International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Research Article)

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Formulation of cashew apple-based products for nutrition-centric sustainability

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International Journal of Science and Research Archive, 2024, 12(01), 2169–2178

Publication history: Received on 19 April 2024; revised on 29 May 2024; accepted on 31 May 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.12.1.0958

Abstract

Background: The excess generated by the fruit processing industry, including peels, seeds, and residue, holds significant nutritional and industrial value. These components are rich in essential nutrients like carbohydrates, vitamins, minerals, and beneficial phytochemicals such as phytosterols, carotenoids, polyphenols, and fiber. These nutrients provide various health benefits, including antioxidant, anti-cancer, and anti-inflammatory properties, as well as supporting gut health. Despite being considered a waste, they present an excellent opportunity for food scientists and nutritionists to innovate, creating ways to boost the nutritional content of food products or even develop entirely new food items.

Objective: Therefore, the current research was designed to harness the potential of cashew apples in creating sustainable value-based products.

Material and Methods: Three products viz., squash, jam, and cashew leather were developed with varying percentages of cashew apples (CA) mixed with orange (O) and pineapple (P) fruit. Sensory analysis was done using the descriptive method and the most acceptable product was analysed for moisture, ash, Vit C, iron, and Phosphorus using established protocols.

Results: Moisture content of jam (OJ1 made with CA75% + Orange 25% and fruit leather (FLO2 made with CA 50% + orange 50%) was 30.25% and 7.9% respectively. Ash depicts the inorganic content that is representative of minerals. The ash content of jam (OJ1 made with CA75% + Orange 25%) and fruit leather (FLO2 made with CA 50% + orange 50%) was 3.96 and 1.06%.

Conclusion: Thus, by processing and using by-products of fruit processing into nutritious food products, one can enhance food and nutrition security.

Keywords: Cashew apples; Jam; squash; Fruit leather; Value addition

1. Introduction

Originally from Brazil, the Cashew tree (*Anacardium occidentale* L.) was brought to India in the 16th century by Portuguese sailors. Primarily cultivated for its cashew kernel, the fruit of the cashew tree is known as the cashew apple and is considered a pseudocarp or false fruit. In the cashew apple, essential minerals, vitamins, and sugars are primarily found in the watery matrix, or juice, while the remaining fiber matrix, or pomace, consists of cellulose, hemicellulose, pectin, and protein. Cashew apple is rich in total sugars, including fructose, glucose, and sucrose, they come in distinguished red and yellow colour. Its vitamin C content ranges from 200 to 300 mg per 100 g of pulp, which is significantly higher than that of citrus fruits and pineapple juice. Additionally, cashew apples contain vitamin B2, calcium, phosphorus, and iron. The biochemical composition, including total soluble solids, acidity, phenols, tannins,

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antioxidants, and minerals such as potassium, phosphorus, calcium, magnesium, zinc, and iron, varies among varieties and growing conditions. It is also noted that yellow apples tend to be larger, less firm, and less astringent compared to scarlet or orange apples [1].

Due to factors such as limited understanding of cashew apple's health benefits, insufficient technical expertise, processing facilities, and its highly perishable nature and astringent flavor, the cashew apple, constituting approximately 90% of the total fruit weight, often remains discarded as agricultural waste in farmers' fields [2].

Generation of waste is inevitable from agriculture, horticulture, or food industries - fruits, vegetables, cereals, pulses, millets milling and processing, plants, coffee processing units etc.

However, it provides an excellent opportunity to explore it for further use like extraction of phytochemicals, antioxidants, dietary fibre, food ingredients like pectin, natural colour, vitamins, antibiotics, and proteases apart from ethanol or biogas [3].

Creating upcycled food products either by incorporating the waste or creating new food items with increased nutritional value can be an add on usage to the existing list of uses. This method strives to reduce waste, optimize resource utilization, and establish sustainable practices in the food sector contributing to nutritional security.

Cashew apples do find use as animal feed and in the production of juice, syrup, wine, alcohol, and as a source of dietary fiber extracts [4]. Researchers examined the potential of clarified cashew apple juice as a medium for microbial cultivation. Findings revealed that cashew apple juice is rich in reducing sugars and can support the growth of *Leuconostoc mesenteroides*, facilitating the production of valuable compounds like dextran, lactic acid, mannitol, and oligosaccharides [5].

