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REVIEW ARTICLE

Cashew apple wine, feni and vinegar: potential industrial products of the future

Thiruvelavan M[1], Neelavathi R[2*], Mohanalakshmi M[1], Uma D[3] & Malathi P[4]

[1]Department of Spices and Plantation crops, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[2]Regional Research Station, Tamil Nadu Agricultural University, Vriddhachalam 606 001, Tamil Nadu, India
[3]Department of Biochemistry and Bio Informatics, Tamil Nadu Agricultural University, Coimbatore, 641 003, Tamil Nadu, India
[4]Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Correspondence email - neelavathi@tnau.ac.in

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Abstract

Portuguese sailors brought Cashew (*Anacardium occidentale* L.) into India in the 16th century to combat soil erosion. In addition to cashew nuts, cashew apples are recognized for their nutritional value, including high levels of vitamins, minerals and sugars. However, their short shelf life and unpleasant taste due to tannins limit their marketability. Non-alcoholic and alcoholic beverages such as feni, cashew apple wine and vinegar are prepared from cashew apples using various methods of fermentation, clarification and preservation. Through value addition, cashew apples can contribute to various sectors, including food, beverages, cosmetics and agriculture, underscoring their potential as a valuable resource. This article explores cashew apples' composition and potential industrial applications, which are often overlooked despite their high production rates. Additionally, the article emphasizes the need to effectively utilize cashew apples to reduce waste and improve sustainability in the cashew industry.

Keywords: alcoholic beverage; cashew apple; tannins; vitamin C; vine; vinegar

Introduction

Cashew (*Anacardium occidentale* L.) is a tropical evergreen tree from the Anacardiaceae family, native to Brazil. It was introduced to India by Portuguese sailors in the 16th century, primarily to combat soil erosion along coastal regions. While the tree is now widely appreciated for its flavorful roasted nuts, the initial intent behind its introduction was environmental restoration (1). Then it was developed as a profitable crop due to the higher value of its kernels. The edible kernels are extracted for consumption during cashew nut processing, whereas the accompanying cashew apples are often discarded as waste. Despite being underutilized, cashew apples are recognized as an excellent source of quick energy and are known to quench thirst, especially for weary travellers (2). They are also nutrient-rich, including vitamins, minerals, polysaccharides, proteins and dietary fiber. However, their high perishability and susceptibility to microbial spoilage limit their shelf life (3).

Additionally, their sharp and astringent taste, primarily caused by tannins, makes them unpleasant for raw consumption and restricts their marketability as table fruits (4). The biomass of cashew apples holds considerable potential for enhancing the soil's biological, chemical and physical properties. Their decomposition positively contributes to soil health, albeit with the potential to produce an unpleasant odour in plantations (5). Therefore, it is crucial to investigate effective methods for processing cashew apples and enhancing their value. Such endeavours can lead to the development of commercially viable industrial products while simultaneously minimizing waste (6). This review underscores the potential applications and value-added opportunities of cashew apples for both domestic and industrial purposes, aiming to optimize their utilization and promote sustainable practices within the cashew industry.

Cashew apple

The cashew apple is a modification of receptacle, so it is called “false fruit” to which the cashew nut or true fruit is attached. The cashew apple is an edible and nutritionally valuable component of the fruit. As depicted in Fig. 1, the production of cashew apples significantly exceeds that of cashew nuts, by approximately 6 - 8 times (7). In India, an estimated 6 to 7 million tonnes of cashew apples are produced annually (8). Although cashew apples are commercially utilized for Feni production in Goa, they are predominantly discarded as waste in many other states (9). Cashew apples are soft and delicate, rendering them highly susceptible to physical damage and rapid microbial spoilage shortly after harvest. The highly perishable nature

Fig. 1. Cashew apple.

of fruits results in a minimal shelf life, often leading to complete deterioration within a short period (10). Additionally, ripe cashew apples are vulnerable to insect and non-insect pests damage. Moreover, the dispersed and unorganized structure of cashew plantations pose challenges for the harvesting and large-scale utilization of these fruits (11). Despite these challenges, cashew apples hold significant potential for value addition. A variety of fermented and non-fermented products can be derived from them. Some of these commercially available products are listed in Table 2. One of the most notable products is feni, described below.

