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Review

A review of cashew (*Anacardiumoccidentale* L.) apple: Effects of processing techniques, properties and quality of juice

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A review including the processing techniques, properties and uses of cashew apple juice is reported. Cashew apple has multi-purpose; it can be processed to obtain human food. The process of cashew apple into several by-products can affect its nutritional, microbiological, and sensorial quality attributes. Therefore, clarification methods, thermal treatment and high hydrostatic pressure modify nutritional, microbiological, and sensorial attributes of cashew apple products. Moreover, the storage stability of cashew apple juice depends on the preservative methods used. Cashew apple is usually used in the fortification of the nutritional quality of some tropical foods,because of its high percentage of vitamin C. Cashew apple juice has great potential for bioprocess to obtain fermented products. Cashew apple contains phenolic compounds generally related to antioxidant. The valorization of cashew apples in developing countries by the improvement of the process of cashew apples available in these countries can contribute to cover the nutritional needs of the populations.

Key words: Cashew apple, physico-chemical, processing, juice quality, storage.

INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a tropical fruit native from Brazil, principally grown in the North and Northeast regions. The pseudo-fruit, known as the cashew apple, is the part of the tree that connects it to the cashew nut, the real fruit, a well-known product worldwide (Zepka and Mercadante, 2009). The cashew nuts represent only 10% of the total fruit weight, and large amounts of cashew apples are left in the field after the removal of the nut (Honorato et al., 2007a).

The cashew tree grows even on poor soils with low rainfall and is cultivated in 32 countries around the world, with Brazil, India, Vietnam, and Nigeria as the main producers (Rabelo et al., 2009). Cashew apple is the peduncle of the cashew fruit, which is rich in reducing sugars (fructose and glucose), vitamins, minerals, and some amino acids, carotenoids, phenolics, organic acids and antioxidants, and also considered as a source of energy (Oliveira et al., 2002; Campos et al., 2002; Trevisan et al., 2006; Carvalho et al., 2007; Honorato et al., 2007a). It can be processed to obtain juice, ice

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cream, and other foodstuffs (Dèdéhou et al., 2015a).

Astringency of cashew apple undertakes consumption, due to polyphenols, tannins (0.35%), and unknown oily substances (3%) present in the waxy layer of the skin (Cormier, 2008; Michodjehoun-Mestres et al., 2009a). Many factors, such as the seasonal nature of the cashew trees produce, the extreme perishable character of apples hindering it full utilization (Bidaisee and Badrie, 2001).

Thermal processing has a negative effect on the sensory and nutritional characteristics of the juice as the compounds responsible for aroma and flavor are volatile and some vitamins are thermosensitive (Polydera et al., 2003).

On the other hand, the biological composition of cashew can be influenced by variety, geographic locality and ripening stage (Lowor and Agyente-Badu, 2009; Sivagurunathan et al., 2010; Adou et al., 2011a; Gordon et al., 2012).

Some studies focused on the physico-chemical characteristics of cashew apple (Assuncao and Mercadante, 2003; Lavinas et al., 2006; Brito et al., 2007; Silva et al., 2008; Michodjehoun-Mestres et al., 2009a; Adou et al., 2011a,b, 2012) and also on the effects of postharvest process on the physico-chemical quality attributes of cashew (Souza et al.,1999, 2009; Falade et al., 2003; Figueiredo et al., 2007; Marques et al., 2007; Martins, et al., 2008; Lima et al., 2010); the effects of processing methods, such as clarification by membrane and enzymatic methods or the use of clarifying agents on the nutritional quality of cashew apple juice have also been investigated. Furthermore, the effect of thermal treatment and high hydrostatic pressure on cashew apple juice have been reported by various workers (Campos et al., 2002; Couri et al., 2003; Jayalekshmy and John, 2004; Abreu et al., 2005; Cianci et al., 2005; Castro et al., 2007; Damasceno et al., 2008; Zepka and Mercadante, 2009; Sampaio et al., 2011; Gyedu-Akoto, 2011; Talasila et al., 2011). Other studies on the storage stability of cashew apple juice by using artificial preservative or microfiltration (Talasila et al., 2012) and the effect of storage conditions on cashew apple juice stability were reported (Lavinas et al., 2006; Queiroz et al., 2008). On the other hand, cashew apple was used in the fortification of the nutritional quality of some tropical foods by mixing the apple juice or powder with other tropical food to increase it vitamins and minerals level for example (Akinwale, 2000; de Carvalho et al., 2006; Silva et al., 2008; Queiroz et al., 2008; Gyedu-Akoto, 2011; Talasila et al., 2011; Gao and Rupasinghe, 2012; Talasila et al., 2012) and in the processing of added values fermented products because of it high content of reducing sugars (Osho, 1995; Melo and Macedo, 2008; Giro et al., 2009; Venkatesh et al., 2009; Honorato and Rodrigues, 2010; Lima et al., 2010; Vergara et al., 2010; Kuila et al., 2011; Silveira et al., 2012).

