Received: 8 June 2022 | Revised: 20 September 2022 | Accepted: 3 February 2023

DOI: 10.1002/jsf2.107

REVIEW

JSFA Reports

Nutritional value and health benefits of cashew apple

Yaw Gyau Akyereko[1,2] | Georgina Benewaa Yeboah[3] | Faustina Dufie Wireko-Manu[1] | Francis Alemawor[1] | F. C. Mills-Robertson[4] | William Odoom[2]

[1]Department of Food Science and Technology, Faculty of Biosciences, KNUST, Kumasi, Ghana

[2]Department of Food and Post-harvest Technology, Faculty of Applied Science and Technology, KTU, Koforidua, Ghana

[3]School of Food and Biological Engineering, Jiangsu University, Zhenjiang, Jiangsu, China

[4]Department of Biochemistry, Faculty of Biosciences, KNUST, Kumasi, Ghana

Correspondence
Yaw Gyau Akyereko, Department of Food Science and Technology, Faculty of Biosciences, KNUST, Kumasi, Ghana.
Email: akyereko.edu@gmail.com

Abstract

Cashew (*Anacardium occidentale*) has received both local and international recognition due to its expanding production capacity, trading, and nut utilization. The cashew apple, which forms about 90% of the total fruit weight, is left on the farmers' fields as agricultural waste owing to limited knowledge of its health benefits, a lack of technical know-how and processing equipment, and its high perishability and astringent taste. Numerous studies have been conducted exploring the nutrients and contribution of the apple to human nutrition. This paper reviewed recent articles on the nutritional composition and health benefits of cashew apples for easy accessibility and readership. Cashew apple contains good amounts of vitamin C, sugars (fructose and sucrose), fibers, flavonoids, carotenoids, total polyphenols, volatile components, flavanols, amino acids, and minerals, such as potassium, magnesium, sodium, and iron, which are good for maintaining strong immunity, scavenging free radicals, neuropathic functioning, cardiac functioning, and maintenance of body and skin integrity. Cashew apple is associated with weight loss, and is good for diabetic patients due to its high content of flavonoids (myricetin and quercetin). Consumption of cashew apple and its value-added products confer good health, therapeutic effects in the management of diabetics and cardiovascular diseases, and also ensure food and nutrition security. It is hoped that this review will contribute significantly to the expanding body of knowledge aimed at promoting cashew apple utilization globally.

KEYWORDS
amino acids, cashew apple, health benefits, minerals, phytochemicals, vitamins

INTRODUCTION

Cashew (*Anacardium occidentale*) is a crop of afforestation and soil conservation,[1] belonging to the family *Anacardiaceae*[2] and genus *Anacardium*.[1] Cashew is a native of Brazil and finds maximum cultivation in North and Northeast regions of Brazil.[3] It is now grown as a cash crop in some West African countries, including Ghana.[4,5] According to International Nuts and Dried Fruits Council (INDFC) report,[6] world cashew nut production currently stands at 3.8 million MT, and Ghana produces about 170,000 MT of raw nuts and 1,530,000 MT of cashew apples which currently are of low economic value and thus, a majority goes to waste.

The cashew fruit consists of the cashew nut (the true fruit) and the cashew apple (pseudo fruit), as shown in Figure 1, and has excellent nutritional and sensory properties.[7,8] It is very juicy, sweet, spongy, and nutritious compared with many other tropical fruits.[1] The apple has found utilization in the development of value-added products like cashew apple juice, jam, drinks, wine, "feni," candy, syrup, canned fruits, prickles, animal feed, flour, and dietary fiber substitute in food systems in some developed countries.[9–11] Studies,[1,12]

FIGURE 1 Parts of the cashew fruit.

however, have revealed that about 90%–95% of cashew apples go waste due to limited knowledge about their health benefits, high perishability, lack of appropriate harvesting techniques, high cost of processing equipment, lack of government support, poor post-harvest management, and non-adoption of processing technologies.

It is against this background that this work aimed to review recent articles on the nutrient composition and health benefits associated with the consumption of cashew apples and thus promote their utilization and maximize their contribution to food security. The review also unraveled areas that needed further research and offered opportunities for investors.

NUTRITIONAL COMPOSITION OF CASHEW APPLE

With recent upsurges in non-communicable diseases and food insecurities, interest in healthier and safer foods is increasing. The health concerns of the populace, with reference to what they consume, have sparked up studies into nutritious foods. Fruits are known to be rich sources of minerals, phytochemicals, and fibers that can help mitigate the prevalence of non-communicable diseases (NCDs), promote healthy living as well as ensuring food security. Cashew apple contains good amounts of vitamin C, sugars (fructose and sucrose), fibers, flavonoids, carotenoids, total polyphenols, volatile components, flavanols, amino acids and minerals such as potassium, and has currently been given much attention.[1,7,8,13] Table 1 presents the major biological molecules or elemental components found in cashew apples.

The cashew apple is highly acidic with a pH value of 3.5–4.8[7,13,14] and contains about 85% moisture, which contributes largely to its high perishability,[7,12] which occurs usually a day or two after harvesting of the nuts. The cashew apple can therefore serve as a good food source with potential utilization in refreshing drinks, smoothies, and juices.

The fruit is rich in carbohydrates, mainly reducing sugars (glucose and fructose),[14–16] that are readily absorbed by the body. The reducing sugar content of cashew apples on a wet basis is 10.5%.[7,14,17] This makes it a good calorific option for use in fruit juices or meals for children and the elderly as a source of energy, if the astringency is minimized. Its utilization in energy booster drinks for sportsmen will be a groundbreaking intervention in the food and beverage industry.

TABLE 1 Chemical composition of cashew apples.

Component (mg/100 mL)	Yellow variety	Red variety
Vitamin C	241.13	221.6
Total polyphenols	265.97	271.03
Anthocyanins	210.67	225.85
Potassium	36.10	43.61
Magnesium	4.13	1.22
Calcium	1.20	6.01
Sodium	2.18	2.34
Iron	0.37	0.35
Phosphorus	2.15	2.21
Sulfur	0.45	0.46
Manganese	0.20	0.03
Ash (%)	1.4	
Crude fiber (%)	3.59	
Total sugars (%)	10.57	2.37
Proteins (%)	1.13	1.09
Lipids (%)	2.25	2.99

Source: References 1,7,14,27,30.

