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Some Processing Steps and Uses of Cashew Apples: A Review

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Abstract

In addition to the cashew nut, which is the main product, the cashew tree also produces the cashew apple which is considered a by-product. The cashew apple has a high nutritional potential. Indeed, it is rich in vitamin C, carotenoids, dietary fibers, vitamins, sugars and mineral elements where are essential for human nutrition. In addition to its nutritional quality, the cashew apple has technological advantages: the edible part of the fruit is between 85% and 100% higher than that of other traditional tropical fruits, and its juicy and sweet flesh is free of seeds or pits. In addition, very large volumes are available. As a result, the development of this fruit represents a considerable economic challenge. This paper first presents the cultivation of cashew trees and the bibliography of the work done on cashew juice. The favorable conditions for cashew tree cultivation and the planting method were presented. Then, the study highlights the work done on the physicochemical characteristics of cashew apples, the effect of the growing area, the variety and the stage of maturity on its characteristics. It also shows the influence of the processing steps on the nutritional value and organoleptic quality of the cashew apple; as well as the methods of clarification, stabilization, concentration and dehydration. Some uses of cashew apple were reviewed: beverage, food, substrate, bioethanol, nutraceutical, food additive and agro materials.

Keywords

Cashew Apple, Processing, Use

1. Introduction

The cashew tree (*Anacardium occidentale* L.) is a tree originating from Brazil. It was discovered by the Portuguese who introduced it into their colonies in Africa and Asia [1].

It is a dicotyledonous plant of the order Sapindales and the family Anacardiaceae to which the mango and pistachio trees also belong [2].

The French naturalist Thévet described the tree and provided the first drawing showing the natives harvesting the nuts and squeezing the juice from the cashew "apples" into a large container in 1558. Gandavo, in 1576, was the first Portuguese writer to describe the nuts and assure that they were better than almonds [3]. The Tupi Indians of Brazil called the cashew tree "acaju". This name became "caju" in Portuguese, "cashew" in English, "cajuil" in Spanish and "acajou" or "cashew" in French. The latter term is actually used because the former also refers to a well-known precious wood [1].

The cashew tree can grow up to about 10 meters and its trunk diameter can vary between 1.2 and 1.5 m [4]. It is hardy, but grows best in hot tropical areas with alternating dry and wet seasons. It adapts to a variety of soils, but prefers light, sandy, deep, well-drained soils with a clay content of 25% [1]. It can be grown for fruiting or for reforestation and has a life span of about 30 years [4].

The main producing countries are Côte d'Ivoire, Vietnam, Nigeria, India and Brazil.

This tree produces fruits composed of two parts: the cashew nut called "true fruit" and the cashew apple "false fruit" which is about 9 times the weight of the nut [5].

Cashew nuts (kernels) are the main commercial product of this tree. It consists of a kernel and a shell. The roasted kernel can be used in a variety of ways (confectionery, pastries, and cashew butter) or roasted, salted and eaten alone or mixed with other nuts or dried fruits. While the shell yields cashew nut shell liquid (CNSL), also a high value-added product, highly acidic and corrosive, used in the manufacture of friction elements [2].

After the nut develops, its stalk becomes enlarged and changes color to give a "false fruit" known as the cashew apple. When ripe, this cashew apple is red, yellow or orange in color. Whatever the color, the flesh is yellow.

The shape of this false fruit is round or pear-shaped, hence the name Anacardium, which means "heart-shaped", and it can be up to 10 centimeters long and 5 centimeters wide. The weight of a cashew apple is generally between 70 and 90 grams [4].

The cashew apple has a high nutritional potential. Indeed, it has great antiscorbutic qualities due to its vitamin C content (200 and 300 mg per 100 grams of fresh material) which is about five times higher than that of an orange. This is used to "fortify" juices of other fruits low in ascorbic acid [6]. It is also rich in polyphenolic compounds (tannins), some of which are responsible for its characteristic astringency, carotenoids, dietary fibre, vitamins, sugars and mineral elements essential for human nutrition [4] [7] [8] [9] [10]. The intensity of sweetness and astringency is quite variable depending on the variety and the stage of ripeness [4]. The ripe cashew apple has a very particular odor due to its content of aroma compounds [11].

