (mg/ml)	Phenol content (%)	Total Antioxidant activity	
				*CUPRAC (α-tocopherol equivalent) (g /100ml)	**FRAP (g/100ml)
NRC 75	2.9	3.29	0.39	1.26	0.63
NRC 111	3.1	2.54	0.35	1.47	0.81
NRC 112	3.6	3.37	0.41	1.25	0.70
NRC 120	3.4	4.58	0.51	1.78	0.89
NRC 140	2.9	3.43	0.48	1.24	0.71
NRC 144	3.3	2.38	0.30	0.92	0.46
NRC 175	3.4	3.05	0.36	1.02	0.62
NRC 176	3.7	3.70	0.42	1.47	0.93
NRC 183	2.8	2.65	0.29	0.56	0.43
NRC 189	3.6	2.84	0.34	1.21	0.69
NRC 270	3.5	3.05	0.38	1.29	0.77
NRC 301	3.4	3.76	0.42	1.32	0.76
NRC 389	3.1	3.25	0.39	1.10	0.53
NRC 493	3.1	2.76	0.31	1.03	0.65
Vengurla 8	3.3	2.90	0.36	1.43	0.68

*Cupric reducing antioxidant property

** Ferric reducing antioxidant property

Table 3. Biochemical characteristics of released cashew apple varieties

Varieties	Colour of the apples	Vitamin C (mg/100 g)	Total sugars (%)	Non-reducing sugars (%)	Reducing sugars (%)	pH	TSS (?Brix)	Titrable acidity (%)	Juice recovery (%)	Pomace (%)
K22-1	Reddish Yellow	215.54	8.11	1.62	6.41	4.34	11.74	0.35	75.3	24.7
BPP-1	Yellow	283.3	9.76	1.86	7.22	4.22	14.73	0.73	78.7	21.3
BPP-3	Yellow	316.3	8.40	2.84	6.54	3.89	14.13	0.55	85.92	14.08
BPP-5	Yellow Red	299.9	9.06	1.49	8.21	3.25	14.13	0.45	85.7	14.3
BPP-6	Yellow	211.40	10.67	1.17	9.43	4.21	12.67	0.39	84.25	15.75
BPP-8	Yellow	275.37	9.90	1.16	8.69	4.65	10.83	0.34	85.9	15.0
Bhaskara	Reddish Yellow	218.86	8.95	8.14	8.95	4.31	11.73	0.32	88.15	11.85
Goa-1	Yellow	189.34	12.76	1.07	11.63	4.10	12.70	0.34	76.2	23.8
Priyanka	Reddish Yellow	222.53	10.38	1.82	8.46	4.54	11.18	0.34	73.1	26.9
Jhargram-1	Yellow	195.58	9.38	0.89	8.44	4.17	12.58	0.36	72.01	27.99
Vengurla-1	Yellow	208.54	6.34	1.33	4.94	4.23	12.3	0.35	67.62	32.38
Vengurla-2	Red	331.7	8.34	2.34	6.00	4.15	12.83	0.34	84.97	15.03
Vengurla-3	Yellow	427.3	10.27	3.17	7.54	4.19	19.07	0.50	75.47	24.53
Vengurla-4	Orange	341.2	10.00	2.86	7.14	3.66	15.83	0.32	81.6	18.4
Vengurlae-6	Yellow	547.3	9.54	3.53	6.18	3.25	14.53	0.40	84.97	15.03
NRCC-2	Reddish Yellow	194.58	11.34	1.98	9.02	4.60	11.36	0.44	77.19	22.81
Chintamani-1	Reddish Yellow	210.51	8.75	0.76	7.93	4.16	10.86	0.30	70.76	29.24
Ullal-3	Red	227.52	5.99	1.06	4.87	4.47	11.51	0.37	75.73	24.27
Ullal-4	Yellow	213.64	8.57	1.95	6.38	4.31	12.35	0.41	75.23	24.77
Madakkathra-1	Yellow	514.7	11.76	2.56	5.99	3.49	15.10	0.43	79.57	20.43
Madakkathra-2	Red	231.56	7.05	1.13	5.86	2.30	11.00	0.43	79.04	20.96
Dhana	Yellow	270.47	11.84	1.38	10.38	2.70	12.35	0.51	80.41	19.59
Kanaka	Yellow	338.3	9.51	2.14	8.46	2.4	16.33	0.62	84.59	15.41
Priyanka	Orange	557.1	9.76	2.33	6.44	4.3	16.10	1.18	62.57	37.43
BBSR-1	Red	240.38	11.66	1.46	10.13	2.8	12.17	0.51	66.59	33.41
Jagannath	Yellowish green	212.32	11.63	0.72	10.86	2.70	12.20	0.47	82.53	17.47
Balabhadra	Yellow	231.12	11.51	1.22	10.24	4.34	12.23	0.34	78.41	21.59
VRI-2	Orange	421.3	8.00	2.36	5.14	4.58	14.43	0.43	82.4	17.6
VRI-3	Red	141.7	11.48	2.33	6.14	4.75	18.43	0.53	78.6	21.4