Cashew apple contains protein (0.5–1.09%) although in very minute quantities as established by Singh et al.[7] On a dry matter basis, the cashew apple was found to contain 61.21% of dietary fiber, of which 13.25% are soluble and 47.96% are insoluble, with appreciable potassium, phosphorus, sodium, magnesium, calcium, copper, zinc, iron, and phenolic contents.[13,18–21] The cashew fiber is being used as a fat replacer in burgers,[22,23] in cereal-based extrudates[21] and cookies[24] to increase fiber content and nutritional value. Thus, the use of this natural source of fiber from the cashew apple may confer health benefits to humans; however, studies have shown that the phytic acid and insoluble fiber content of the cashew apple might limit the bioaccessibility of the nutrient contents.[18,25] An in vitro digestion of cashew apple juice and its fiber (pulp) showed that the juice is highly

TABLE 2 Amino acid content of cashew apple pulp.

Amino acid (mg/100 g)	Yellow variety	Red variety
Leucine	2.79	3.11
Tyrosine	1.11	1.27
Glycine	1.83	2.09
Alanine	1.99	2.28
Lysine	1.84	2.22
Serine	1.79	1.52
Threonine	1.41	1.93
Valine	2.20	2.61
Isoleucine	1.65	1.97
Cysteine	0.40	0.60
Methionine	0.49	0.63
Proline	2.24	2.65
Aspartic acid	3.32	3.97
Lysine	1.84	2.22
Arginine	1.47	1.90
Histidine	0.76	1.04
Phenylalanine	1.87	1.94
Glutamic acid	3.64	4.24

Source: Reference 33.

bio-accessible than the fiber, even though the raw, undigested fiber had a higher copper content (12.20 mg/L) than the juice (2.10 mg/L). The bioaccessibility was attributed to the phytic acid (0.25%) present in the fiber (peels and insoluble fiber).[18] The ash content of the cashew apple (1–1.5%) is an indication of its high mineral content.[7,14]

Cashew apple is a very rich source of vitamin C compared to most tropical fruits. The content of vitamin C (between 200–241 mg/100 g) in the cashew apple is about 3–5 times higher than citrus.[26] Studies have revealed that the vitamin C content (241.13 mg/100 g) of the yellow cashew apple is generally higher than that (221.60 mg/100 g) of the red variety, while the latter has more amino acids and tannins than the former.[16,25,27,28] The juice is a good source of vitamin C but not so with provitamin A.[29] Thus, the cashew apple can be utilized as a source of Vitamin C in Africa, especially in Ghana, where the fruit is underutilized and usually left to rot. Cashew apple also has substantial quantities of B vitamins (thiamine, niacin, riboflavin, pantothenic acid, pyridoxine, and folate).[19,30] The apple juice is a rich source of minerals and is high in potassium, magnesium, phosphorus; but low in sodium, calcium, iron, copper with the least being zinc.[14,19,31] The high mineral (potassium, magnesium, and phosphorus) content could be a good food source for incorporation into the DASH diet in the management of hypertension.

Studies have shown that cashew apples contain a significant amount of amino acids such as alanine, aspartic acid, glutamic acid, serine, threonine, phenylalanine, leucine, tyrosine, proline, and gamma-aminobutyric acid (GABA) (Table 2), which have many physiological functions in the human body.[16,32,33] Findings from[16,31] indicated that leucine was the most abundant amino acid in the cashew apple juice. Nonetheless, Okpanachi et al.[33] found that glutamic acid and aspartic acid were the most abundant amino acids in the cashew apple. These variations might have resulted from the effects of processing and the type of cashew cultivar.

With respect to bioactive compounds, the cashew apple is a significant source of polyphenols and other organic acids like flavonoids, carotenoids, anacardic acid, and tannins.[7,14,34] Carotenoids are the natural (red, orange, and yellow) pigments in plants, algae, and microorganisms,[35] which play key roles in physiological and developmental functions in plants, animal health, and nutrition. Cashew apple contains about 2.9–136 mg/100 g carotenoids,[17,20,36–39] mainly composed of cryptoxanthin, zeaxanthin, lutein, β-carotene, and α-carotene.[40] Although various carotenoids are present in the fruit, the major ones in the juice are the β-cryptoxanthin and β-carotene. The amount of carotenoids in a cashew apple is dependent on the type; the red variety has a higher concentration than the yellow ones.[29] Again, it has been reported that carotenoids and anthocyanins content reduces with storage and processing.[41] Irrespective of the fruit color, the total carotenoid content of the juice is lower compared to the fiber (cashew apple pulp).[14,29] The fiber is rich in carotenoids, mainly because the pigments are embedded in the tissues, but poor in vitamin C, which is water soluble.[18] It has been reported that the cashew apple has higher carotenoid content than the aqueous extracts.[17,37–40] Thus, consuming the apple is good enough to have a balance of all the nutrients.

Polyphenolic compounds, such as flavonoids (anthocyanins, myricetin, quercetin, Kaempferol) tannins, and phenolic acids (caffeic acid, coumaric acid, ferulic acid, and gallic acid) are prominent constituents of cashew apple (Table 3). Tannins are polyphenols that have been classified as anti-nutrient due to their negative effect on nutrients absorption and bioavailability.[42] They are classified as hydrolysable and condensed tannins (also known as proanthocyanidins). Apart from its negative effects, tannins have been shown to exhibit antioxidant, anti-tumor, anti-inflammatory, anthelmintic and antimicrobial properties.[43,44] Tannins also contribute to the astringent taste of cashew apples, one of the key reasons for its low utilization.[12,45,46] Tannins range between 0.01 and 197 mg/100 mL in cashew apples, depending on the processing, cultivar, and type (red, yellow, or other variants).[14,47] Hydrolysable tannins were found to be present in higher concentrations in cashew apples and correlated with astringency compared to condensed tannins.[48] Methods such as blanching, addition of gelatin, fermentation, removal of fruit skin, addition of tannase, hydrothermal processing, centrifugation and microfiltration, and natural coagulants (such as okra pod) have been identified as effective ways of reducing the tannin content to appreciable levels.[45,49–53]

Other organic acids like citric, malic, and acetic acid that mediate a lot of physiological functions are also in abundance in the cashew apple.[16] The variations in the nutritional composition of the cashew apple are influenced by variety, soil quality, environmental conditions (climate), agronomic practices, maturity stage of the fruits, and processing conditions.[14,47] The various phenolic or bioactive compounds in cashew apples are summarized in Table 3.