However, there remains vast scope to further explore its potential in creating newer products by incorporating it in already widely established and acceptable fruit-based products, which can add to ever curious human being's sensorial-gastronomic experience and most importantly paving way for sustainable food and nutritional security. Working in the direction the current study was designed to develop cashew apple-based products and to analyse its sensory acceptability and nutritional value.

2. Material and Methods

2.1. Procurement of raw materials

Three products were developed with cashew apples viz., squash, jam, and cashew leather were developed. The ingredients for the recipes were bought from a local market in Mysore and cashew apples, yellow and red were procured from a local cashew farm.

2.2. Products developed with cashew apple

- **Squash:** Sugar and citric acid were dissolved in water and boiled. Clarified cashew apple juice was then added to the boiling mixture and boiled for an additional 5 minutes. Once cooled, the mixture was strained and carefully poured into sterilized glass bottles, ensuring an airtight seal. These bottles were then stored in a cool, dry place. When ready to serve, the squash could be diluted with three times its volume of cool water, creating a refreshing beverage.

Four variations of the squash were made, OS1 with 75% of cashew apple with 25% of Orange, OS2 with 50% of cashew apple with 50% of Orange, PS1 with 75% of cashew apple with 25% Pineapple and PS2 with 50% of cashew apple with 50% Pineapple.

- **Jam:** The fruit was cleaned, washed, and had its outer skin removed. It was then boiled in salted water for 5 minutes, causing its pulp to turn yellow. After draining and rinsing the boiled fruit, it was placed back on the stove. Using a blender, a paste was made from the fruit. This fruit paste was combined with sugar and lime juice, and the mixture was brought to a boil. Finally, the jam was carefully filled into pre-sterilized glass bottles, ready to be enjoyed.

Four variations of the jam were made, OJ1 with 75% of cashew apple with 25% of Orange, OJ2 with 50% of cashew apple with 50% of Orange, PJ1 with 75% of cashew apple with 25% Pineapple and PJ2 with 50% of cashew apple with 50% Pineapple.

- **Fruit Leather**: The fruit was cleaned, washed, and had its outer skin removed. It was then boiled in salted water for 5 minutes, resulting in the pulp turning yellow. After draining and rinsing, the boiled fruit was returned to the stove. It was blended until smooth, and sugar was added to the mixture. The paste was then boiled in a pan before being spread onto an oiled plate. This mixture was left to dry in the sun for 2 to 3 days, allowing it to solidify into a delicious fruit snack.

Four variations of the jam were made, FLO1 with 75% of cashew apple with 25% of Orange, FLO2 with 50% of cashew apple with 50% of Orange, FLP1 with 75% of cashew apple with 25% Pineapple and FLP2 with 50% of cashew apple with 50% Pineapple.

2.3. Sensory analysis

Sensory analysis was done using the descriptive method which is a systematic approach to evaluate and quantify sensory attributes of food products. 50 panelists assessed the various sensory characteristics, such as appearance, aroma, flavor, texture, and overall quality, using standardized terminology and scales [6].

2.4. Nutrient analysis

The developed products were subjected to proximate analysis viz., moisture, ash (AOAC methods). Iron was analysed using Wong's method, phosphorus using a variation of the phosphomolybdate method and Vit C using titrimetric method involving 2,6-dichlorophenolindophenol (DCPIP) dye.

2.5. Vitamin C Estimation

Vitamin C was estimated using a titrimetric method involving 2,6-dichlorophenolindophenol (DCPIP) dye. A standard ascorbic acid solution (1 mg/mL) was made by dissolving 100 mg of ascorbic acid in 100 mL of distilled water. 0.001 M DCPIP solution was made and standardized against the ascorbic acid solution. 0.4% oxalic acid solution was made by dissolving 0.4 g of oxalic acid in 100 mL of distilled water and a 5% metaphosphoric acid solution by dissolving 5 g in 100 mL of distilled water. The metaphosphoric acid helps stabilize the ascorbic acid in the sample. For the titration, the sample was mixed with an equal volume of metaphosphoric acid to which 5 mL of the oxalic acid solution was added. This mixture was titrated with the standardized DCPIP solution until a persistent pink color appeared, indicating the endpoint. The volume of DCPIP used was recorded and compared with the volume used for the standard ascorbic acid solution. The concentration of vitamin C in the sample is then calculated using the ratio of the volumes of DCPIP used for the sample and the standard solution. This method ensures accurate determination of vitamin C content by preventing its oxidation and using the redox reaction between ascorbic acid and DCPIP [7].