The valorization of cashew products especially cashew apple in developing countries is a relevant topic. In order to improve the valorization of cashew products, it is necessary to find out what is already done in this respect. This review aims to give information on the physico-chemical characteristics of cashew (*A. occidentale*) apple and the effects of some processing methods on the quality of cashew apple juice.

PHYSICO-CHEMICAL CHARACTERISTICS OF CASHEW (*A. OCCIDENTALE*) APPLE

Geographical and varietal effects

Biochemical profile of the apples of different species of cashew grown in some area of Ivory Coast on specific soils and climate in the various producing regions were evaluated (Adou et al., 2011a). The analyses of the juices found 10 minerals of which seven were macro-minerals and three were trace elements. The macro-minerals in order of occurrence were K>P>Mg>S>Na>Si>Cl; the distribution of the three trace elements was not uniform in all the analyzed juice samples. In addition, the minerals were not free, but in the oxidized state with oxide contents in the apples. In Ghana,the juices, from both the red and yellow cashew apples from three agro ecological zones, mineral composition (mg/100 ml) showed potassium (76.0) to be the highest, followed by calcium (43.0), magnesium (10.92), phosphorous (0.79), and sodium (0.41). While, zinc, copper, and iron concentrations were lower and ranged from 0.05 to 0.08 mg/100 ml. Phenol and tannin contents in the juice showed significant ($p<0.05$) variation among the ecological zones (Agostini-Costa et al., 2002; Lowor and Agyente-Badu, 2009). Moreover, protein, reducing sugars, total sugars showed significant ($p<0.05$) variation among the ecological zones except the pH value (Adou et al., 2011a). The variations in the physico-chemical characteristics of cashew apple juices from the different locations is associated with changes in soil conditions, cultural practices and other climatic conditions such as temperature and humidity (Egbekun and Otiri, 2010).

The results of vitamin C content, total sugars, concentrations of glucose, fructose and sucrose, level of organic acids, citric acid, tartaric acid, acetic acid, oxalic acid, fumaric acid, pH, titratable acidity, total soluble solid content, dry matter, ash, protein content, and amino acids showed that except pH, the color of apples influenced significantly ($p<0.05$) the parameters analyzed (Adou et al., 2012). In general, elongated red variety showed higher carotenoid levels than the yellow one. In contrast, ascorbic acid values were higher in the yellow variety from both regions (Assuncao and Mercadante, 2003).

Different clones of early dwarf cashew tree (*A. occidentale*, L.) CCP-06, CCP-1001, and CCP-76, developed by Embrapa Agroindústria Tropical (Brazilian Agricultural Research Corporation) located in Fortaleza, Ceará, Brazil were characterized. Physical-chemical determinations were done in cashew apples, randomly at interval period of 15 days (during 75 days). Chemical analysis evaluated the total acidity, reduced content, not reduced and total sugars, vitamin C, phenolic compounds (tannins), pH, soluble solids, moisture, ash, protein, fiber, iron, calcium, and phosphorus (Maia et al., 2004). The authors concluded that the stems of different cashew clones differ in acidity, moisture, and tannin content,being a good source of sugar and excellent vitamin C.

Effect of ripening stage

Cashew apples at three different maturity stages (Unripe fruits grew for 33 to 36 days, medium-ripe fruits 45 to 50 days and ripe fruits 52 days) were examined according to their ascorbic acid content, phenolic compounds and antioxidant capacity (Gordon et al., 2012). The results showed that the quantities of phenolic compounds were higher in immature cashews and decreased during the ripening process. Myricetin-3-O-rhamnoside, 3-O-galactoside quercetin, and quercetin 3-O-rhamnoside were the main flavonoid present in all phases.The antioxidant capacity and the concentration of ascorbic acid increased in the course of ripening. The antioxidant activity was significantly ($p < 0.05$) influenced by ascorbic acid, more than the content of phenolic compounds.

Different early dwarf clones: CCP 76, CCP 09, BRS 189, and BRS 265 during seven ripening stages were analyzed for vitamin C, total carotenoid, total anthocyanin, yellow flavonoids and polyphenol contents, and total antioxidant capacity. Clone BRS 265 ripe cashew apple presented the highest vitamin C content (279.37 mg/100 g). The ripe BRS 189 cashew apple is colored bright red, and its total anthocyanin content was the highest (21.16 mg/100 g). Yellow flavonoid content was higher in ripe CCP 76 and BRS 189 cashew apples with 56.32 and 50.75 mg/100 g, respectively. The highest levels of extracts of polyphenols and antioxidant capacity were observed in CCP 09 during the first five ripening stages. The antioxidant activity of cashew apples (*A.occidentale* L.) was mainly attributed to polyphenol content ($r = 0.90$; $p < 0.01$) (Almeida Lopes et al., 2012).