TABLE 3 Phenolic compounds in cashew apples.

Compound	Concentration (mg/L)	Compound	Concentration (mg/100 g)	Compound	Concentration (mg/g)
Caffeic acid	20.2–25.9	Epigallocatechin	0.02–0.11	Myricetin 3-O-galactoside	0.05
p-coumaric acid	2.5–7.9	Myricetin 3-O-rhamnoside	0.86–0.91	Myrecetin 3-O-glycoside	0.027
Ferulic acid	4.6–13.4	Quercetin 3-O-galactoside	0.83–0.99	Myricetin 3-O-xylopyranoside	0.0124
Gallic acid	1.9–15.4	Quercetin 3-O-glucoside	0.31–0.44	Myricetin 3-O- arabinopyrannoside	0.0104
Naringenin	4.3–10.3	Quercetin pentoside-1	0.42–0.45	Myricetin 3-O-arabinofuranoside	0.0097
Quercetin	1.2–7.9	Quercetin pentoside-2	0.36–0.40	Myricetin 3-O- rhamnoside	0.04
		Quercetin 3-O-arabinoside	0.37–0.38	Total myricetin glycosides	0.1511
		Quercetin 3-O-rhamnoside	0.65–0.69	5-Methylcyanidin 3-O-hexoside	0.0197
		Quercetin 3-O-xylopyranoside	1.16	Total glycosylated flavonoids	0.2847
		Quercetin 3-O- arabinopyrannoside	1.08	Total quercetin glycosides	0.1139
		Quercetin 3-O- arabinofuranoside	0.79		
		Oleic acid	21.87		
		Linoleic acid	5.55		

Source: References 32,34,57,89.

HEALTH BENEFITS OF CASHEW APPLE

The nutritious nature and high polyphenolic content have various implications for the use of the cashew apple in maintaining and promoting health. The significant amount of essential minerals found in cashew apples make them a good choice for maintaining strong immunity, promoting proper fluid balance, nerve transmission and muscle contraction, and also for the management of micronutrient deficiencies.[1,27] The high mineral content can aid bones, cardiovascular health, and assist in metabolism, and bioactive pathways.

Due to its high caloric content and amount of reducing sugars, the cashew fruit is and can be used as an instant energy booster. A cohort study[54] discovered that cashew apple juice enhanced fat oxidation and proposed that it might increase endurance during exercise. The high vitamin C content of the fresh juice promotes its usage in treating sore throat, maintaining good gum/oral health, serving as cofactors for enzyme and bioactive compounds activity, and as an antioxidant.[9,10,47]

The fruit has various traditional and medicinal uses,[34] due to its rich phytochemical profile. Thus, the cashew fruit has the potential to be used as a nutraceutical and pharmaceutical ingredient. Traditionally, cashew juice is used for the treatment of sore throats, colds, and coughs, and gastric disorders, including diarrhea, dysentery, and ulcer.[36,55] Pharmacological studies have demonstrated the ability of the anacardic acids in the fruit to protect against ulcers by inhibiting the growth of *Helicobacter pylori*.[45,56] Hence, the cashew apple is gastro protective.[36] The significant amounts of polyphenolic compounds in the apple make it an excellent source of natural antioxidants, such as anthocyanins, flavonoids, flavones, carotenoids, gallic acid, protocatechuic acid, conjugate cinnamic acid, and free cinnamic acid.[34,57] These compounds are very prominent in scavenging reactive oxygen species (ROS) and inhibiting free radical formation, thus preventing cardiovascular diseases and damage to cellular components.[58] Pascal et al.[13] also demonstrated the anti-radical scavenging activity of the cashew apple. Cashew apple is classified as a functional food ingredient due to its high carotenoid content, which is very potent in maintaining good health and acting as antioxidant.[36]

Phytochemicals like flavonoids, tannins, and other acids have been found to contribute significantly to the anti-inflammatory, anti-microbial, and wound-healing properties of human cells upon consumption of cashew apples.[34,36,55] The presence of bioactive compounds and polyphenols inhibits microbial growth and activity, as the cashew apple proved effective against the growth of *Streptococcus spp*., *Micrococcus luteus*, *Salmonella typhimurium*, *Entrococcus faecalis*, *Streptococcus spp*., *and Bacillus cereus*.[37,59,60] A similar study in Cote D'Ivoire[61] also revealed the inhibitory potential of apple juice against *Staphylococcus aureus*. The anti-tumor properties of cashew apple have also been confirmed using mice models.[62] Studies have indicated that phenolic compounds like anacardic acid and gallic acid have a cytotoxic effect and inhibit the proliferation of cancer cells.[34,36] However, the cashew apple extract from the residue had no effect on human tumor and non-cancerous cell lines.[37]

Studies have also reported the lowering effect of consumption of meals rich in flavonoids (myricetin and quercetin) on the risk of developing type 2 diabetes, obesity, and insulin insensitivity in mice fed with a high-fat and high-sucrose diet.[63,64] Beejmohun et al.[65] demonstrated the effectiveness of the cashew apple in the management of obesity and diabetes through the use of obese experimental mice. The study revealed that cashew apple extracts, which are rich in derivatives of myricetin and quercetin, inhibited the accumulation of fat and insulin resistance in obese mice. The study also established the reductive effect of cashew apples on body weight gain, fat storage, hyperglycemia, hyperinsulinemia, and insulin resistance in the obese mice. Rani et al.[66] studied the anti-obesogenic effect of cashew extracts on the lipid profile of mice and discovered a considerable reduction in total cholesterol, triglycerides, and low density lipoprotein (LDL) cholesterol with an increase in high density lipoprotein (HDL). Asmawati et al.[67] reported similar findings that the cashew apple juice had a positive effect on blood lipid profiles of rats. The reduction in these biomarkers, which are precursors for cardiovascular

diseases, demonstrates that cashew apples, can be a cardio-protective agent.