2.6. Iron estimation by Wong's method

This method provides a reliable means to determine iron content based on the intensity of the red color developed upon reaction between ferric ions with potassium thiocyanate, offering a quantitative assessment of iron content in the sample.

A series of steps were undertaken to quantify the iron content in the sample. Initially, 1ml to 5ml aliquots of a standard solution containing $FeCl_3.6H_2O$ were pipetted into multiple test tubes. Subsequently, the volume in each test tube was adjusted to 5ml by adding distilled water. Following this, 30% sulfuric acid was introduced into all test tubes, bringing the total volume to 6ml. Then, 1ml of potassium persulfate solution was added to initiate the reaction. In the final step, 1.5ml of potassium thiocyanate solution was uniformly added to each test tube, and the mixture was allowed to incubate for 20 minutes at room temperature. The intensity of the resulting red coloration, indicative of the iron concentration, was measured spectrophotometrically at 540nm against a blank [8].

2.7. Phosphorus estimation

A modification of the phosphomolybdate method was used to estimate phosphorus from the samples.

A phosphorus working standard (Potassium dihydrogen phosphate in water plus 10N sulphuric acid) solution is treated with ammonium molybdate reagent, hydroquinone, and sodium sulphate. First, 1 mL of ammonium molybdate reagent, containing ammonium molybdate and sulfuric acid, is added to an aliquot of the standard solution. Following this, 1 mL of hydroquinone solution, serving as a reducing agent, and 1 mL of sodium sulphate solution are introduced. The mixture is thoroughly mixed and then allowed to incubate for 30 minutes. During this incubation, phosphorus reacts with the ammonium molybdate reagent, forming a yellow phosphomolybdate complex. After incubation, the optical density of the solution is measured at 660 nm using a spectrophotometer. The intensity of the blue color produced is directly proportional to the phosphorus concentration, allowing for its quantification by comparison with a standard curve [9].

2.8. Statistical Method

Descriptive statistical methods, like standard deviation and percentage, were used to analyse the data. Percentages were used to understand the relative proportions of the nutrients analysed, offering a clear picture of the variable distribution within the sample. Standard deviation assessed the variability of data points around the mean. Bar and radar charts were used to depict the analysed data.

3. Results and discussion

Cashew is native of Brazil and was introduced to India in the 16th century by the Portuguese travelers on the west coast of the country. Mainly grown for it nuts, the pseudo fruit termed cashew apple is mostly wasted despite being rich in nutrients and phytochemicals. Seeing an opportunity to utilise it in making nutritionally viable products, three fruit-based products viz squash, jam and fruit leather in combination with varying percentage of orange and pineapple were developed.

3.1. Nutrient analysis of red and yellow types of cashew apple

To develop the products, two types of cashew apples, yellow and red, were initially analysed for moisture, ash, Vit C, iron, and phosphorus content (Fig 1). Yellow cashew fruit was used to make products due to its higher nutritional profile. Yellow fruit had 86.75±0.21% moisture content compared to red with 84.85±0.35% moisture. Ash was found to be 3.35±0.35 % and 3.05±0.21 in red and yellow fruits respectively. Vitamin C, iron, and phosphorus content was 105±1.14 mg/100ml which was higher than yellow fruit which had 96.1±0.14 of Vit C/100ml. However, yellow fruit had more of Fe and P, 27.5±2.12 and 74.25±3.18 mg/100g compared to 23±4.24 and 63.7±1.84 mg/100g in red fruits. The products, squash, jam and fruit leather developed thereof were subjected to descriptive sensory analysis fig 2 to 4.