Tannin contents and flavonoid components of cashew apple (*A. occidentale*)

The interference of the genetic and climatic variations in cashew apple tannin contents was evaluated during 2000 and 2001 harvest. Cashew apples were harvested from microcarpum cashew tree and from seven clones of early cashew tree (var. nanum) in the Experimental Stations of the Embrapa in Pacajus and Paraipaba (CE) (Brazil) and the Pimenteiras Farm in Aracati (CE) (Brazil).Cashew apples from CP-076 early cashew tree, the most popular commercial clone at Northeastern Brazil, were used as control. Table 1 shows that tannin contents in cashew apples from CP-09 clone were significantly higher than other analyzed clones and the cashew apples from CP-1001 clone presented the lowest tannin values. For 2001-harvest, the tannin values of CP-09 cashew apples from Pacajus, CE, were 14% higher than tannin values of Paraipaba, CE. This difference is certainly due to climatic variations. The harvest year also significantly influenced tannin. For example, tannin values obtained in 2000 were about 25% higher than tannin values obtained in 2001 for CP-09 cashew apple. This difference was probably induced by rainfall which was more intensive at Pacajus in 2000. Indeed, a significantly positive correlation between rainfall intensity and tannin content was demonstrated, mainly during ripening period of cashew apples, when these phenolic compounds were metabolized (Agostini-Costa et al., 2002).

Table 1. Tannin contents of peduncle of microcarpum cashew tree from seven clones of early cashew tree (var. nanum) (Agostini-Costa et al., 2002).

Clones	Harvest	Origin	Tannins (mg/100 g)
Microcarpum	2001	Pacajus	116
Embrapa-50	2001	Paraipaba	134
Embrapa-51	2001	Pacajus	162
Embrapa-51	2001	Paraipaba	134
Embrapa-51	2000	Aracati	211
Embrapa-51	2000	Pacajus	196
END-157	2001	Paraipaba	108
END-157	2001	Pacajus	105
END-157	2000	Aracati	168
END-189	2000	Aracati	125
END-183	2000	Aracati	183
CP-1001	2001	Pacajus	84
CP-1001	2001	Paraipaba	85
CP-1001	2000	Paraipaba	124
CP-1001	2000	Pacajus	166
CP-076	2001	Pacajus	121
CP-076	2001	Paraipaba	104
CP-076	2000	Pacajus	132
CP-076	2000	Paraipaba	133
CP-076	2000	Aracati	154
CP-09	2001	Pacajus	274
CP-09	2001	Paraipaba	237
CP-09	2000	Pacajus	181
CP-09	2000	Paraipaba	304

In addition, it was reported that the various types of tannins were unequally distributed in the skin and the flesh of cashew apples (Michodjehoun-Mestres et al., 2009b). Results showed that both skin and flesh tannins contained high percentages of (-)-epigallocatechin and (-)-epigallocatechin-O-gallate, followed by low quantities of (-)-epicatechin and (-)-epicatechin-3-O-gallate; 100% of

Table 2. Flavonoids components detected in cashew apple (Brito et al., 2007).

Compound	Cashew apple (mg/g)
Myricetin 3-O-galactoside	0.0532
Myricetin 3-O-glucoside	0.0274
Myricetin 3-O-xylopyranoside	0.0124
Myricetin 3-O-arabinopyrannoside	0.0104
Myricetin 3-O-arabinofuranoside	0.0097
Myricetin 3-O-rhamnoside	0.0400
Total myricetin glycosides	0.1511
Quercetin 3-O-galactoside	0.0465
Quercetin 3-O-glucoside	0.0144
Quercetin 3-O-xylopyranoside	0.0116
Quercetin 3-O-arabinopyrannoside	0.0108
Quercetin 3-O-arabinofuranoside	0.0079
Quercetin 3-O-rhamnoside	0.0227
Total quercetin glycosides	0.1139
Kaempferol 3-O-glucoside	Trace amount
5-Methylcyanidin 3-O-hexoside	0.0197
Total glycosylatedflavonoids	0.2847

the compounds were 2,3-cis configuration. Skin tannins were half as galloylated (20%) than flesh tannins (40%).

The 14 flavonoids determined in cashew apple by Brito et al. (2007) are shown in Table 2. The results showed that one anthocyanin and thirteen glycosylated flavonols were detected in cashew apple methanol-water extract. This study demonstrated that cashew apple is a good source of flavonoids. Indeed, flavonoid of food plants has been reported to offer biological benefits, such as reduced risk of cancer and cardiovascular disease.

FLAVOR CHEMISTRY OF CASHEW JUICE

The evaluation of the volatile flavor compounds from cashew juice by the Osme gas chromatography/ olfactometry technique showed that ethyl 3-methyl butanoate (16.70%), *trans*-2-hexenal (14.27%), methyl 3-methyl butanoate (9.72%), 2-methyl-2-pentenal (9.27%), ethyl butanoate (8.47%), hexanal (7.68%), 2-butoxyethanol (3.35%), 3-methyl-1-butanol (3.23%), and 2-methyl butanoic acid (3.01%) were the major compounds (Garruti et al., 2003).