A recent study,[68] which involved feeding mice on a high fat diet, observed that the ingestion of cashew apple fiber was effective at controlling hunger/appetite, preventing high blood glucose, insulin resistance, and blood lipid profile, and reducing liver injury related to diet. This effect was attributed to the high fiber and bioactive compounds in the apple, which are well noted for promoting satiety and improving the metabolism of lipids and glucose in mice.[68] The cashew apple juice and fiber again act as prebiotics, contributing to gastrointestinal (GI) health.[69,70] Fiber has good implications for GI health, visceral fat/blood lipids, and the postprandial glucose response,[71,72] and as a result, aids in the prevention and management of diet-related diseases. Thus, the ability of cashew apples to serve as a functional food ingredient in promoting good health and development has been demonstrated, and all fears regarding their toxicity have been allayed.

Leucine, a branched chain amino-acid present in large quantities in cashew apple have been found to enhance muscle synthesis (anabolism) and influence the activity of insulin, and hence, good for regulating blood glucose level in sarcopenic patients and the elderly.[73–75] There is an abundance of GABA in cashew apples, which have been revealed to promote mental health by inhibiting brain neurotransmitters, and subsequently acting against depression and anxiety.[76,77] Studies[78–82] have also established the antihypertensive and anti-proliferative effects of GABA in humans and on cancerous cells.

PROCESSING AND VALUE-ADDITION OF CASHEW APPLE

High losses from the cashew apples could be prevented by processing them into shelf-stable intermediate products. Many processes and techniques have been developed to transform cashew apples into value-added products, such as unfermented cashew beverages like pulpy and clarified juice; fermented beverages like wine and ethanol; fruit powder used in the production of cookies, chocolates, bread spreads, and sponge cakes; and other products from cashew apple bagasse (cashew apple pomace powder in cookies, as fat replacers in burgers, and for increased fiber in cookies).[21–24]

Juice concentrate, syrup, squash and ready-to-serve (RTS) drinks are some of the nutritious beverages that can be obtained from cashew apple juice by adding sugar, citric acid and other preservatives.[8] Fruit blends have also been made from the cashew apple together with other fruits.[83]

Wines, ethanol, and probiotic beverages can be developed from the fermentation of the cashew apple juice with specific strains of microorganisms.[8,46] Cashew wine, which has an alcohol content between 6% and 12%, also has a low cost of production. Other fermented products, such as vinegar and prebiotic beverages, have also been developed.[21]

Dried cashew apple powder could be used in the development of value-added products such as cookies, bread spread, wheat-based confectionaries, chocolates, and sponge cakes.[84] Cashew apple pomace powder can be used for the preparation of other products because it is rich in flavonoids, carotenoids, anthocyanin, dietary fiber, ascorbic acid, and reducing sugars.[47] The addition of cashew fiber improved the crude fiber content of cookies irrespective of the method used in their preparation, and both the physical and sensory characteristics were acceptable.[85]

Cashew can also be processed into products like jam and marmalades. Studies[86,87] have demonstrated that cashew apple jam is a good source of nutrients, phytochemicals, and energy. Nonetheless because the jam involves the use of the juice, Figueroa-Valencia et al.[88] proposed the use of the apple pulp in making marmalade, due to the high phenolic content of the pomace.

FUTURE DIRECTIONS AND RESEARCH AREAS

Cashew production keeps on increasing with numerous challenges like pest and disease infestation, low yields, poor quality fruits, price instability, lack of market, limited utilization for the apples, among others. It is imperative for plant breeders to possibly deepen their breeding programs in providing cashew varieties with less perishability, a robust system against pests and diseases, and increased yield and quality of the fruit. Harvesting of cashew fruit is a major issue of concern, and in order to promote utilization of the cashew apples, engineers must intensify their efforts in developing equipment to facilitate the harvesting of the cashew fruit. Industry players must realize the need to put cashew apples to good utilization considering the economic gains and the health benefits they would offer in addressing food and nutrition insecurity in Africa. In addition, the development of cheaper and simpler processing, drying, and storage systems like solar or cold facilities at the community level will help to preserve the cashew apples for a longer period.

Food scientists and technologists may also play an important role in developing value-added products, such as powders, dry strips or fruit leathers, concentrates, and others out of the fruit when they are in bumper seasons to create diverse utilization for the apples and reduce losses.

Heads of States, agriculture ministries, departments, and agencies owe the cashew-growing countries the responsibility to educate or train community members on the possible uses of the apples and their value-added products. Tree Crops Development Board in Ghana, which is in-charge of all tree crops including cashew, can also prioritize their operations on the industrialization of cashew apple value-added products, taking into account the contribution of cashew to Ghana's Gross Domestic Products (GDP), and the potential of the apple in providing extra income for farmers, and job creation for the youth. This could be realized through a partnership with the Ministry of Trade and Industry. Intensification of education on the nutritional components and health benefits of cashew apples by nutritionists and health promoters through organizations like the Ministries of Health and Education, the World Health Organization, the World Food Program, the Deutsche Gesellschaft für Internationale Zusammenarbeit

(GIZ), and other non-governmental organizations could help maximize cashew apple utilization.

The use of cashew apples in interventional studies in human beings for the management of micronutrient deficiency may be required. In addition, studies on the incorporation of cashew apples into other food products like drinks, juice blends, bread, cake, biscuits, and others would help to promote patronage and utilization of cashew apples. Comparative studies on the complete profiling of the nutritional and phytochemical composition of the various varieties of cashew apple grown in Ghana could be a good research focus. Research on appropriate preservative methods for the preservation of the fresh cashew apple and its value-added products is needed to mitigate their rate of deterioration and extend their shelf life. Although studies have shown the presence of some phenolic compounds in the apples, information on the concentrations or levels of the compounds are scanty.