The processing of cashew apples is limited by the characteristics of the fruit. Indeed, its tannin content gives it a particularly strong astringency. In addition, the very high content of reducing sugars (glucose and fructose) in it, which are precursors of the Maillard reaction and non-enzymatic browning, poses a problem of color when the fruit is processed into juice. Also, the very short shelf life of cashew apples at room temperature, between 24 hours and 48 hours maximum, is the main limiting factor for quality, both for fresh sales and for processing [4].

However, the cashew apple, despite its great fragility, has many advantages. In addition to its nutritional quality and medicinal properties, the apple has technological advantages: the edible part of the fruit (between 85% and 100%) is higher than that of other traditional tropical fruits, and its juicy and sweet flesh is free of seeds or pits. Moreover, very large volumes are available [4].

Thus, the valorization of this false fruit, often considered as a by-product of nut exploitation, represents a considerable economic challenge. Therefore, in order to explore the full potential of the cashew apple, it is necessary to know what work has already been done.

In this review, we first look at bibliometrics to know in particular the publications made in recent years and the main fields of application of cashew apple juice. Then, the review presents the physico-chemical characteristics of cashew apples as well as the influence of the growing area, varieties and maturity stage on the said characteristics. We conclude with the processing of cashew apples and the various uses.

2. Culture

The cashew tree grows preferably at altitudes below 1000 meters, in areas with a warm tropical climate, with alternating dry and wet seasons. It adapts to a variety of rainfall patterns, but for good fruiting, an annual rainfall of between 760 and 1800 millimeters is preferable. The cashew tree adapts to various soil types. It does not require rich soil but prefers light, sandy, deep, well-drained soils with a clay content of 25%. On lateritic breastworks and shallows it vegetates as its pivot is sensitive to indented obstacles and flooding. Favorable pH ranges from 4.5 to 6.5. It can be sensitive to magnesium deficiency but is recognized as a hardy tree, adapted to many tropical areas, as it is not very sensitive to drought: a 6 month dry season favors fruiting and allows good seed storage [4]. On the other hand, the plant, which can withstand temperatures ranging from 12 to 32˚C, is sensitive to temperature variations as well as to the cold [4].

For cashew cultivation, the choice of seeds to be sown is made using the flotation test, which consists of putting the nuts in a bucket of salted water (a 10% salt solution) and using only the nuts that sink straight down. Before planting cashew seed, it should be left for 24 to 72 hours in water at room temperature, which accelerates the lifting of dormancy and the seed germinates more quickly [1].

Staggered planting is recommended; this method consists of planting the nuts with a spacing of 12 meters in the row and 11 meters between the rows. This method is considered the most economically profitable and facilitates thinning at the age of 10 - 14 years, and allows the trees to be well distributed so that they benefit more from the sun [1].

The actual sowing can be done in two ways: either by direct sowing in the soil in a plantation or by nursery in a bag. In both cases, the seeds must be planted vertically. The point of attachment of the seed to the apple should be at the top. A minimum of 3 seeds should be planted; the plants will compete with each other and the best will grow faster than the others. When it is well identified, the others can be removed and only one plant is left at the end [1].

Furthermore, some producer countries have realized that cashew plantations grown from seed have a number of disadvantages, including heterogeneous production, low production yields and a high rate of atypical plants [5]. These countries have undertaken varietal selection programs based on criteria such as: production yield, resistance to certain diseases, fruit size, physicochemical characteristics of cashew nuts and apples, and tree height.

3. Bibliometry

The bibliometric analysis base on "SCIFINDER" database made it possible to ensure that the theme "Study of the impact of the cultivation area on the nutritional value of cashew apples with a view to its valorization" is relevant. Indeed, 212 publications relating to the term "cashew apple juice" have been made since 2000. Moreover, this theme is used in 18 areas.