EFFECTS OF CROPPING SYSTEM, IRRIGATION, MANAGEMENT AND SPACING ON CASHEW APPLE QUALITY

The quality of post-harvested cashew apples has been influenced by the production systems. The integrated fruit production (IFP) and conventional cropping production (CP) systems in dwarf cashew orchard did not influence the firmness of pulp, total soluble solids, and color of apples. For the titratable acidity and vitamin C content, the IFP system was significantly higher than the CP ones. For the pH variable, a significant difference was observed between the averages of the systems, the value of pH obtained from CP was superior to that of IFP (Andrade et al., 2008).

The influence of spacing on physical-chemical characteristics of peduncles of irrigated early dwarf of cashew (*A.occidentale*L. var. *nanum*) was evaluated. In the Experimental Station of Vale do Curu, located in the county of Paraipaba, Ceará, Brazil, four treatments were evaluated: one traditional (6.0 × 8.0 m) and three densely spaced (4.0 × 3.0, 6.0 × 3.0, and 8.0 × 3.0 m) to which trimming and paring were applied. There were no significant ($p > 0.05$) differences among treatments for the characteristics, such as total soluble solids (TSS), total titratable acidity (TTA), TSS/TTA ratio, vitamin C, and tannin (polymeric, dimeric and oligomeric) contents (Damasceno and Bezerra, 2002).

CASHEW TOXICITY

The study of *in vivo* toxicity of mixture of "cashew apple juice and milk" on mice to confirm or refute the idea that the cashew apple juice consumed with milk would be fatal showed that there was no toxicity of apple “juice-milk” mixture. Instead, the richness of the mixture positively affects erythropoiesis in the studied mice. For the authors, the toxicity of the mixture is not proven on mice; it is permissible to conclude that it is not fatal also for human. So, the idea that the cashew apple juice consumed with milk would be fatal is refuted (Adou et al., 2013). On the other hand, the toxicological assessment of locally produced cashew wine on albino rats (*Rattus novergicus*) at 10, 7.5, and 5% alcohol content administered to them orally at 1ml/160g body weight using canular for eighteen days was done. Results revealed that at 7% alcohol content and above it caused the distortion of the liver architecture of animals, indicator of toxicity (Awe et al., 2013). Dare et al. (2011) investigated the effects of aqueous extract of *A.occidentale* leaf on pregnancy outcome of Wistar rats. The results showed that the extract of *A. occidentale* should not be taken by pregnant women, even if they suffer of diabetes (Dare et al., 2011). Indeed, for example, intravenous administration of the hexane extract of the bark of (cashew) in normal, healthy dogs produced a significant lowering of the blood glucose levels probably due to the presence of stigmast-4-en-3-ol and stigmast-4-en-3-one (Alexander-Lindo et al., 2004).

EFFECTS OF POSTHARVEST PROCESS ON PHYSICO-CHEMICAL CHARACTERISTICS AND OTHER QUALITY ATTRIBUTES OF CASHEW PSEUDO-FRUITS

Cashew apple is subjected to several processes after the harvest which influences its physico-chemical characteristics and the quality attributes, because of its highly perishable nature.

The effects of postharvest calcium applications for storage on physico-chemical characteristics, other quality attributes and calcium concentration in tissue of the pseudo-fruits of early dwarf cashew (*A. occidentale* L.), stored under refrigeration at 4°C and modified atmosphere showed that the total soluble solids (Brix) and soluble sugars decreased during storage (Figueiredo et al., 2007). According to the authors, this could be attributed to the consumption of sugars through respiratory metabolism. Cashew apples, irrespective of the dose of calcium used showed significant variations in the acidity according to the time, with trend of reduction. The pseudo-fruits, regardless of the chloride calcium concentration, showed a tendency of decrease in the total vitamin C and an increase in pH during storage. The anthocyanin content showed no variation in treated cashew pseudo-fruits. Low reductions in less polymerized poly-phenolic fraction were observed during the storage period.

The doses of calcium and time of storage had significant effect on compounds, phenol polymeric, oligomerics, and dimerics; also the effect of storage time on cashew apple calcium concentrations was significant. Authors found significant interaction between time of storage and treatment with calcium for total calcium, soluble calcium and insoluble calcium. Cashew apple subjected to the treatment of calcium, showed an increase in the values of total calcium until 15 days of storage, and decreased slightly until the end of the experiment. The treatment of cashew apple from mature dwarf of cashew tree with gamma radiation with doses of 0, 0.5, and 1.0 kGy followed by a storage for nine days at 4°C showed that the levels of vitamin C decreased during storage and according to the applied doses of radiation, while the firmness of the fruits was influenced by both the radiation doses and storage time, increasing during storage and decreasing as the radiation doses increased (Souza et al., 2009).

The combined methods (reduction of water activity, mild heat treatment, pH reduction, addition of ascorbic acid, 1000 ppm sodium benzoate, 600 and 900 ppm of SO_2 addition) were capable of assuring the micro-biological stability and sensorial acceptance of the cashew apples during storage at room temperature for 120 days (Mesquita et al., 2003).