CONCLUSION AND RECOMMENDATION

Cashew apple contains a high concentration of phytochemicals like flavonoids, anthocyanins, flavones, carotenoids, vitamin C, fiber, sugars, important minerals (calcium, magnesium, iron, potassium, phosphorus, sodium, copper), and organic acids, such as anacardic, gallic, protocatechuic, conjugate cinnamic, free cinnamic, and malic acids. These nutrients and phytochemicals in cashew apples are good for maintaining strong immunity and good eyesight, preventing cancer, managing obesity, ulcers as well as cardiovascular diseases. Consumption of cashew apples and their value-added products will thus offer numerous health benefits, and boost the cashew industry.

It is recommended that the utilization of cashew apple can be enhanced through its incorporation in food products and blending with other fruit juices to reduce the level of its astringency for better nutrition and food security. Governments, non-governmental organizations, industry players, businessmen and women, researchers, and engineers are encouraged to contribute their quotas toward promoting the utilization of the cashew apples through the formulation of a good regulatory framework, the establishment of industries for processing, mass education on the health benefits of the apples, hands-on training on value-addition, and the provision of stimulus packages for small scale processors.

FUNDING INFORMATION

No external funding was sourced for this research.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

ORCID

Yaw Gyau Akyereko https://orcid.org/0000-0002-4750-1107
Faustina Dufie Wireko-Manu https://orcid.org/0000-0002-5020-6299

REFERENCES

1. Gawankar MS, Salvi BR, Pawar CD, Khanvilkar MH, Salvi SP, Dalvi NV, et al. Technology development for cashew apple processing In Konkan region–a review. J Adv Agric Res Technol. 2018;2(1):40–7.
2. Dendena B, Corsi S. Cashew, from seed to market: a review. J Agron Sustain Dev. 2014;34(4):753–72.
3. Moreira RFA, Trugo LC, Pietroluongo M, de Maria CAB. Flavor composition of cashew (*Anacardium occidentale*) and Marmeleiro (croton species) honeys. J Agric Food Chem. 2002;50(26):7616–21.
4. African Cashew Initiative. A value chain analysis of the cashew sector in Ghana. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ); Ghana; 2010. p. 1–48.
5. Catarino L, Menezes Y, Sardinha R. Cashew cultivation in Guinea-Bissau–risks and challenges of the success of a cash crop. Sci Agric. 2015;72:459–67.
6. INDFC (International Nuts and Dried Fruits Council) (2020). Global statistical review: Nutfruit magazine. Available at https://www.nutfruit.org/industry/news/detail/cashew-crop-2021-2022-forecast. Accessed 18 Sep 2022.
7. Singh SS, Abdullah S, Pradhan RC, Mishra S. Physical, chemical, textural, and thermal properties of cashew apple fruit. J Food Process Eng. 2019;42(5):e13094.
8. Das I, Arora A. Post-harvest processing technology for cashew apple–a review. J Food Eng. 2017;194:87–98.
9. Attri BL. Effect of initial sugar concentration on the physico-chemical characteristics and sensory qualities of cashew apple wine. J Nat Prod Radiance. 2009;8(4):374–9.
10. Prasertsri P, Leelayuwat N. Cashew apple juice: contents and effects on health. Nutr Food Sci Int J. 2017;491:1–3.
11. Lowor S, Yabani D, Winifred K, Agyente-Badu CK. Production of wine and vinegar from cashew (*Anacardium occidentale*) apple. Biotechnol J Int. 2016;12(3):1–11.
12. Akyereko YG, Wireko-Manu FD, Alemawor F, Adzanyo M. Cashew apples in Ghana: Stakeholders' knowledge, perception, and utilization. Int J Food Sci. 2022;2022:1–10.
13. Pascal ADC, Virginie G, Diane BFT, Estelle KR, Félicien A, Valentin WD, et al. Nutritional profile and chemical composition of juices of two cashew apple's varieties of Benin. Chem J. 2018;4(4):91–6.
14. Reina LJC, Durán-Aranguren DD, Forero-Rojas LF, Tarapuez-Viveros LF, Durán-Sequeda D, Carazzone C, et al. Chemical composition and bioactive compounds of cashew (*Anacardium occidentale*) apple juice and bagasse from Colombian varieties. Heliyon. 2022;8:e09528.
15. Adou M, Adjouman YD, Kouadio KO, Tetchi AF. Improvement of cashew apple juice (*Anacardium occidentale* L.) by association with passion fruit juice (Passiflora edulis). Food Nutr Sci. 2021;12(7):787–804.
16. Leite AK, Fonteles TV, Miguel TB, da Silva GS, de Brito ES, Alves Filho EG, et al. Atmospheric cold plasma frequency imparts changes on cashew apple juice composition and improves vitamin C bioaccessibility. Food Res Int. 2021;147:110479.
17. Souza EF, Furtado MR, Carvalho CW, Freitas-Silva O, Gottschalk LM. Production and characterization of Gluconacetobacter xylinus bacterial cellulose using cashew apple juice and soybean molasses. Int J Biol Macromol. 2020;146:285–9.
18. de Lima ACS, Soares DJ, da Silva LMR, de Figueiredo RW, de Sousa PHM, de Abreu Menezes E. In vitro bioaccessibility of copper, iron, zinc and antioxidant compounds of whole cashew apple juice and cashew apple fibre (*Anacardium occidentale* L.) following simulated gastro-intestinal digestion. Food Chem. 2014;161:142–7.
19. Ukonze JA, Ogu E, Onu FM, Dimelu I, Ifeanyieze FO, Ejiofor TE. Impact of clarification process on the nutritional, mineral and vitamin