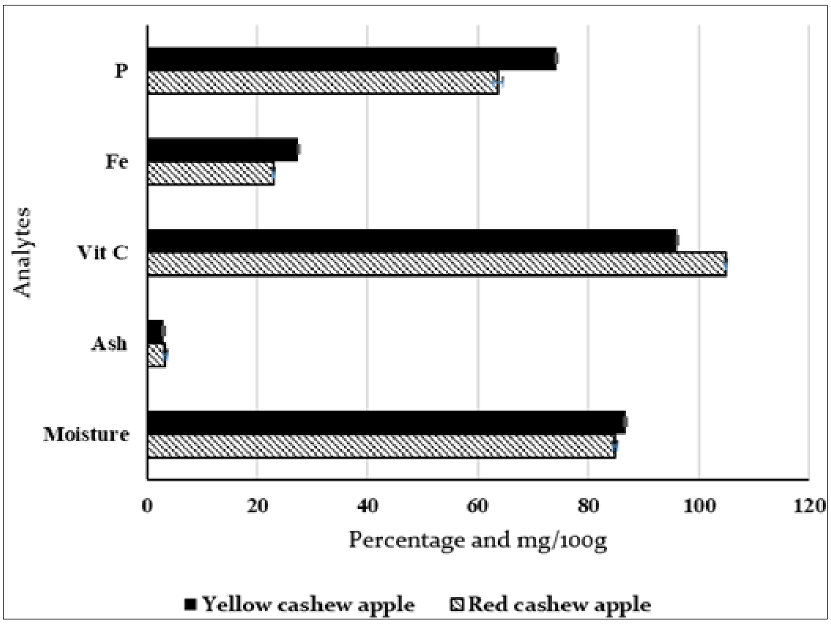

Figure 1 Moisture (%), ash (%) and nutrient content of the two types of cashew apples, red and yellow (mg/a00g)

3.2. Sensory evaluation of developed products

Squash fruit concentrates are typically created by incorporating sugar, and they are commonly diluted with water when consumed as juice or used as flavourings in different food and drink items. Squash made with equal percentages of orange juice (OS2) and pineapple juice (PS2) with cashew apple juice were most acceptable, this could be attributed to the strong astringent taste of cashew apple which got mellowed down due to the flavour of orange and pineapple.

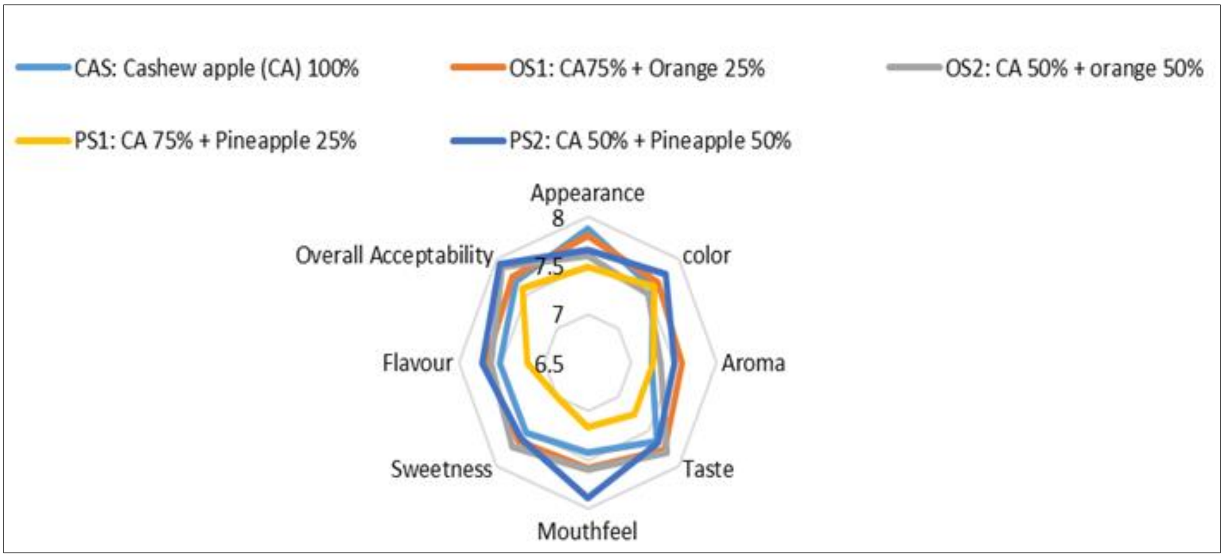

Figure 2 Mean sensory scores of squashes developed with cashew apple

Jam was the second product made with varying proportions of cashew apples, orange, and pineapple. Jams are a type of fruit spread typically made with fruit, pectin, acid, and sugar that have a spreadable consistency and are used on bread, toast, or pastries [10]. Examining the sensory analysis captured in the radar charts shows how different formulations impact sensory perceptions, as variations in shape or distribution across the axes signify differences in sensory profiles (Fig 3). Jam made with 75% of Cashew apple and 25% orange (OJ1) was more acceptable with an overall acceptability score of 7.6. Similarly, Jam made with 75% of Cashew apple and 25% (PJ1) pineapple was most acceptable with an overall acceptability score of 8.1.