The osmotic dehydration of cashew apples showed that the higher the concentration of the osmotic syrup (50, 60, and 70°Brix), induced higher water loses and solute gain during the same period of dehydration. The osmotic dehydration is a relevant factor in the processing of cashew because it removes the water by osmotic pressure and presents the advantage in the characteristics of color, taste and texture, and it also decreased the enzymatic darkness of the fruits during the dehydration process (Marques et al., 2007). The combined methods (bleaching, osmotic process, heat treatment, and storage) affect the major physical and chemical characteristics of cashew apple (Souza Filho et al., 1999). Changes were pH decrease, soluble solids and reducing sugars increase. Ascorbic acid loss was 23.3% after bleaching, 31.7% after one day osmosis, 35.5% after five days osmosis, 69.0% after heat treatment and 87.3% after 60 days storage at ambient temperature (~ 28°C). The reducing sugars, at the end of the period of storage, represented 83.1% of soluble solids value in the product.

The effects of different osmotic pretreatments on cashew apples, drying kinetics, and product quality were investigated. It was found that drying rates of pretreated fruits decreased owing to the presence of infused solutes. The osmotic pretreatment of the samples showed greater losses of vitamin C and lower levels of water activity (Moreira et al., 2009).

The cashew apples treated at high temperatures (100 to 180°C) showed that generating temperature profiles of heat processes would help to preserve the ascorbic acid content of cashew apples as well as the control of the color development during high-temperature processes (Lima et al., 2010).

Effect of processing on the nutritional quality of cashew juice: Clarification followed by membrane and enzymatic process

Membrane separation processes have been studied as alternatives to heat processes due to their characteristics being conducted at low temperatures, allowing the preservation of heat sensitive compounds, such as vitamins.

Comparing the processing performed in three steps: enzymatic treatment of the pulp, microfiltration for obtaining the clarified juice, and concentration of clarified juice by reverse osmosis showed that tannins were retained by microfiltration membrane and it was not verified in clarified and concentrated juice (Cianci et al., 2005). According to the authors, it is possible to obtain a clarified and concentrated cashew juice with high vitamin C content without using thermal processes, but microfiltration and the inverse osmosis. The sterile filtration and chemical preservation was efficient in decreasing astringency, microbial count, and in retaining nutritional quality of the juice, since soluble solids, total sugar content, and vitamin C are suitable for preservation of cashew apple juice up to three months under refrigeration (Talasila et al., 2011).The cross-flow microfiltration on mineral membranes for the production of clarified cashew apple juice showed that membranes produced a completely clarified juice in which the ascorbic acid content was very close to that of the fresh juice. In contrast, the phenols present at a great quantity in the raw cashew apple juice were almost completely eliminated during the process (Abreu et al., 2005). But the clarification of cashew apple juice using enzymatic treatment combined with microfiltration decreased the Vitamin C content whereas soluble solids, pH, and acidity were unaffected by the process (Campos et al., 2002).

Clarification of cashew apple juice using clarifying agents

The clarification of cashew apple juice by removing phenols and tannins is an important step in cashew apple processing, because these compounds are responsible for its astringency. Many clarifying agents recommended, such as sago (a refined commercial preparation of starch from cassava (*Manihot esculenta*), starch, gelatin, and poly vinyl pyrolidone (PVP) were used (Jayalekshmy and John, 2004). The clarifying agent, sago at a concentration of 2 g/L, decreased the tannins by 42.85% with visual clarity of 94%. The same clarifying agent with the same concentration along with sterile filtration decreased the tannins by 41.75% with improved visual clarity of 96% (Talasila et al., 2011). 'Sago', a natural commercial starch preparation, is an efficient clarifying agent. Tannin content of the juice clarified with starch was significantly higher than that of sago, PVP and gelatin (Jayalekshmy and John, 2004). The effects of dose of cassava and rice starch, incubation time at 30°C on clarity of cashew apple juice were investigated by Dèdéhou et al. (2015b). Cassava starch at 6.2 ml/l for 300 minutes decreased tannins content at 34.2% with visual clarity of 93.75%, while rice starch at 10 ml/l for 193 minutes decreased tannins content at 42.14% with visual clarity of 94.8%. The mechanism of separation of tannin from cashew apple juice is different from different clarifiers, and may probably explain the variations in the juice quality observed. For instance, PVP chelates tannins and sediment it at the bottom. However, starch owing to its great affinity for tannins, removes it from the juice through the technique of flocculation. The efficiency with which different types of starch remove tannins from the juice may vary depending on the size and arrangement of amylose and amylopectin chains. Furthermore, the organic compounds available in the natural starch grains may interfere negatively with the flocculation technique. Sago has further advantages of being substantially cheaper especially in comparison to the traditional use of PVP, which is both costly and to be imported (Jayalekshmy and John, 2004). In addition, clarification with PVP reduced both the chemical and sensorial quality of cashew apple juice (Gyedu-Akoto, 2011).