composition of cashew (*Anacardium occidentale*) apple juice. Afr J Biotechnol. 2018;17(10):337–42.
20. Sucupira NR, de Sousa Sabino LB, Neto LG, Gouveia ST, de Figueiredo RW, Maia GA, et al. Evaluation of cooking methods on the bioactive compounds of cashew apple fibre and its application in plant-based foods. Heliyon. 2020;6(11):05346.
21. Preethi P, Mangalassery S, Shradha K, Pandiselvam R, Manikantan MR, Reddy SVR, et al. Cashew apple pomace powder enriched the proximate, mineral, functional and structural properties of cereal based extrudates. LWT. 2021;139:110539.
22. Pinho LX, Afonso MRA, Carioca JOB, Costa JMCD, Ramos AM. The use of cashew apple residue as source of fiber in low fat hamburgers. Food Sci Technol. 2011;31(4):941–5.
23. Guedes-Oliveira JM, Salgado RL, Costa-Lima BR, Guedes-Oliveira J, Conte-Junior CA. Washed cashew apple fiber (*Anacardium occidentale* L.) as fat replacer in chicken patties. LWT-Food Sci Technol. 2016;71:268–73.
24. Ebere CO, Emelike NJT, Kiin-Kabari DB. Physico-chemical and sensory properties of cookies prepared from wheat flour and cashew-apple residue as a source of fibre. Asian J Agric Food Sci. 2015;3(2):213–218.
25. Oliveira MEBD, Oliveira GSFD, Maia GA, Moreira RDA, Monteiro ACDO. Major free amino acids in cashew apple juice: behaviour during the harvest season. Rev Bras Frutic. 2002;24(1):133–7.
26. Oliveira NN, Mothé CG, Mothé MG, de Oliveira LG. Cashew nut and cashew apple: a scientific and technological monitoring worldwide review. J Food Sci Technol. 2020;57(1):12–21.
27. Agbangnan P, Gbohaïda V, Mossi I, Adjou ES, Yehouenou BB, Sohounhloué DC. Morphological and physicochemical characterizations of cashew apples from Benin for their use as raw material in bioethanol production. Int J Pharm Sci Res. 2015;35(2):7–11.
28. Naka T, Martin DK, Soumaila D, Lucien K. Assessment of some biochemical parameters of apple juices from two cashew varieties as affected by three regions of Côte D'ivoire. J Adv Agricu. 2015;5(2):621–33.
29. Assunção RB, Mercadante AZ. Carotenoids and ascorbic acid from cashew apple (*Anacardium occidentale* L.): variety and geographic effects. Food Chem. 2003;81(4):495–502.
30. Lowor ST, Agyente-Badu CK. Mineral and proximate composition of cashew apple (*Anarcadium occidentale* L.) juice from northern Savannah, Forest and coastal Savannah regions in Ghana. Am J Food Technol. 2009;4(4):154–61.
31. Vergara CMDAC, Honorato TL, Maia GA, Rodrigues S. Prebiotic effect of fermented cashew apple (*Anacardium occidentale* L) juice. LWT-Food Science and Technology. 2010;43(1):141–5.
32. Marc A, Achille TF, Mory G, Nestor KK, Georges ANG. Physicochemical characterization of cashew apple juice (*Anacardium occidentale*, L.) from Yamoussoukro (Côte D'ivoire). Innov Rom Food Biotechnol. 2012;11:32–43.
33. Okpanachi U, Attah S, Shaahu DT. A comparative study between vitamins and amino acid profile of sun-dried red and yellow cashew pulp. Int J Anim Biol. 2015;1(5):237–42.
34. Salehi B, Gültekin-Özgüven M, Kirkin C, Özçelik B, Morais-Braga MFB, Carneiro JNP, et al. Antioxidant, antimicrobial, and anticancer effects of anacardium plants: an ethnopharmacological perspective. Front Endocrinol. 2020;11:295.
35. Kiokias S, Proestos C, Varzakas T. A review of the structure, biosynthesis, absorption of carotenoids-analysis and properties of their common natural extracts. Curr Res Nutr Food Sci J. 2016;4 (special issue carotenoids march 2016):25–37.
36. da Silva GG, de Oliveira Braga LE, de Oliveira ECS, Tinti SV, de Carvalho JE, Lazarini JG, et al. Cashew apple byproduct: gastroprotective effects of standardized extract. J Ethnopharmacol. 2021;269:113744.
37. Sousa JMS, de Abreu FAP, Ruiz ALTG, da Silva GG, Machado SL, Garcia CPG, et al. Cashew apple (*Anacardium occidentale* L.) extract from a by-product of juice processing: assessment of its toxicity, antiproliferative and antimicrobial activities. J Food Sci Technol. 2021;58(2):764–76.
38. Coelho TLS, Silva DSN, dos Santos Junior JM, Dantas C, de Araujo Nogueira AR, Júnior CAL, et al. Multivariate optimization and comparison between conventional extraction (CE) and ultrasonic-assisted extraction (UAE) of carotenoid extraction from cashew apple. Ultrason Sonochem. 2022;84:105980.
39. Servent A, Abreu FA, Dhuique-Mayer C, Belleville MP, Dornier M. Concentration and purification by crossflow microfiltration with diafiltration of carotenoids from a by-product of cashew apple juice processing. Innovative Food Sci Emerg Technol. 2020;66:102519.
40. de Abreu FP, Dornier M, Dionisio AP, Carail M, Caris-Veyrat C, Dhuique-Mayer C. Cashew apple (*Anacardium occidentale* L.) extract from by-product of juice processing: a focus on carotenoids. Food Chem. 2013;138(1):25–31.
41. Sena EDOA, da Silva PSO, de Aragão Batista MC, Sargent SA, de Oliveira Junior LFG, Pagani AAC, et al. Calcium application via hydrocooling and edible coating for the conservation and quality of cashew apples. Sci Hortic. 2019;256:108531.
42. Popova A, Mihaylova D. Antinutrients in plant-based foods: a review. Open Biotechnol J. 2019;13(1):68–76.
43. Sharma K, Kumar V, Kaur J, Tanwar B, Goyal A, Sharma R, et al. Health effects, sources, utilization and safety of tannins: a critical review. Toxin Rev. 2021;40(4):432–44.
44. Farha AK, Yang QQ, Kim G, Li HB, Zhu F, Liu HY, et al. Tannins as an alternative to antibiotics. Food Biosci. 2020;38:100751.
45. Abdullah S, Pradhan RC, Aflah M, Mishra S. Efficiency of tannase enzyme for degradation of tannin from cashew apple juice: modeling and optimization of process using artificial neural network and response surface methodology. J Food Process Eng. 2020;43(10):13499.
46. Kaprasob R, Kerdchoechuen O, Laohakunjit N, Sarkar D, Shetty K. Fermentation-based biotransformation of bioactive phenolics and volatile compounds from cashew apple juice by select lactic acid bacteria. Process Biochem. 2017;59:141–9.
47. Aidoo R, Kwofie EM, Ngadi MO. Circularity of cashew apples: examining the product-process pathways, techno-functional, nutritional/Phytomolecular qualities for food applications. ACS Food Sci Technol. 2022;2(7):1051–66.
48. Kaprasob R, Kerdchoechuen O, Laohakunjit N, Thumthanaruk B, Shetty K. Changes in physico-chemical, astringency, volatile compounds and antioxidant activity of fresh and concentrated cashew apple juice fermented with lactobacillus plantarum. J Food Sci Technol. 2018;55(10):3979–90.
49. Emelike NJT, Hart AD, Ebere CO. Influence of drying techniques on the sensory properties, physicochemical and mineral composition of beetroot juice. IOSR J Environ Sci Toxicol Food Technol. 2015;9(12–2):20–6.
50. Prommajak T, Leksawasdi N, Rattanapanone N. Optimizing tannin precipitation in cashew apple juice. Chiang Mai Univ J Nat Sci. 2018;17(1):13–23.
51. Shang YF, Cao H, Ma YL, Zhang C, Ma F, Wang CX, et al. Effect of lactic acid bacteria fermentation on tannins removal in Xuan Mugua fruits. Food Chem. 2019;274:118–22.
52. Ojo MA. Tannins in foods: nutritional implications and processing effects of hydrothermal techniques on underutilized hard-to-cook legume seeds–a review. Preventive Nutr Food Sci. 2022;27(1):14–9.
53. Das I, Sasmal S, Arora A. Effect of thermal and non-thermal processing on astringency reduction and nutrient retention in cashew apple fruit and its juice. J Food Sci Technol. 2021;58(6):2337–48.
54. Prasertsri P, Roengrit T, Kanpetta Y, Tong-Un T, Muchimapura S, Wattanathorn J, et al. Cashew apple juice supplementation enhanced