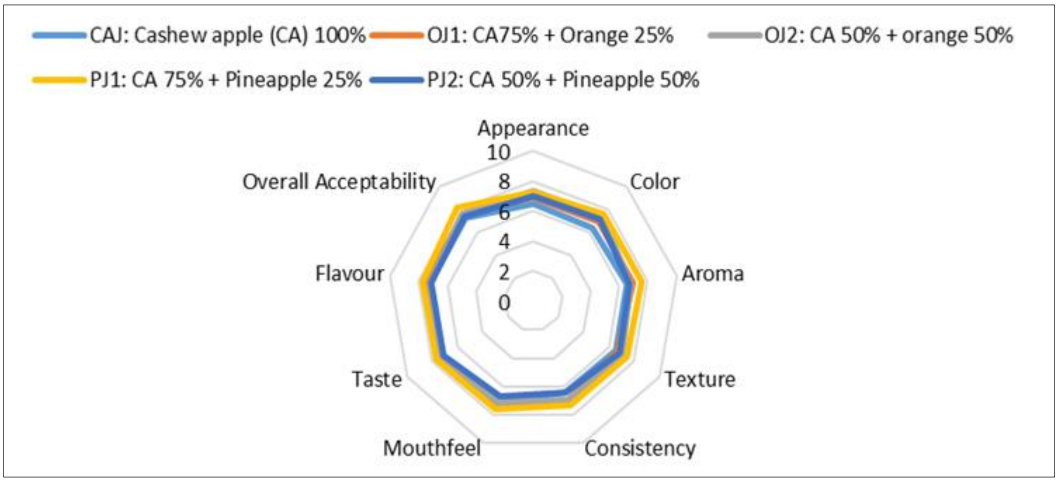

Figure 3 Mean sensory scores of jams developed with cashew apple

The third product developed with cashew apple and varying percentages of orange and pineapple was fruit leather which is a type of snack made from pureed fruit that has been dried into a flexible, chewy sheet. It is sometimes called fruit roll-up, fruit jerky, fruit bar or a fruit slab [11]. Cashew fruit leather, FLO2, made with 50% cashew apple and 50% orange got a score of 6.62 on overall acceptability and FLP2 made with similar percentages i.e., 50% cashew apple and 50% pineapple scored an overall acceptability score of 7.22. It's interesting to observe that products containing higher proportions of orange and pineapple received higher scores. This phenomenon can likely be attributed to their ability to mitigate the astringent flavor of cashew apples (fig 4).