The clarification methods of cashew apple juices using tannase or gelatin revealed that juices treated with tannase showed a decrease in total tannin (46%), hydrolysable tannin (88%), proanthocyanidins(2%) and turbidity (88%) compared with 39, 50, 32, and 94% for those treated with gelatin, respectively. Therefore, treatment with tannase when compared with gelatin application was more efficient at reducing hydrolysable tannins, but less efficient at reducing proanthocyanidin levels in the juices. No visual differences were observed for the juices clarified by the two methods (Couri et al., 2003).

The effects of clarification with gelatin, PVP or the adsorbent resin XAD-16, singly or in combination, on the composition and the quality of the juice showed that treatment with gelatin alone (at a concentration of 2.7 to 3.0 g/L at 20°C) resulted in good clarification, and eliminated approximately 94% of tannins. The 2 resins gave the poorest elimination rates of tannins (24% for PVP and 4.3% for XAD-16). Treatment with gelatin followed by adsorbent resins gave a clear, stable and pleasant taste juice with no astringency. Tannin and protein contents were reduced by approximately 99%. These clarification treatments resulted in losses of nutrients, especially ascorbic acid (Quoc et al., 1999).

Effect of thermal treatment on cashew apple juice

The effect of thermal treatment on clarified cashew apple juice at temperatures from 88 to 121°C showed that increasing processing time increased the absorbance at 420 nm. Increasing temperature also showed the rise of browning rate measured at 420 nm. The results obtained for total sugars and the reduction of sugars did not show any definite tendency at any temperature used, and the steady concentration of sugars during thermal treatment showed that sugars did not react with amino acids and therefore did not affect browning. Increasing processing time and temperature had a significant effect on decomposition of ascorbic acid. The correlation of the change in absorbance at 420 nm with loss of ascorbic acid showed an inverse relationship, indicating that ascorbic acid may be the main factor that causes browning in clarified cashew apple juice (Damasceno et al., 2008). During the concentration of cashew apple juice in an industrial plant, 71 volatile aroma compounds were identified (Table 3); of these, 47 were odor active. Alcohols were preferentially recovered in the cashew water phase, notably heptanol: *trans*-3-hexen-1-ol and 3-methyl-1-butanol, accounting for 42% of the total chromatogram area and imparting green grass and fruity aroma in the water phase. Esters represented 21% of the total chromatogram area, especially ethyl 2-hydroxyhexanoate, ethyl *trans*-2-butenoate, and ethyl 2-methylbutanoate, and were responsible for the fruity/cashew-like aroma in the water phase. On the other hand, 3-methylbutanoic and 2-methylbutanoic acids were volatile acids that demonstrated the greatest odor impact in the GC effluents of the water phase (Sampaio et al., 2011). According to the authors, further concentration of esters recovered in the water phase, either by partial

Table 3. The volatile compounds identified in the aqueous phase of the cashew juice by chromatography of the different areas expressed by percentage (Sampaio et al., 2011).

Linear retention indices (LRI) (DB-Wax)	Compound	% Area (FID)
-	Ester	20.99
<1000	Ethylpropanoate b	0.12
<1000	Ethyl 2-methylpropanoateb	0.16
1010	Methyl 2-methylbutanoateb	Tr
1014	Methyl 3-methylbutanoatea	0.15
1032	Ethylbutanoatea	0.17
1048	Ethyl 2-methylbutanoatea	0.97
1067	Ethyl 3-methylbutanoatea	3.31
1115	Methyl*trans*-2-butenoateb	0.03
1127	Isoamylacetatea	0.05
1166	Ethyl*trans*-2-butenoatea	0.04
1182	Ethyl 3-methylpentanoateb	0.04
1203	Methyl 2-ethylacrylatec	Tr
1237	Ethylhexanoatea	0.69
1239	Ethyl*trans*-2-methyl-2-butenoatea	-
1298	Ethyl*trans*-3-hexenoateb	0.05
1338	Ethyl*trans*-2-hexenoateb	0.09
1407	Ethyl 3-hydroxy-3-methylbutanoatec	0.24
1429	Ethyloctanoateb	Tr
1486	Methyl 2-hydroxy-3-methylpentanoateb	0.03
1522	Methyl 2-hydroxy-4-methylpentanoatec	0.34
1547	Methyl 2-hydroxy-4-methylpentanoatec	13.97
1596	Ethyl 2-hydroxyhexanoateb	0.12
1662	Ethyldecanoateb	Tr
1696	Ethyl 3-hydroxyhexanoateb	0.04
1800	2-Phenylethyl acetateb	0.08
1936	3-Phenylpropyl acetatec	Tr
2134	Ethylcinnamateb	0.30
-	Alcohol	42.06
1038	2-Methyl-3-buten-2-olb	0.29
1096	2-Methyl-1-propanola	1.62
1119	3-Pentanolb	0.05
1159	1-Butanola	036
1173	1-Penten-3-olb	0.98
1178	3-Buten-1-olb	0.72
1226	3-Methyl-1-butanola	24.03
1262	1-Pentanola	0.95
1314	*Trans*-2-Penten-1-olb	0.10
1318	4-Methyl-1-pentanolb	0.29
1323	Cyclopentanolc	0.91
1330	3-Methyl-1-pentanolb	0.56
1359	Hexanolb	4.11
1366	*Trans*-3-Hexen-1-olb	0.94
1388	*cis*-3-Hexen-1-ola	4.52
1409	*Trans*-2-Hexen-1-olb	0.36
1460	Heptanolb	0.14
1502	2-Ethyl-1-hexanolb	0.10
1566	1-Octanola	0.39
1907	Phenylethylalcoholb	0.45
2049	3-Phenyl propanolb	0.19

Table 3. Contd.