Feni

Feni is a traditional alcoholic beverage produced through the fermentation of juice extracted from cashew apples, renowned for its distinctive fruity aroma and flavour. Feni holds cultural significance in India and is predominantly produced in Goa (12, 13). Feni comprises ethanol (42.85 %), acetic acid (12.28 %), ethyl acetate (55.97 %), acetaldehyde (18.28 %) and furfural (3.22 %). Feni is recognized for its unique sensory profile and is increasingly acknowledged as a premium artisanal beverage. It not only embodies the cultural heritage of Goa but also contributes to the local economy. Efforts continue to preserve and promote traditional Feni production techniques, reinforcing its global identity (14). Feni is typically produced through fermentation and distillation processes. The production of feni commences with the harvesting of fully ripened cashew apples, followed by juice extraction and natural fermentation, often facilitated by indigenous yeast strains. Upon completion of the fermentation process, the fermented juice undergoes distillation to yield a potent alcoholic spirit (15).

Table 1. Composition of Cashew apple

Constituents	Quantity (per 100 g)	References
Moisture	86.6 %	(29, 30)
Fibre	0.90 %	
Fat	0.2 %	
Carbohydrate	12.6 g	
Protein	0.8 g	
Reducing sugars	11.80 g	
Tannin	1.90 g	
Ash	0.3 g	
Calcium (Ca)	41 mg	
Phosphorus (P)	19 mg	
Iron (Fe)	0.4 g	
Vitamin B1	0.2 g	
Vitamin B2	99 mg	
Vitamin C	240 mg	

Table 2. Products of Cashew apple

Non-alcoholic / non-fermented beverage	Alcoholic/fermented beverage	Reference
Juice	Cashew apple wine, feni	(31)
Jam	Cashew apple vinegar	
Squash	Bio ethanol	
Ready-to-serve	Probiotics	
Syrup	Bio surfactants	
Pickle	Latic acid	

Cashew wine

Cashew apple wine is an undistilled alcoholic beverage prepared by fermenting cashew apple juice with yeast, *Saccharomyces cerevisiae* var. *bayanus*. It is slightly yellowish in colour, acidic in taste and characterized by low alcohol and high tannin content. The composition and detailed production methods provide insights into cashew wine characteristics (Table 3 - 4). The quality of the final product depends on the proper preparation of yeast, which plays a crucial role in the fermentation process (16). The detailed process steps are given below.

The fruits are thoroughly washed under running tap water to remove surface dirt. Subsequently, they are soaked in a 5 % salt solution for 2 - 3 days to reduce tannin content. The apples are then steam-treated under 15 lbs of pressure for 15 min using either an autoclave or a pressure cooker. Following steaming, the softened fruits are crushed using a squeezer or grinder to extract the juice, which is then filtered through a muslin cloth to remove any solid residues (18). To inhibit microbial growth, sodium metabisulfite is added at a concentration of 1 g/L of juice (19). While stirring continuously, 1 kg of sugar and 6 g of tartaric acid are incorporated into the juice until it reaches the 17°B value. The mixture is then fermented at ambient room temperature (28 ± 3 °C) for 6 days using *S. cerevisiae* var. *bayanus*, added at a 2 % (v/v) concentration. Upon completion of fermentation, the resulting wine exhibits total soluble solids ranging between 1-3° Brix. To enhance clarity, 0.04 % bentonite is added during the racking process (20).

Yeast for fermentation (Wine production)

Yeast genera such as *Torulaspora, Lachancea* and *Saccharomyces* are generally present in small quantities on the surface of cashew apples. However, fermentative yeast strains can become dominant when the fruit undergoes mechanical damage or exposure to spoilage-causing bacteria and fungi. Like grapes, the microbial environment of cashew apples becomes dominated by highly fermentative yeast strains, facilitating greater access to sugars and nutrients during fermentation (21).