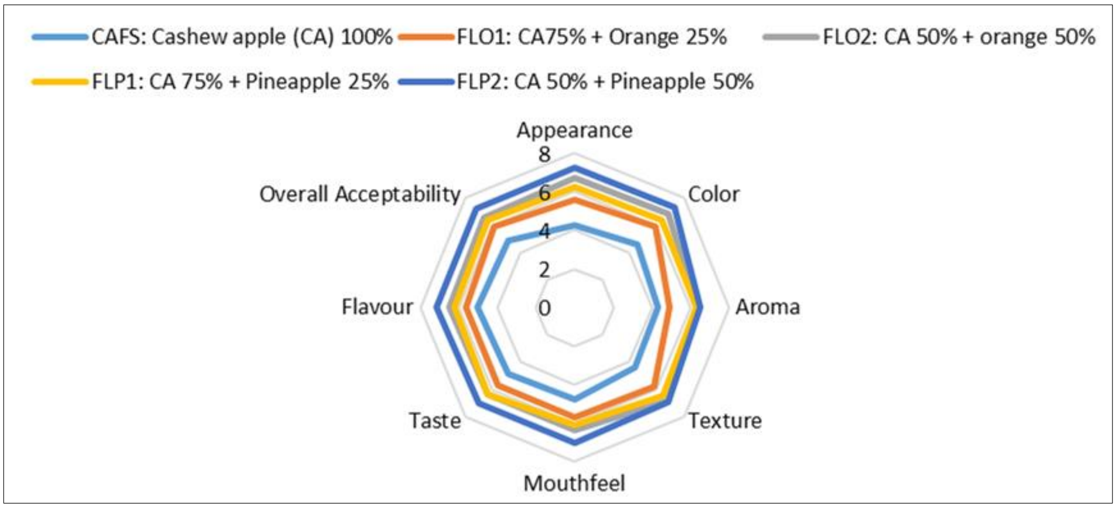

Figure 4 Mean sensory scores of fruit leather developed with cashew apple

A research-based skill development training program was implemented in the tribal areas of Vizianagaram district, Telangana, India, aimed at enhancing awareness and promoting greater consumption of cashew apple. Syrup, squash, juice, jam, pickle, and candy were produced and underwent sensory evaluation. Squash and juice garnered the highest acceptance score of 5, attributed to their favorable attributes such as color, taste, odor, and ease of preparation. Conversely, jam and candy scored between 3 and 4 due to the complexities involved in their preparation and the limited availability of materials at home. Encouraged by the positive feedback, participants initiated the production of these products at the household level and showed interest in establishing a cottage industry. Notably, syrup squash juice was particularly well-received for household consumption by farmers, whereas jam, pickle, and candy required more intensive processing efforts [12].

A similar research project focused on creating a new jam product from cashew apple bagasse generated during juice manufacturing, involved adding cashew apple juice in three different proportions (5%, 10%, and 15%) to develop various jam types, which were then subjected to sensory evaluation. Results indicated that the jam with 5% cashew apple juice content received favourable ratings across all sensory aspects, suggesting its superior quality compared to the other formulations. This finding underscores the potential for utilizing cashew by-products effectively in food production while optimizing sensory appeal. Moreover, the study explored the transfer of this technology to local communities, potentially benefiting both the environment and socioeconomic development [13].

3.3. Analysis of nutrient composition of best accepted products

Analysing the nutritional content of a food product alongside sensory evaluation is crucial as it provides insights into its acceptability, impact on health, and potential role in disease prevention. This comprehensive approach empowers consumers to make informed choices based on the nutritional value of foods, thus aligning the choice with their health goals. The cashew apple is rich in various beneficial nutrients such as vitamin C, fructose, sucrose, fibers, flavonoids particularly including myricetin and quercetin, carotenoids, polyphenols, volatile compounds, flavanols, amino acids, and minerals like potassium, magnesium, sodium, and iron. These components contribute to scavenging free radicals, supporting neuropathic and cardiac functions [2].

Among the developed products the most acceptable products were only analysed for moisture, ash, Vit C, iron, and phosphorus. The results are captured in fig 5-6. Moisture is an important determinant of shelf life of a food product, higher the moisture content and water activity, higher the chances of spoilage. One of the main reasons for cashew apples being wasted is its high moisture content that makes incurs higher storage costs. Moisture content of jam (OJ1 made with CA75% + Orange 25% and fruit leather (FLO_2 made with CA 50% + orange 50%) was 30.25% and 7.9% respectively. Ash depicts the inorganic content that is representative of minerals. The Ash content of jam (OJ1 made with CA75% + Orange 25%) and fruit leather (FLO_2 made with CA 50% + orange 50%) was 3.96 and 1.06%.