-	Aldehyde	1.94
1074	Hexanala	0.11
1141	2-Methyl-4-pentenalc	0.12
1209	*Trans*-2-Hexenalb	1.54
1451	Furaldehydeb	0.17
-	Ketone/lactone	12.88
<1000	2,3-Butanedioneb	3.30
1055	2,3-Pentanedioneb	0.07
1282	3-Hydroxy-2-butanonea	7.08
1628	Acetophenoneb	0.38
1721	*γ* -Hexalactoneb	Tr
2025	*γ* -Nonalactoneb	Tr
-	Acids	12.62
1445	Aceticacidb	Tr
1566	2-Methylpropanoic acidb	Tr
1667	3-Methylbutanoic acidb	11.63
1667	2-Methylbutanoic acidb	-
1846	Hexanoicacida	0.34
1873	Benzylicacidb	0.03
2058	Octanoicacidb	0.27
2176	Nonanoicacidb	0.08
2271	Decanoicacidb	0.27
2484	Undecanoicacid	Tr
2560	Phenylaceticacidb	Tr
-	Hydrocarbon	0.11
-	Unidentified compounds	5.09
1379	NI	1.05
1414	NI	Tr
1513	NI	2.85
1951	NI	Tr
2437	NI	1.19

NI: Compound not identified; tr: detected in trace amounts (<0.01%). [a]Compound positively identified (pure standard). [b]Compound identified by MS and linear retention index. [c]Compound tentatively identified.

distillation or by alternative technologies, such as per-evaporation, could generate a higher-quality natural cashew apple essence. Besides, among the 19 carotenoids identified in the unheated simulated cashew apple juices, with all-trans-b-cryptoxanthin and all-trans-b-carotene as the major ones, heating caused the loss of five xanthophylls, whereas two new cis isomers and five epoxides or furanoid-derivatives were formed and the levels of all cis isomers increased but the amounts of total carotenoids lost were not compensated by those formed. These facts indicated that isomerization and oxidation of both colored and non-colored compounds were the main reactions occurring during heating of carotenoids in aqueous-based and juice systems (Zepka and Mercadante, 2009).

STORAGE STABILITY OF CASHEW APPLE JUICE

The test of the efficiency of chemical preservatives in combination (sodium benzoate and sodium metabisulphite at 0.1 g/L each, sodium benzoate and citric acid at 0.1 g/L each and sodium metabisulphite and potassium metabisulphite at 0.05 g/L each) prolonged shelf life of cashew apple juice up to 20 days. Vitamin C and total sugars of the preserved samples were found to be almost stable. Sensory attributes also revealed good overall acceptability of the juice (Talasila et al., 2012). The shelf life of juice treated with citric acid and benzoic acid at 0.1 g/L each and stored at 4°C was prolonged up to 90 days (Talasila et al., 2011).

Cashew apple juice first hydrolyzed and then microfiltered in a 0.3-μm pore size tubular membrane and stored at lower temperature was still appropriate for consumption after 2-month shelf life, as a vitamin C source and without any haze (Campos et al., 2002).Ultrasound treatment has a potential to be used as an alternative non-thermal technique for traditional thermal pasteurization process for maintaining the quality of beverages prepared from fruit and vegetable juices (Gao and Rupasinghe, 2012).

Storage temperature (frozen, refrigeration or room temperature) differently affect physico-chemical stability of cashew apple juices. For example, the storage of cashew apple juices kept at room temperature for 24 h, refrigerated for seven days or frozen for 120 days showed that the ascorbic acid content in fresh cashew apple juice was 147.29 ± 0.41 mg/ 100 ml and decreased to 6.57% when kept under room temperature. For the juices stored when refrigerated and frozen, reduction rates of ascorbic acid were 1.16%/day and 0.05%/day, respectively. However, the cashew apple juices stored at 4°C reduced polyphenol oxidase (PPO) activity and hydrolyzed cinnamic acid. 5-Hydroxymethylfurfural content in cashew apple juices increased after injury and storage at higher temperatures, indicating non-enzymatic browning. For microbiological stability, in the juices kept at room temperature, an increase in the counts of mesophile bacteria and yeasts and moulds was observed. In the juices stored when refrigerated for seven days, mesophile bacteria counts decreased and yeast and mould counts increased. In the frozen juices, the yeasts and moulds counts remained lower than the initial counts, while mesophile bacteria counts showed decreased variation up to the thirteenth day, and then remained stable (less than one logarithmic cycle) above the initial count (Lavinas et al., 2006).