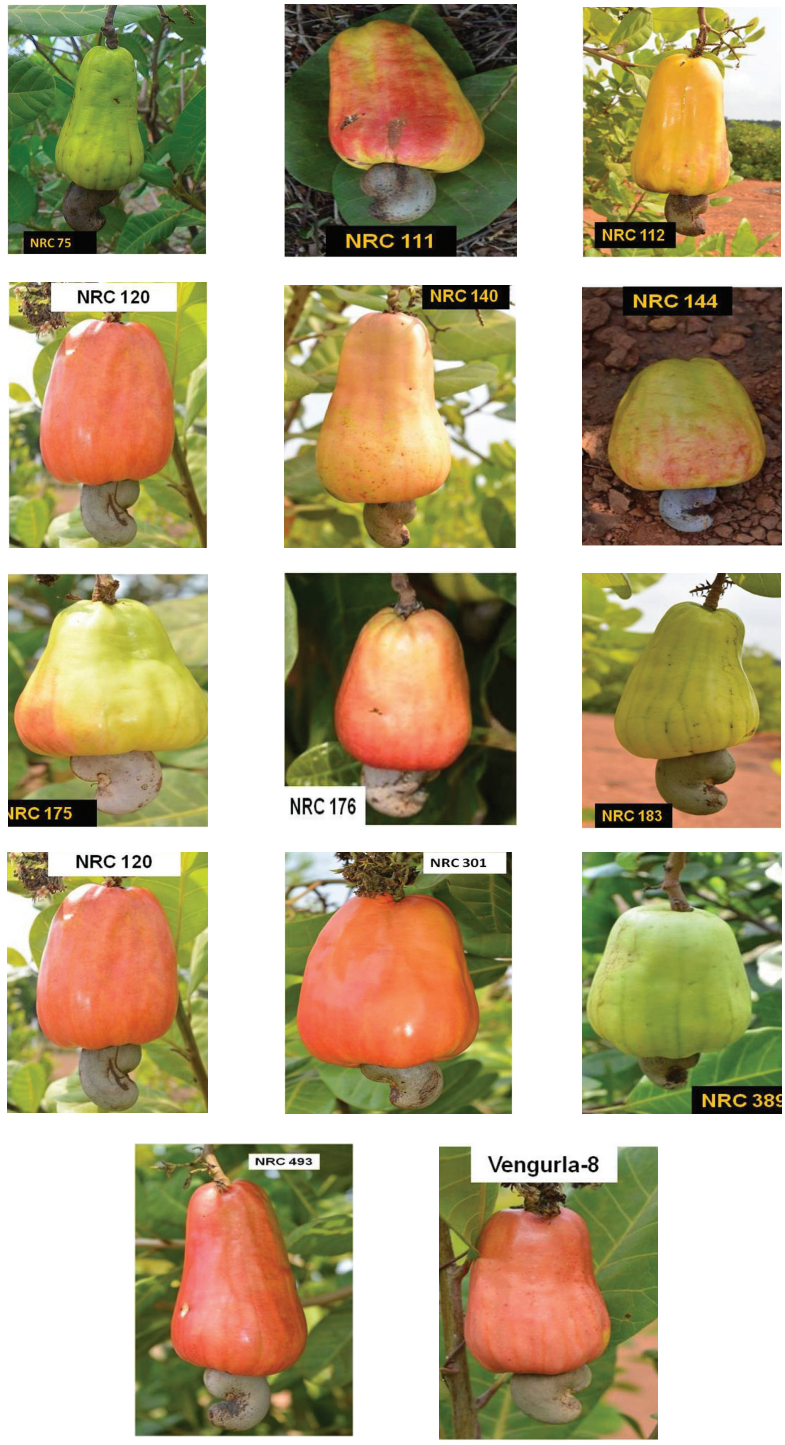


Fig. 4. Some selected Cashew apple genotypes at ICAR-DCR, Puttur

12. Biochemical characteristics of cashew apple products developed at ICAR-DCR, Puttur

The directorate has developed four self-stable cashew apple based products namely Cashew RTS, Cider, Jam and Jelly (Fig. 5).

CashLime is a cashew apple and lemon juice blend RTS/Nectar prepared using cashew apple pulp. The nutrient rich drink can be stored under refrigerated conditions for maximum of five months with maximum retention of nutrients and biochemical quality parameters (TSS- 10.5°Brix, vitamin C - 72 mg/100 ml, Tannins - 76 mg/100 ml, Total Phenols - 58 mg/100 ml, CUPRAC Assay - 186 mg/100 ml and FRAP Assay - 123 mg/100 ml) compared to fresh one (TSS- 12°Brix, vitamin C - 86 mg/100 ml, Tannins - 76 mg/100 ml, Total Phenols - 72 mg/100 ml, CUPRAC Assay - 242 mg/100 ml and FRAP Assay - 169 mg/100 ml) whereas the samples stored at room temperature began to lose its quality after two months of storage.

Cashew Apple Cider: Cashew apple cider was analyzed for its functional nutrient value and shelf life. The product was stored at refrigeration temperature and room temperature as well. Based on biochemical behavior of the products at both the storage conditions, it was observed that the product stored at refrigeration temperature could retain maximum of its nutrients till completion of 24 months (vitamin C - 109 mg/100 ml, Total Phenols - 137 mg/100 ml, CUPRAC Assay - 84 mg/100 ml and FRAP Assay - 246 mg/100 ml) compared to fresh one (vitamin C - 220 mg/100 ml, Total Phenols - 205 mg/100 ml, CUPRAC Assay - 98 mg/100 ml and FRAP Assay - 452 mg/100 ml) whereas the samples stored at room temperature were found stable with maximum nutrient retention up to 12 months of storage without any detrimental change in sensory quality of the product.