Robust yeast strains often prevail during fermentation due to their strong fermentative abilities and high alcohol tolerance. Although *Saccharomyces* species are most

Table 3. Composition of Cashew apple wine

Composition		Reference
pH	2.92	(32)
TSS	2° Brix	
Reducing sugars	0.9 %	
Titrable acidity	1.21 %	
Phenols	0.12 g/100 mL	
Tannins	1.9 mg/100 mL	
Ethanol	5-6 %	

Table 4. Methods of Feni production

Process	Feni production method I process	Feni production method II process	Feni production method III process	Reference
Juice extraction	Manual Stomping	Perforated manual plate press cage	Two-step process (Hydraulic press followed by screw process)	
Fermentation	The collection tank of 2000 L capacity is directly employed as fermentation tanks.	The concrete tanks lined with tiles are used for fermentation along with a rake for occasional manual agitation of the juice during the process.	Syntax plastic tank with a capacity of 2000 L used for fermentation.	
Distillation	Batch distillation of fermented juice is carried out in a copper (and/or aluminum) pot, which is fixed the wood-fired hearth. The capacity of the copper pot is 150 L. Temperature is controlled by the traditional model of pushing and pulling out the firewood.	Same process that is done in the production method I procedure.	About 1500 L of fermented juice is taken for the first distillation. For Feni production, about 1: 2 ratio of Urrakh and fresh fermented juice are taken for the distillation. The yield of feni obtained is 20- 25 L with 19 - 20 Grau strength in alcohol content	(33)
Condensation	The vapor generated from the distillation pot is passed through the helical tube kept in a cold-water tank and subsequently, The condensate (Urrakh / Feni) is collected from the other end of the tube.	The traditional condensation method is employed, wherein the vapor is directed into the clay pots for condensation using cooling water, continuously sprayed over the pot.	Same process which is done in the production method I procedure.	
Quality control	There are no systematic quality checks. The quality of the final product is checked by the simple taste-based method.	All quality measures were in place to obtain a consistent product regarding aroma and alcohol content.	The quality of the final product is checked through the alcohol meter, which is used to determine the percentage volume of alcohol content in the wine.	

commonly associated with wine fermentation, other yeasts like *Torulaspora delbrueckii* and *Lachancea thermotolerans* also play significant roles, especially in the later phases of natural fermentation. Notably, these species are naturally occurring and available commercially as fermentation inoculants due to their desirable fermentation characteristics (22).

Cashew apple vinegar

Cashew apple vinegar is produced through a two-step fermentation process through sequential alcoholic and acetic acid fermentations. This method, one of the oldest known fermentation techniques, is detailed in Table 5. The production of vinegar from cashew apple juice involves using thermo-tolerant acetic acid bacteria, which efficiently convert alcohol into acetic acid (23). Successful vinegar production relies on properly preparing the must (fermentable juice mixture) and using high-quality yeast cultures, which help enhance the fermentation process and improve the final aroma and flavour of the vinegar. The nutritional composition of cashew apple vinegar is presented in Table 6, while its applications and benefits are illustrated in Fig. 2.

Preparation of must

To prepare the cashew apples for vinegar production, the fruits were first thoroughly washed under tap water and then washed with a 2 % bleach solution. After decontamination, the apples were cut into small pieces and blended into a smooth puree using a handheld immersion blender (24). The resulting juice was extracted by filtering the puree through a clean muslin cloth. The juice underwent a coarse clarification process to minimize the astringency caused by tannins. The clarified juice was then left undisturbed in a refrigerator at 4 ° C for approximately 6 hr. After settling, the clear supernatant was gently collected and used as the base for vinegar fermentation (25).

Table 5. Composition of Cashew apple vinegar

pH	4.6	Reference
TSS	17° Brix	(35)
Reducing sugars	6.44 %	
Titrable acidity	0.36 %	
Phenols	0.12 g/100 mL	
Tannins	2.2 mg/100 mL	
Acetic acid	1.2 %	