THE USE OF CASHEW PRODUCTS FOR HUMAN

Fortifying the nutritional quality of some tropical foods

Cashew apple juice is generally used in fortifying some tropical fruits when mixed with other tropical fruits low in vitamin C (for example, pineapple, mango), raised the nutritional quality (Akinwale, 2000).

A ready-to-drink cashew apple juice sweetened with honey in substitution to saccharose showed in the stability studies, that the product maintained good acceptability until the end of the storage period, with regards to the attributes of color, flavor, overall acceptability and the purchase intention. The product maintained satisfactory microbiological quality, in agreement with the current Brazilian legislation. The physicochemical changes did not characterize the lack of stability of the product, except for vitamin C content, which showed an accentuated decrease at the end of storage (Silva et al., 2008).

Mucamalt (malt drink belongs to the category of brewed drinks that are considered non-alcoholic beverage drink, fortified with vitamin C and other minerals that are of benefit to human health) can be produced with vitamin C obtained from cashew apple fruits(Abdulraheem et al., 2013). Cashew apple juice was also used in the formulation of coconut water/cashew apple juice blends containing 100 ppm of added caffeine. The formulation with 12.5% cashew apple juice and 87.5% coconut water reached the highest hedonic scores. All formulations showed good microbiological quality. The vitamin C content showed a great difference among the formulations which vary according to the proportion of cashew apple juice used (Carvalho et al., 2006).

Cashew apple residues from fruit juice industry as dehydrated fruit powders can be used for wheat flour substitution for cookies formulations. pH, fiber, and protein contents were significantly affected by fruit powder substitution levels during the biscuit-type cookies process. However, cashew apple waste from fruit juice industry can be useful to prepare cookies with good acceptability among consumers. Therefore, the fruit powder addition in biscuit-type cookies formulation seems to be better suited for cookie process and enrichment, since it is possible to use them as partial ingredients for wheat flour substitution as well as functional ingredients in formulated foods (Uchoa et al., 2009).

Other uses

The utilization of cashew apple juice for bioethanol production with optimized fermentation parameters (substrate concentration 10%, pH 6.0, temperature 32.5°C and inoculum level of 8% (v/v) on 24 h which gives maximum yield of ethanol 7.62%, respectively) using immobilized yeast cell technology by *Saccharomyces cerevisiae* was established (Neelakandan and Usharani, 2009). *Acinetobacter calcoaceticus* was able to grow and to produce bio-surfactant on a defined culture medium and on cashew apple juice, reducing the surface tension of both media (Rocha et al., 2006).

Cashew apple juice revealed to be efficient as dairy product for *Lactobacillus casei* growth. The fermented juice with *L.casei* is a good and healthy alternative functional food containing probiotics. *L. casei*was able to overcome the natural microbiota of cashew apple juice dismissing thermal treatment, and thus, reducing the production costs. The fermentation optimal conditions were: initial pH 6.4, fermentation temperature of 30°C, inoculums size of 7.48 Log CFU/ml and 16 h of fermentation (Pereira et al., 2011). However, cashew apple juice is a good source of reducing sugars and can be used as substrate for the production of dextransucrase by *Leuconostoc citreum* B-742 for the synthesis of oligosaccharides using the crude enzyme (Rabelo et al., 2009), with *Leuconostoc mesenteroides* (Honorato et al., 2007b; Kuila et al., 2011). Cashew apple juice can be used to grow *L. mesenteroides* to produce dextran, mannitol, and oligosaccharides (Honorato et al., 2007b).

Cashew apple juice containing *in vitro* synthesized oligosaccharides can be used as raw material or as ready-drink beverage or as food ingredient in other products by enzymatic process with addition of dextransucrase enzyme (Honorato et al., 2010) or for *L.casei* B-442 culture and lactic acid production (Silveira et al., 2012). Also, it is feasible to produce surfactin from cashew apple juice by *Bacillus subtilis* LAMI005 (Giro et al., 2009) and to extract sugar (Kuila et al., 2011).

Based on the level of sugar, crude protein, trace metal constituents, and its ability to support the growth of yeasts, the use of cashew apple juice as feed-stock for single cell protein and for wine production was suggested (Silveira et al., 2012).

CONCLUSION

Cashew (*A.occidentale*L.) apple is a good source of antioxidant compounds, reducing sugars, minerals, and some amino acids. Several parameters, such as genetic and climatic variations as well as ecological zones and ripening stage can significantly affect the chemical composition of cashew apples. The quality of post-harvested cashew apples has been influenced by the production systems. Cashew apple is subjected to several processes after the harvest which influences its physico-chemical characteristics and quality attributes. There are many traditional and industrial ways of removing the astringency of cashew apple juice, while clarifying the juice. It is important to encourage the valorization of cashew apples in developing countries by the improvement of the process of cashew apples available in these countries in order to contribute to the nutritional needs of the populations.

Conflict of Interests

The authors have not declared any conflict of interests.

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