Cashew Apple jam: Jam being a self-stable processed product due to its high TSS content (68?Brix) could retain maximum of its nutrients (vitamin C - 83 mg/100 ml, Tannins 103 mg/100 ml, Total Phenols -119 mg/100 ml, CUPRAC Assay 372 mg/100 ml and FRAP Assay 169 mg/100 ml) even after five months of storage at room temperature compared to fresh preparation (TSS- 68, vitamin C - 121mg/100 ml, Tannins - 112 mg/100 ml, Total Phenols - 134 mg/100 ml, CUPRAC Assay - 403 mg/100 ml and FRAP Assay - 200 mg/100 ml).

Cashew Apple Jelly: The trend of nutrient retention of jelly was found similar to that of jam. Jelly was also stored at room temperature and was observed for change in its nutrient content during storage. Jelly also being a self-stable processed product like jam. Due to its high TSS content (65.5°Brix) it could retain maximum of its nutrients (vitamin C - 91mg/100 ml, Tannins - 90 mg/100 ml, Total Phenols - 107 mg/100 ml, CUPRAC Assay - 282 mg/100 ml and FRAP Assay - 122 mg/100 ml) even after five months of storage at room temperature compared to fresh preparation (vitamin C - 142mg/100 ml, Tannins - 93 mg/100 ml, Total Phenols - 117 mg/100 ml, CUPRAC Assay - 316 mg/100 ml and FRAP Assay - 152 mg/100 ml).

CashLime

Cashew apple cider

Cashew apple jam

Cashew apple jelly

Fig. 5. Cashew apple products developed at ICAR-DCR, Puttur

13. Conclusion

Cashew apple and their products have a potential market in the domestic and international forum. Though there are some limitations, certain physical and chemical processing steps are to be followed to bring out quality and palatable cashew apple products with significant nutritive properties. This bulletin comprehensively covers different aspects of cashew apple preservation and processing.

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