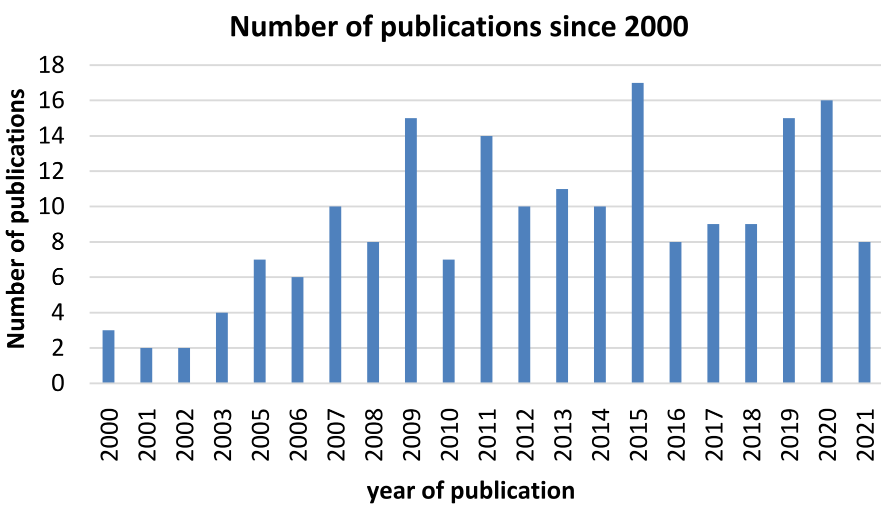

Figure 1. Number of publications per year since 2000.

The analysis of **Figure 1** shows that the number of publications has been increasing since 2003, which demonstrates that the interest of authors in cashew apples is growing over the years.

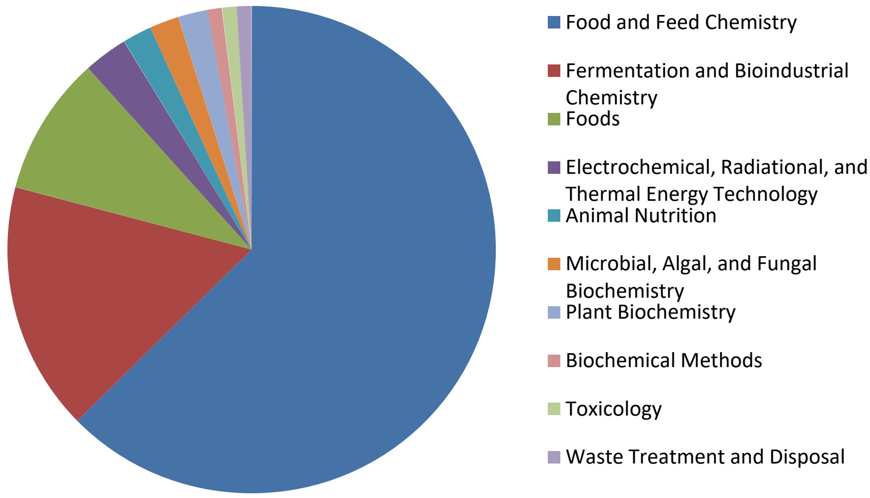

Figure 2. Main areas of application.

Cashew apples are used in various fields, the main ones being: food chemistry, bio-industrial chemistry, nutrition, electrochemical energy technology, animal nutrition, microbial biochemistry, biochemical methods and toxicology (**Figure 2**).

4. Physical and Chemical Characteristics of Cashew Apples

Some studies have focused on the physicochemical characteristics of cashew apples.

Studies conducted on the physicochemical composition of cashew apples produced in South Africa gave a pH in the order of 4.52; a condensed tannin concentration of 55.34 mg/L; a vitamin C content is 112 mg/100ml, total mineral and protein concentrations which are 15.89 ppm and 1.78 g/L respectively [7]. These values are different from those found by Lowor on cashew apples in Ghana in which the pH is 4.15; condensed tannins and vitamin C concentrations range from 145.30 to 306.4 mg/L; and 206.20 to 268.6 mg/100ml respectively [12].

In Côte d'Ivoire, the physicochemical characteristics of yellow cashew apples from the Yamoussoukro area were determined by Adou *et al.* in 2017; these are pH 4.43; vitamin C 476.3 mg/100g; dry matter 10; ash content 1.5; refractometric dry extract 10.9; total sugars 168.1 g/L [9]. For the Zanzan region, other authors found roughly the same values for pH 4.0; dry matter 9.5; ash content 1.43. Different values for vitamin C of 276.73 mg/100g, dry extract refractometry 14.4; total sugars 364.88 g/L. In addition to these parameters, Lautié also determined the values of other physicochemical parameters presented in the following **Table 1**.

5. Geographical and Varietal Effects

The results of the study conducted on red and yellow apples in three regions of Côte d'Ivoire showed that, with the exception of the red variety cashew apple juice from the Marahoué region with a refractometric dry extract of 9.66 ± 0.28

Table 1. Composition of cashew apples [4].