fat utilization during high-intensity exercise in trained and untrained men. J Int Soc Sports Nutr. 2013;10(1):1–6.
55. da Silveira Vasconcelos M, Gomes-Rochette NF, de Oliveira MLM, Nunes-Pinheiro DCS, Tomé AR, Maia de Sousa FY, et al. Anti-inflammatory and wound healing potential of cashew apple juice (*Anacardium occidentale* L.) in mice. *Journal of*. Exp Biol Med. 2015; 240(12):1648–55.
56. Morais TC, Pinto NB, Carvalho KMM, Rios JB, Ricardo NMP, Trevisan MTS, et al. Protective effect of anacardic acids from cashew (*Anacardium occidentale*) on ethanol-induced gastric damage in mice. Chem Biol Interact. 2010;183(1):264–9.
57. Braga DC, Alves Filho EG, Ribeiro PRV, da Silva Araújo ÍM, de Brito ES, dos Santos Garruti D. Multivariate correlation of the astringency sensory perception with the phenolic profiling of cashew apple genotypes. Food Biosci. 2021;41:100931.
58. Stagos D. Antioxidant activity of polyphenolic plant extracts. Antioxidants. 2019;9(1):19.
59. Laxmanaswami B, Urooj A. Phytochemical profile and antimicrobial activity of cashew apple (*Anacardium occidentale* L.) extract. GSC Biol Pharm Sci. 2018;5(3):95–8.
60. Vivek MN, Manasa M, Pallavi S, Swamy SH, Prashith KTR. Antibacterial potential of cashew apple (*Anacardium occidentale* L.) juice against clinical isolates of Staphylococcus aureus and Streptococcus mutans. Sci Technol Arts Res J. 2013;2(3):144–6.
61. Naka T, Koua A, Mohamed C, Soumaila D. Antioxidant and antibacterial activities of cashew (*Anacardium occidentale* L.) apple juice concentrated from western three regions of Côte D'ivoire. J Appl Biosci. 2019;141:14343–52.
62. Sukumari-Ramesh S, Singh N, Jensen MA, Dhandapani KM, Vender JR. Anacardic acid induces caspase-independent apoptosis and radiosensitizes pituitary adenoma cells. J Neurosurg. 2011; 114(6):1681–90.
63. Choi HN, Kang MJ, Lee SJ, Kim JI. Ameliorative effect of myricetin on insulin resistance in mice fed a high-fat, high-sucrose diet. Nutr Res Pract. 2014;8(5):544–9.
64. Henagan TM, Cefalu WT, Ribnicky DM, Noland RC, Dunville K, Campbell WW, et al. In vivo effects of dietary quercetin and quercetin-rich red onion extract on skeletal muscle mitochondria, metabolism, and insulin sensitivity. Genes Nutr. 2015; 10(1):2.
65. Beejmohun V, Mignon C, Mazollier A, Peytavy-Izard M, Pallet D, Dornier M, et al. Cashew apple extract inhibition of fat storage and insulin resistance in the diet-induced obesity mouse model. J Nutr Sci. 2015;4:38–8.
66. Rani TJ, Prasad KVSRG, Dodoala S. Evaluation of antiobesity activity of ethanolic extract of cashew apple against high fat diet induced obesity in rodents. FASEB J. 2017;31:565–5.
67. Asmawati, A., Marianah, M., Yaro, A. & Hendroko Setyobudi, R. (2021). The potential of cashew apple juice as anti hypercholesterol agent on whistar rats (rattus norvegicus Berkenhout, 1769). In E3S web of conferences (vol. 226).
68. Carvalho DV, Silva LMA, Alves Filho EG, Santos FA, de Lima RP, Viana AFSC, et al. Cashew apple fiber prevents high fat diet-induced obesity in mice: an NMR metabolomic evaluation. Food Funct. 2019; 10(3):1671–83.
69. Menezes FNDD, da Cruz Almeida ÉT, da Silva Vieira AR, de Souza Aquino J, dos Santos Lima M, Magnani M, et al. Impact of cashew (*Anacardium occidentale* L.) by-product on composition and metabolic activity of human colonic microbiota in vitro indicates prebiotic properties. Curr Microbiol. 2021;78(6):2264–74.
70. do Nascimento LB, Pessoa VA, de Oliveira Júnior SD, Chevreuil LR, de Aguiar LV, dos Santos Gouvêa PR, et al. Bioactive properties and evaluation of the prebiotic potential of cashew apple fiber using Bifidobacterium lactis Propriedades bioativas e avaliação do potencial prebiótico da fibra do pedúnculo de caju utilizando Bifidobacterium lactis. Braz J Dev. 2021;7(8):76181–94.
71. Gill SK, Rossi M, Bajka B, Whelan K. Dietary fibre in gastrointestinal health and disease. Nat Rev Gastroenterol Hepatol. 2021;18(2): 101–16.