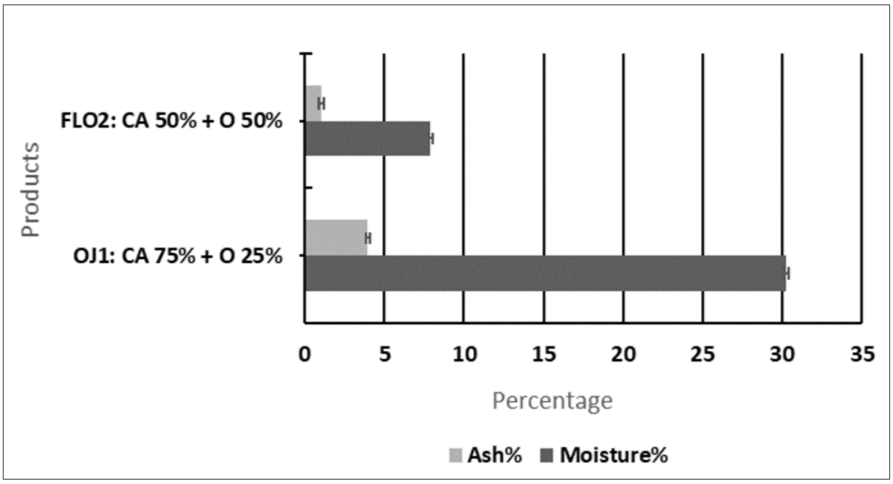

Figure 5 Moisture and ash content of products developed with cashew apple

Products made with different percentages of orange scored better than made with pineapple therefore were analysed for the said components. Vit C in all the products analysed viz., OS2, OJ1 and FLO2 showed a drastic decrease in Vit C content. It was found to be 2.1, 5.7 and 6.5 mg/100g. Vitamin C, also known as ascorbic acid, is a water-soluble vitamin essential for numerous bodily functions, including collagen synthesis, wound healing, and the production of L-carnitine. It also acts as a potent antioxidant. Additionally, Vitamin C is critical for the absorption of non-heme iron from plant-based foods, thereby enhancing its bioavailability. However, it is quite susceptible to processing methods, which significantly reduce its quantity and its degradation can be influenced by various factors temperature, oxygen exposure, light exposure, processing techniques, storage conditions, pH, as well as the presence of enzymes, oxygen, and metallic catalysts [14].

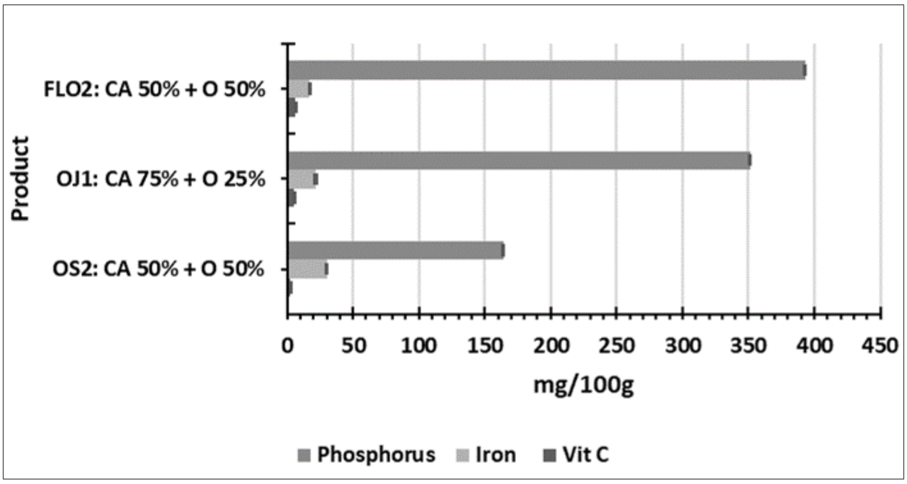

Figure 6 Micronutrients composition of products developed with cashew apple

In a study conducted in Campinas, Brazil, cashew apple products available in the market were examined for their carotenoid and ascorbic acid (AA) content using high-performance liquid chromatography (HPLC) and the official method established by the Association of Official Analytical Chemists (AOAC), respectively. The analysed products included concentrated juice, frozen pulp, nectar, ready-to-drink, and sweetened concentrated juice. Results indicated that AA levels ranged from 13.7 to 121.7 mg/100 g, while total carotenoid levels varied between 8.2 and 197.8 μg/100 g. β-Carotene emerged as the predominant carotenoid in most products, followed by α-carotene, β-cryptoxanthin, and 9-cis- +13-cis-β-carotene in comparable proportions. While cashew apple products were identified as rich sources of vitamin C, their contribution to carotenoids in the human diet was found to be relatively limited [15].

Iron content OS2 (Cashew apple 50% + orange 50%, squash), OJ1 (Cashew apple 75% + Orange 25%, jam), FLO2 (Cashew apple 50% + orange 50%, fruit leather) was 30, 22 and 17mg/100g respectively. Iron is an essential dietary mineral needed for haemoglobin formation and the form majorly present in plant sources is non-heme iron which is less bioavailable compared to animal food-based heme iron. Iron is quite stable to cooking temperatures used but absorption is hindered by presence of antinutritional factors like phytates, polyphenols and higher concentrations of calcium. However, vitamin C, an unidentified factor in meat known as the meat–fish–poultry factor, and organic acids like citric acid, as well as fermented foods, tend to enhance its bioavailability [16].