Compounds	Content per 100 g of fresh material
Soluble dry extract	10 à 12 g
pH	4.2 à 4.4
Titratable acidity (malic acid)	0.33 à 0.59 g
Reducing sugars	7.8 à 8.6 g
Dietary fiber	2.6 à 3.1 g
Tannins	0.29 à 0.38 g
Proteins	0.7 à 0.8 g
Vitamin C	200 à 300 mg
Calcium	10 à 40 mg
Iron	0.4 à 3.0 mg
Phosphorus	10 à 30 mg

˚Brix, the refractometric dry extract (RDE) values of the apple juices are above 10 ˚Brix which is the minimum value required by the Brazilian legislation [13].

As for vitamin C, the apple juices from the Marahoué region have the highest content with a predominance for the yellow cashew apple juice samples (403.54 ± 8.88 mg/100g juice). This value is lower than that obtained by some authors who obtained 476 mg/100g [9]. According to Nagy, the difference in vitamin C content of the different zones would be influenced by the intensity of the sun because vitamin C is a thermolabile compound and therefore sensitive to heat [14]. Of the three ecological zones studied, the Marahoué region is the region with the lowest sun intensity compared to the other two zones.

The polyphenol contents are in the range of 1587.59 ± 76.99 to 3043.03 ± 69.87 mg/L of apple juice; these values are lower than those found by some authors which are 2506.510 to 4247.690 [15]. The juice of the yellow variety from the Gbèkè region has the lowest total polyphenol content (1587.59 ± 76.99 mg/L) while that of the red variety from the Zanzan region has the highest total polyphenol content (3043.03 ± 69.87 mg/L) [13].

The biochemical characteristics of the juices of yellow and red cashew varieties from different growing areas highlight the influence of the variety (color of the apples) and the growing area on certain biochemical parameters. Indeed, some parameters are influenced by the variety for their presence and by the growing area for their content. Other parameters are mainly influenced by the growing area. This shows that the composition of apple juice can be strongly influenced by its origin [15].

6. Effects of Stage of Ripeness

Some authors analyzed the changes in the physicochemical properties of the juice of two apple varieties (yellow and red) from Yamoussoukro, at different stages of maturity. The results show that the vitamin C content varies between 370.9 and

480.3 mg/100g; total sugars vary from 162.7 to 168.1 g/L. The concentrations (g/L) of glucose, fructose and sucrose varied from 47.2 to 65.8; 100.7 to 110.3 and 2.5 to 5.3 respectively. In terms of organic acids, citric acid was the highest with levels ranging from 290.7 to 1092.1 (μg/ml); followed by tartaric acid 497.5 to 693.3; acetic acid 48.2 to 266.5, oxalic acid 197.8 to 204.3 and finally fumaric acid. The pH of the juice is between 4.37 and 4.5, the titratable acidity between 0.5% and 0.85%, the total soluble solids content between 10.2 and 10.9 ˚Brix; dry matter between 7.80% and 10.0% and ash from 1.31% to 1.88%. The protein content varied from 0.51 to 0.53 g/100g and the main amino acids in order of size were leucine, cysteine and asparagine.

These results showed that apart from pH, color and maturity of the apples significantly ($p < 0.05$) influenced the analyzed parameters [9].

Some authors have studied the influence of the degree of ripeness (ripe and lightly ripe apples) and inter-morphotype variations (red, yellow and orange) on the physicochemical composition of cashew apples. The ripeness index of the apples varied from 20.19 to 44.17. The results showed that the yields of juice and pressing residues varied from 76% to 86% and from 10% to 16% respectively. The total sugar content ranged from 60.49 to 64.14 g/l. The concentrations (mg/l) of polyphenols, flavonoids and condensed tannins vary from 2506.510 to 4247.690; 134.60 to 450.95 and 130.30 to 614.70 respectively. The pH of the juice is between 3.37 and 4.52; the total titratable acidity varies from 0.24% to 0.61% citric acid; the refractometric dry extract content from 8.2 to 10.2 ˚brix, dry matter from 7.20% to 8.43% and ash from 0.15% to 0.23%.

Generally, the degree of ripeness and the color have a significant influence on the parameters measured. Mature cashew apples have a fairly high ash content and a high sugar potential. This sugar richness makes cashew apples, especially the orange morphotype, a preferred substrate for fermentation for the production of spirit drinks [15].