Table 6. Steps involved in vinegar production from Cashew apple

Steps	Description	Reference
Starter solution	Addition of 2.0 g of yeast into 20 mL of coconut water and kept for 12 hr	(34)
Clarification	Addition of 5 g of cooked, cooled sago gruel to 1 L of cashew apple juice along with the starter solution	
Alcoholic fermentation	Filling in narrow-mouthed plastic bottles with cotton plugs and allowing	
Filtration	Separate the fermented supernatant juice into a wide-mouth glass	
Acidic fermentation	Add three times the amount of mother vinegar and allow for acidic	
Filtration	Filter the clear juice into a clean stainless steel vessel.	
Pasteurization	On the 16th day of acidic fermentation, Pasteurization by keeping them in boiling water for 10 min followed by	
Bottling	Bottling of vinegar with 5 - 6 % acidity	

Preparation of yeast culture

To prepare the yeast inoculum, 2 g of commercial yeast were dissolved in 20 mL of sterile distilled water and incubated at 37 °C. Upon activation, 150 mL (one-tenth) of the total 1.5 L must volume was inoculated with this yeast suspension. The inoculated mixture was subsequently agitated at 150 rpm for 24 hr at room temperature to facilitate initial fermentation activity. Thereafter, the pre-cultured mixture attained an

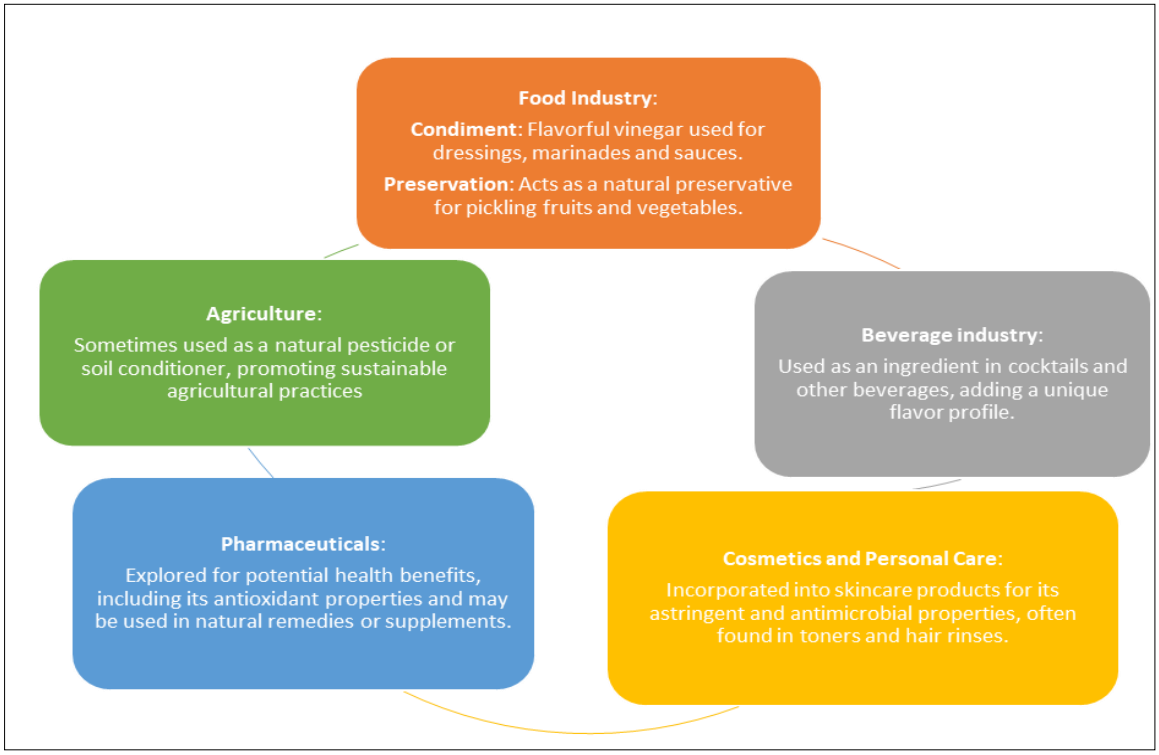

Fig. 2. Uses of Cashew apple vinegar.

optical density between 0.8 and 1 at 600 nm and was employed to inoculate the remaining 1350 mL (nine-tenths) of the must in a 2 L Erlenmeyer flask. The flask was loosely sealed with cotton plugs to ensure adequate aeration during incubation. As fermentation advanced, the total soluble solids (TSS) were consistently measured and monitored until they stabilized at the lowest consistent level, indicating the completion of the primary alcoholic fermentation (26).