A study subjected both whole cashew apple juice and cashew apple fiber to simulated in vitro gastrointestinal digestion which involved subjecting samples before and after digestion to assess their levels of copper, iron, zinc, ascorbic acid, total extractable phenols, and total antioxidant activity. The findings indicated that in whole cashew apple juice, the bioaccessible fractions of copper and iron were 15% and 11.5%, respectively, while zinc was 3.7%. In contrast, the bioaccessible fractions for these minerals in cashew apple fiber were below 5%. For whole cashew apple juice, the bioaccessible fractions for ascorbic acid, total extractable polyphenols, and total antioxidant activity were 26.2%, 39%, and 27%, respectively. However, cashew apple fiber exhibited low bioaccessible levels for these components. Overall, the bioaccessible percentages of zinc, ascorbic acid, and total extractable polyphenols were higher in cashew apple juice compared to cashew apple fiber [17].

Phosphorus was found to be 164, 351 and 393 mg/100g in OS2 (Cashew apple 50% + orange 50%, squash), OJ1 (Cashew apple 75% + Orange 25%, jam), FLO2 (Cashew apple 50% + orange 50%, fruit leather) respectively. Phosphorus is essential for bone, teeth, DNA, and RNA formation. It's also found in phospholipids, which contribute to cell membrane structure, and in adenosine triphosphate (ATP), the body's primary energy source. Phosphorus is present in various foods, primarily as phosphates and phosphate esters. However, in seeds and unleavened breads, it exists in the form of phytic acid, serving as a storage form of phosphorus [18, 19].

A study compared the proximate and phytonutrient composition of cashew nuts and apples from various regions of Burkina Faso. The trace elements measured included Mg, Cu, Mn, Fe, Zn, K, Na, Ca, P, and Cl. Both parts of the cashew fruits grown in Burkina Faso were found to be very rich in potassium, with contents reaching 650 mg/100 g DW, exceeding the global average of 622 mg/100 g DW. Following potassium, sodium was the most abundant mineral in cashew nuts, followed by phosphorus, chlorine, magnesium, iron, and calcium. Cashew apples, besides potassium, contained significant amounts of phosphorus, magnesium, iron, and sodium. Copper, zinc, and manganese were present in trace amounts in both nuts and apples [20].

A study analyzed five cashew apple varieties for their vitamin C, carotenoids, total sugar, total phenolic content (TPC), minerals, pH, total soluble solids (TSS), and total titratable acidity (TTA) using standard methods. Significant differences were found in vitamin C, total sugar, TPC, TSS, and TTA among the varieties and sites. Mineral content (Ca2+, K+, Mg2+, Na+, $P3^{-}$, Fe2+, Zn2+, and Cu2+) varied significantly among both varieties and sites except for calcium, magnesium, and sodium. These findings highlighted the nutritional potential of locally available cashew apples for enhancing food and nutrition security [21].

Apart from the nutrient profile cashew apples can also be explored and used for its rich phytochemicals which have health benefits. Phytochemical screening and assessment of biochemical characteristics and antioxidant indices were conducted on juice from red and yellow varieties of domestically grown cashew apples in Western Nigeria. The assessment identified therapeutic phytochemicals, including total phenolics, flavonoids, tannins, and anthraquinones [22].

The findings of a study examining the mutagenicity, antioxidant potential, and antimutagenic activity against hydrogen peroxide of cashew apple juice (CAJ) and cajuina indicated that both CAJ and cajuina exhibited mutagenic, radical trapping, antimutagenic, and comutagenic properties, likely due to their chemical composition. These properties were connected to the antioxidant activity of the juices, as shown by a total radical-trapping potential assay [23].

Thus, cashew apples hold significant potential for utilization both domestically and commercially to create nutrient-dense products. Their rich content of vitamins, minerals, and antioxidants makes them an excellent candidate for health supplements, beverages, and functional foods. Additionally, the presence of therapeutic phytochemicals such as phenolics, flavonoids, tannins, and anthraquinones further enhances their value. By tapping into these benefits, cashew apples can contribute to improved nutritional intake and overall health maintenance, offering a versatile ingredient for a variety of innovative food products and can be a potential candidate for skill development training programs in rural areas or women self-help groups.

4. Conclusion

Cashew tree cultivation primarily focuses on producing cashew nuts, leaving substantial quantities of cashew apples as agricultural waste. Transforming this waste into value-added products offers a promising solution. With global demand for cashews rising, due to their wide usage as a snack, in making sweets, nut butter and in various cuisines, there is considerable potential to utilize cashew by-products, especially cashew apples effectively. By processing and reusing these by-products into innovative, nutritious food products, one can enhance environmental sustainability and economic viability, while also contributing to food and nutritional security.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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