7. Effect of Processing on the Physicochemical Characteristics of Cashew Apples

Cashew apple can be processed into various products: juice, alcohol, wine, vinegar, fruit pastes, preserves in syrup, jellies, jam, powder, functional foods, [4] [10] [16] [17], agro materials [18], etc.

The main processing stage of the cashew apple is the cashew juice during which certain physicochemical characteristics are more or less preserved. This transformation is done through extraction and clarification, followed by fermentation, concentration and dehydration depending on the use.

7.1. Extraction of Cashew Apple Juice

Cashew apples are either harvested from the trees or collected from under the trees. The nuts are carefully separated from the apples to avoid injury. They are transported in baskets, cleaned, washed and disinfected for 30 minutes with 100 ppm active chlorine in tanks. They are then rinsed with water before being crushed.

Cashew juice is extracted on an industrial scale using a screw press. However, studies conducted by Padonou have shown that the use of a device, that combines prior crushing pressing by a hydraulic type press improves both the processing yield and the nutritional quality of the final juice obtained [19], for artisanal extraction of cashew apple juice.

Furthermore, the extraction yield decreases when the storage time of cashew apples increases. The decrease in yield can be explained by the loss of water from the cashew apples. Indeed, once harvested, cashew apples are very fragile. Storage at room temperature (28˚C - 30˚C), would favor transpiration phenomena but also a loss of juice at the point where the cashew apple was attached to the nut (cutting wound) [5].

7.2. Clarification of Cashew Apple Juice

Cashew juice after extraction has a cloudy appearance, so there is a need to clarify it to make it more attractive and to remove the phenols and tannins that are responsible for its astringency. Thus, several clarification methods have been developed by researchers.

For some authors, rice porridge as a naturally occurring clarifying agent can better replace industrial clarifying agents for cashew juice production [20].

Other authors have used gelatin and cashew gum for clarification of cashew apple juice. The results show a significant reduction in tannin and protein content up to a concentration of 2.439 g/L gelatin. Above this concentration, the tannin and protein content increases progressively for concentrations above 4.762 g/L gelatin. The tannin and protein content decreases as the amount of gum used increases up to 4.762 g/L. Above this level, the protein and tannin concentrations increase very slightly in the juice. This work revealed that the effective concentrations of gelatin and cashew gum used for clarification of cashew apple juice are 2.439 g/L and 4.762 g/L respectively.

After treatment, the clarity of the cashew apple juice increased from 4.60% ± 0.12% for the raw juice to 78.00% ± 0.17% and 57.4% ± 0.12% for the juice clarified by cashew gum and gelatin respectively. Thus, it appears that the juice treated with cashew gum has more clarity than that treated with gelatin. Furthermore, the clarification treatment with gelatin leads to a decrease in the total sugar content, whereas clarification with cashew gum has less impact on the total sugar content. The pH of the juice is not affected by the clarification treatments with both gelatin and cashew gum [21].

The use of macroporous resin allowed the removal of condensed tannins present in cashew apple juice up to 80% under optimal conditions (30˚C, ratio 1: 6, 122 rpm) [22]. This result is superior to that obtained with the use of immobilized tannase, which removed 51% of tannin, after incubation at 40˚C for 120 minutes. However, acidity, color and viscosity decreased, while flavonoids, glucose and antioxidant activity increased significantly [23].

Pressure gradient membrane techniques that are: microfiltration (MF), ultrafiltration (UF) nanofiltration (NF) and reverse osmosis (RO) can be used for clarification and filtration of cashew apple juice [3] [5] [24] [25].

7.3. Storage Stability of Cashew Juice

The very short shelf life of cashew apples at room temperature, between 24 h and 48 h maximum, is the main limiting factor for quality, both in terms of fresh sales and processing. The deterioration of the quality of the product is very rapid due to the physiological characteristics of this plant organ. The fruit is characterized by a particularly high respiratory intensity, which is higher than most tropical fruits. In addition, its high water content and pH of around 4.2 are quite favorable to microbial growth. After a treatment to reduce the microbial load of surface treatment (citric acid and bisulphite bath, sorbic acid or chlorinated water), the optimum conditions for preservation are low temperature (down to 0˚C - 2˚C) and high relative humidity of around 90% [4].

For its use in the industry and to improve the shelf life of the juice, some authors have described conditions to ensure good storage stability of cashew juice: packaging or use of chemical preservatives.