72. Cassidy YM, McSorley EM, Allsopp PJ. Effect of soluble dietary fibre on postprandial blood glucose response and its potential as a functional food ingredient. J Funct Foods. 2018;46:423–39.
73. Devries MC, McGlory C, Bolster DR, Kamil A, Rahn M, Harkness L, et al. Protein leucine content is a determinant of shorter-and longer-term muscle protein synthetic responses at rest and following resistance exercise in healthy older women: a randomized, controlled trial. Am J Clin Nutr. 2018;107(2):217–26.
74. Zhang H, Wang J, Zeng Y, Wang G, Han S, Yang Z, et al. Leucine-coated cobalt ferrite nanoparticles: synthesis, characterization and potential biomedical applications for drug delivery. Phys Lett A. 2020;384(24):126600.
75. Manders RJ, Little JP, Forbes SC, Candow DG. Insulinotropic and muscle protein synthetic effects of branched-chain amino acids: potential therapy for type 2 diabetes and sarcopenia. Nutrients. 2012;4(11):1664–78.
76. Hinton T, Johnston GA. GABA-enriched teas as neuro-nutraceuticals. Neurochem Int. 2020;141:104895.
77. Lee SE, Lee Y, Lee GH. The regulation of glutamic acid decarboxylases in GABA neurotransmission in the brain. Arch Pharm Res. 2019;42(12):1031–9.
78. Kawakami K, Yamada K, Yamada T, Nabika T, Nomura M. Antihypertensive effect of γ-aminobutyric acid-enriched brown rice on spontaneously hypertensive rats. J Nutr Sci Vitaminol. 2018;64(1):56–62.
79. Zareian M, Oskoueian E, Majdinasab M, Forghani B. Production of GABA-enriched idli with ACE inhibitory and antioxidant properties using aspergillus oryzae: the antihypertensive effects in spontaneously hypertensive rats. Food Funct. 2020;11(5):4304–13.
80. An J, Seok H, Ha EM. GABA-producing lactobacillus plantarum inhibits metastatic properties and induces apoptosis of 5-FU-resistant colorectal cancer cells via GABAB receptor signaling. J Microbiol. 2021;59(2):202–16.
81. Yoshimura M, Toyoshi T, Sano A, Izumi T, Fujii T, Konishi C, et al. Antihypertensive effect of a γ-aminobutyric acid rich tomato cultivar "DG03-9" in spontaneously hypertensive rats. J Agric Food Chem. 2010;58(1):615–9.
82. Oh CH, Oh SH. Effects of germinated brown rice extracts with enhanced levels of GABA on cancer cell proliferation and apoptosis. J Med Food. 2004;7(1):19–23.
83. Pinheiro AM, Maia GA, Figueiredo RW, Azeredo HM, Oliveira LDS, Silva MDFG, et al. Response surface methodology optimization of blended fruit nectar: cashew apple and açai. Int J Fruit Sci. 2022; 22(1):275–86.
84. Lagnika C, Amoussa AMO, Sanni A, Lagnika L. Effect of blanching and ultrasound on drying time, physicochemical and bioactive compounds of dried cashew apple. Am J Food Sci Tech. 2019;7(6): 227–33.
85. Adegunwa MO, Kayode BI, Kayode RMO, Akeem SA, Adebowale AA, Bakare HA. Characterization of wheat flour enriched with cashew apple (*Anacardium occidentale* L.) fiber for cake production. J Food Meas Charact. 2020;14(4):1998–2009.
86. Atta, K., Ekissi, G. S. E., Ya, C. K., Fagbohoun, B. J., & Patrice, L. (2021). Physicochemical and sensory parameters of cashew apple jam (Anarcadium occidental L.) harvested in Bondoukou area (North East, Côte d'Ivoire).
87. Khaing, H., Ngwe, K., Mar, S., & Hatey. H. (2021) Assessment of soil properties using GIS Technologies in a Selected Area in Myanmar.
88. Figueroa-Valencia M, Rosales-Martinez P, Santoyo-Tepole F, Ramos-Monroy OA, García-Ochoa F, Hernández-Botello MT, et al.

Antioxidant properties of red and yellow varieties of cashew apple, nut and husk (*Anacardium Occidentale* L.) Harvested in Mexico. J Antioxid Act. 2019;1(4):19–32.

89. Gordon A, Friedrich M, Da Matta VM, Moura CFH, Marx F. Changes in phenolic composition, ascorbic acid and antioxidant capacity in cashew apple (*Anacardium occidentale L.*) during ripening. Fruits. 2012;67(4):267–76.

How to cite this article: Akyereko YG, Yeboah GB, Wireko-Manu FD, Alemawor F, Mills-Robertson FC, Odoom W. Nutritional value and health benefits of cashew apple. JSFA Reports. 2023;3(3):110–8. https://doi.org/10.1002/jsf2.107