Yeast for alcoholic beverage

Hanseniaspora guilliermondii, recognized as the second most dominant species within the *Hanseniaspora* genus, is known for producing high concentrations of acetate esters such as hexyl acetate, isoamyl acetate and 2-phenyl-ethyl acetate - compounds that impart pleasant floral and honey-like aroma, including rose and sweet notes. However, this yeast also generates sulfur-containing compounds, such as 3-mercapto-1-propano and trans-2-methyltetrahydrothiophen-3-ol, which can introduce undesirable odor resembling rancid or sweaty smell during fermentation (24).

Like *Hanseniaspora uvarum, H. guilliermondii* is predominantly active during the initial stages of fermentation, influencing the early aromatic profile of spontaneous or wild fermentation. Due to its dual role in producing both favourable and off-putting volatiles, this yeast significantly contributes to the overall complexity of wild ferments (27). Additionally, various other essential ingredients used in preparing feni and vinegar are outlined in Table 7, each playing a specific role in enhancing fermentation efficiency and product quality.

Table 7. Ingredients required for feni and vinegar production

Ingredients required for Feni / Vinegar	Purpose	Reference
Yeast	Speeds up fermentation	(36)
Sago	Clarifies the juice	
Citric acid	Clarifying agent	
Ammonium sulfate	Bleaching agent	
Mother vinegar	Contains live *Acetobacter aceti* bacteria that converts alcohol to acid	

The preparation of cashew apple vinegar involves a two-stage fermentation process: alcoholic fermentation followed by acetic (acidic) fermentation. Initially, a starter solution is prepared by dissolving 2 g of yeast in 20 mL of coconut water, which is allowed to activate for 12 hr. This starter is mixed with 1 L of unclarified cashew apple juice and 5 g of cooked, cooled sago gruel to initiate fermentation. The prepared mixture is transferred into narrow-mouthed plastic bottles sealed with cotton plugs and left undisturbed for 12 days, allowing alcoholic fermentation (20). Once fermentation is complete, the fermented supernatant is filtered and transferred into a wide-mouthed glass container or clay pot. To start the acetic fermentation phase, 3 parts of mother vinegar are added to the alcoholic ferment. The container is loosely covered with muslin cloth to facilitate air circulation and the mixture is left to undergo acidic fermentation for 15 days. The clear vinegar is filtered and poured into sterilized stainless-steel jars on the 16th day. The jars are then pasteurized in boiling water for 10 min to ensure product safety and achieve a 5 - 6 % acidity level. Once cooled, the vinegar is bottled for storage or distribution. The remaining filtrate serves as mother vinegar for subsequent fermentation batches (28).

Conclusion

The cashew apple, often regarded as a byproduct of cashew nut processing, possesses considerable potential for value addition and sustainable utilization. Despite its abundance and rich nutritional profile, its application remains limited due to challenges such as rapid spoilage and an astringent taste attributed to tannins. Nevertheless, through innovative processing techniques, such as fermentation, cashew apples

can be converted into high-value products, including cashew wine, feni and vinegar, which hold cultural significance and offer economic benefits at the local level. Promoting the effective utilization of cashew apples can support various sectors, including the food and beverage industry, cosmetics, pharmaceuticals and agriculture. The use of these fruits contributes to the reduction of agricultural waste and promotes value-added products enriched with nutritional and functional benefits. Ultimately, the cashew apple exemplifies the untapped potential of underutilized horticultural resources, offering a pathway toward a more sustainable, eco-friendly and circular economy.

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Authors' contributions

TM wrote the first draft of the manuscript and contributed to its initial structure and content development. NR revised the manuscript and provided critical guidance for overall corrections and improvements. MM assisted with literature collection and helped in organizing and formatting references. UD contributed to gathering relevant literature and supported formatting tasks. MP participated in the literature review and assisted in formatting and aligning the manuscript with journal guidelines. All authors contributed to revising the manuscript and approved the final version.

Compliance with ethical standards

Conflict of interest: The authors do not have any conflicts of interest to declare.

Ethical issues: None

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