Talasila used Aloe vera juice and hydroxychavicol after sterile filtration to extend the shelf life of cashew apple juice. This juice was stable with preserved nutritional quality and medicinal properties for 45 days [26].

Cashew apple juice pasteurized at 80˚C for 15 min in a water bath was packaged in different packaging materials: green (G), brown (B), white (W) bottles and polyethylene sachet (S) in batches of 200 ml and stored for four months at room temperature (28˚C) and refrigeration (4˚C) to study the effect of packaging materials on the color and sensory qualities of cashew apple juice (CAJ). The results showed that cashew apple juice can be stored in green and brown bottles for up to four months at refrigeration temperature and retain its vitamin C content, pH, color and sensory qualities; and stored in a polyethylene bag but not longer than two months [3] [27].

Different combinations and concentrations of chemical preservatives (from 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) were used to extend the shelf life of cashew apple juice to 20 days. Vitamin C and total sugars in the preserved samples were found to be almost stable; sensory attributes were also acceptable [28].

The stability of unfermented cashew juice (control) and juice fermented with Lactobacillus casei NRRL B-442 (sweetened and unsweetened samples) was studied along storage at 4˚C for 42 days. The viability of probiotic bacteria, sugars, lactic acid and vitamin C content in addition to color, antioxidant activity, enzymatic activity and sensory characteristics of the probiotic cashew apple juice were evaluated. It was found that the fermented cashew juice showed more stability (viability of probiotic bacteria, sugars, lactic acid and vitamin C content, color, antioxidant activity, enzymatic activity and sensory characteristics) when stored at 4˚C for 42 days, than the unfermented cashew juice [29].

Three samples of unpasteurized cashew juice were pre-treated with 1% Garlic and Ginger Filtrate, 1% sodium benzoate and 1% ascorbic acid. All samples were stored on the tray at 26˚C ± 2˚C for 5 weeks. The pH, total titratable acidity, Total Soluble Solids and microbial load counts were measured weekly. The results showed that the pH of the unpasteurized cashew juice from garlic treated with ginger was relatively stable for 3 weeks. The garlic-ginger filtrate was the most effective preservative, followed by ascorbic acid and sodium benzoate, without microbial and physicochemical deterioration for 3 Weeks [30].

7.4. Heat Treatment of Cashew Juice

Heat treatment of cashew apple juice results in the decrease of compounds such as anacardic acids, sucrose, malic acid, Tyrosine, phenylalanine and important flavor compounds (esters, aldehydes and ketones) [31].

During the heat treatment of cashew juice, the thermal degradation of carotenoids leads to the formation of volatiles that influence the aroma and flavor of heat treated cashew [32].

7.5. Fermentation of Cashew Juice

Cashew juice is generally used to produce alcohol or alcoholic beverages by fermentation using micro-organisms.

Work by some authors has revealed that the yeast *Saccharomyces cerevisiae* var. Bayanus showed the highest efficiency (96.025%), the highest productivity (1.604 $g \cdot L^{-1} \cdot h^{-1}$), the highest ethanol yield (0.491 $g \cdot g^{-1}$) and the highest substrate consumption (2.067%$\cdot h^{-1}$). The study shows that the yeast *Saccharomyces cerevisiae* var. Bayanus has the best bioconversion performance of fermentable sugars into ethanol [10] (Dedehou *et al.*, 2015). Ethanol has also been produced from the fermentation of cashew apple juice by the flocculant yeast *Saccharomyces cerevisiae* CCA008 [33] [34] [35] [36].

Other authors have carried out the fermentation of cashew apple juice by *Lactobacillus plantarum* at 11.4 ˚Bx. The result shows that total phenols remained unchanged throughout the fermentation period, while condensed tannins increased and hydrolysable tannins decreased indicating a reduction of astringency compounds in the resulting juice [37].

Other studies have compared fermented cashew apple juice with unfermented cashew apple juice, showing that the former has more stability (viability of probiotic bacteria, sugars, lactic acid and vitamin C content, color, antioxidant activity, enzymatic activity and sensory characteristics) when stored at 4˚C for 42 days, than unfermented cashew apple juice [29].

Authors have produced cashew wine by fermenting cashew apple juice with *Saccharomyces cerevisiae*, the acetic acid in the resulting cashew wine underwent spontaneous natural fermentation to yield vinegar [38].

7.6. Concentration of Cashew Juice

Concentration of cashew apple juice changes the aroma and flavor of the drink, compromising its acceptability to the consumer. To understand the mechanisms involved in these changes, studies characterized the dynamics of loss and emergence of volatile compounds during cashew juice concentration, reporting their impact on the sensory quality of the beverage. Five samples were taken throughout the concentration process following the soluble dry extract content: 11.8 ˚Brix, 14.9 ˚Brix, 20.2 ˚Brix, 29.6 ˚Brix and 42.1 ˚Brix. The results indicated that esters were the main component of the Juice (226.46 µg·kg/1) representing 45.0% of the total volatile mass, followed by terpenes (118.98 µg·kg/1), acids (45.23 µg·kg/1), aldehydes (39.10 µg·kg/1), alkanes (18.91 µg·kg/1), lactones (19.15 µg·kg/1), hydrocarbons (18.02 µg·kg/1) and ketones (11.05 µg·kg/1). In beverages concentrated to 20.2 ˚Brix or higher, there is an increase in the intensity of flavor and in the concentration of hydrocarbons, alcohols and some aldehydes generally associated with them. This raises the possibility that some of these components may have been formed during juice processing. Juice with better sensory quality was obtained by concentrating cashew juice to levels below 20.2 ˚Brix, recovering the esters that evaporate out of the juice to about 15 ˚Brix, and adding them to the concentrated juice [11].

Authors have shown the impact of coupling tangential microfiltration and vacuum concentration on juice quality. Microfiltration tests were carried out on raw cashew apple juice followed by its concentration under vacuum at different temperatures (40˚C, 60˚C and 80˚C). The different juices (clarified and concentrated) obtained were characterized and compared to the raw juice. The results show that tangential microfiltration allows the removal of tannins and therefore astringency without affecting the nutritional value of the juice. Concerning the concentration by vacuum evaporation, it has no influence on the titratable acidity, whatever the temperature. However, it does affect the vitamin C content, color and flavor profile of the juice. This process induces increasing losses of vitamin C depending on the temperature used. Regarding color, concentrated juices have a high absorbance between 400 and 480 nm. The higher the evaporation temperature, the higher the absorbance. Finally, the aromatic profile of juice concentrated by vacuum evaporation is more modified compared to juice clarified by microfiltration [5].

Furthermore, work has shown that the concentration of the liquid extract obtained from cashew apple fibres, by microfiltration increases the carotenoid content compared to the initial cashew apple [39].

7.7. Dehydration of Cashew Juice

Cashew apple juice was subjected to foam drying to study the effect on the physical, nutritional and sensory properties of the juice powder. Improved Brazilian cashew varieties, soybean and fresh eggs as raw materials were obtained in Anyigba, Nigeria. The fruits were prepared into pulpy juice (30% - 35% solids). While soybean and egg were prepared as soy protein isolate and liquid egg albumin respectively as foaming agents at 2 Concentrations (1.0% and 2.0% pulp juice). The mixture of juice and foaming agent was whipped in a blender for 10 minutes, together with the control sample. The resulting stable foam was dried (60˚C) in a tray dryer, ground to a powder (375 μSize), packed (HDPE) and stored at room temperature for up to 2 weeks for physical, nutritional and sensory evaluation. The results show that cashew apple powder is more wettable at room temperature, 28˚C ± 2˚C. Similarly, the pH value of the reconstituted cashew apple juice is between 4.4 and 4.7. The ascorbic acid content of cashew apple powder varies between 209 and 230 mg/100g. The beta-carotene content of cashew apple powder is 0.19 to 0.34 mg/100g. The taste and flavor of the foam-dried cashew juice (2.0% soy protein) and the control were similar. Cashew apple powder with 2% soy protein gave desirable physical, nutritional and sensory properties [40].

Spray-drying of cashew apple juice containing probiotic bacteria was carried out in order to avoid loss of viability of the micro-organism during drying and storage. The dehydration by spray-drying of cashew apple juice containing Lactobacillus casei NRRL B-442, and the influence of the storage temperature (25˚C and 4˚C) on the viability of L. casei NRRL B-442 and on the physical properties of the powder during 35 days of storage were evaluated. It was found that the microbial survival rate was above 90% for the powder stored at 4˚C for 35 days, the water activity was kept low (Aw < 0.30) during storage, and the characteristic color of the product was maintained [41].

The cashew juice was encapsulated by the spray drying technique, for dehydration. The result shows that the powder has higher physicochemical stability for vitamin C and color measurements; and is in an amorphous state after the 140th day of storage [42].

8. Uses of Cashew Apples

8.1. Drink

One of the main uses of cashew apple juice is as a beverage for direct consumption by the population. These beverages can be non-alcoholic or mixed with other fruit juices as a tonic [9] [43]; be alcoholic (wine, liquor, vinegar) [38] [44]; or of local names such as Cajuina in Brazil, Mucamalt in Nigeria [45].

However, it should be noted that some authors have studied the toxicity of the mixture of cashew apple juice and milk. Indeed, the work done by Bokossa showed that the mixture of cashew apple juice and cow's milk is not toxic for animal cells, but the mixture of juice and yoghurt has a toxic effect only on the liver cells of animals [46].

8.2. Substrate

Cashew apple juice is used as a potential source of substrate for the production of bacterial cells, bioethanol and other value added products such as dextran, lactic acid, mannitol and oligosaccharides etc.; for microbial cell fuel generating an open circuit voltage of 0.4 V [47].

Authors used cashew apple and soy molasses to produce bacterial cells by *Gluconacetobacter xylinus* in comparison with the usual Hestrin and Schramm (HS) medium. The bacterial cell production obtained (4.50 g/L) from the medium using cashew apple juice as carbon source (20 g/L) with soy molasses as nitrogen source (10 g/L) was higher than the HS medium (4.03 g/L) [48].

Cashew apple juice is used as a carbon source and urea as a nitrogen source by Cupriavidus necator to produce polyhydroxyalkanoates which are the R-hydroxyalkanoic acid polyesters exploited as bioplastics due to their complete biodegradable and environmentally friendly characteristics [49].

Cashew apple juice is used to obtain bacterial cell nanofibres that produce thermally stable and tensile resistant films [50].

Cashew apple juice is used as a substrate for the production of hydrogen [51]; gluconic acid [52]; biosurfactant [53]-[58].

8.3. Bio-Ethanol

Bio-ethanol obtained through the bioconversion of fermentable sugars from cashew juice by yeasts into ethanol has a wide range of applications such as fuel for electric power, in fuel cells, in energy cogeneration systems, etc. [10] [34] [35] [36] [59] [60] [61].

8.4. Food

Cashew apple can be processed for human food: spreads (jam, jelly), cakes, sweets [62]; and also for animal feed. Indeed, consumption of sun-dried ripe cashew apple feed results in weight gain in ducks [63].

8.5. Nutraceuticals

Traditionally, cashew apples are used to cure a number of chronic diseases such as diarrhea, uterine disorders, cholera, rheumatism etc. [64]. It is also taken as a remedy for stomach disorders and is used to treat throat infections in Cuba and Brazil. In Bolivia, it is taken as a brain stimulant to improve human memory. Many therapeutic properties are attributed to cashew apple juice: anti-oxidant, anti-fungal, anti-bacterial, Anti-tumor, anti-inflammatory, anti-mutagenic [62].

Cashew apple juice also exhibits antibacterial activity against certain microorganisms such as Gram-positive bacteria [65].

Work conducted has shown that supplementation with cashew apple juice for 4 weeks results in the reduction of stress hormone concentration [66]; biotreatment of cashew apple juice by-products with *Lactobacillus plantarum* and Lactobacillus casei results in nutraceutical antioxidants for the fight against type 2 diabetes [37]. Fermented cashew apple juice can serve as a new source of B-group vitamin probiotic for functional foods and nutraceutical applications in human health [37]; cashew apple juice supplementation improves fat oxidation during exercise [67].

Mature and immature cashew apple juices were analyzed for their antioxidant, anti-inflammatory and wound healing properties. These were evaluated in mouse models. Swiss mice were treated with cashew apple juice by gavage. The thickness of the oedema was measured and the skin lesions were analyzed by planimetry and histology. It was found that unripe cashew apple juice showed higher anti-inflammatory and healing activity while ripe cashew apple juice only showed higher antioxidant activity [68].

8.6. Other Uses

The pectin content of cashew bagasse ranges from 8.6% to 10.1% and could be used as gelling agents, texturizers, thickeners, emulsifiers and stabilizers in food processing as well as in the cosmetic and pharmaceutical industries. Cashew apple bagasse could well be used to produce agromaterials using the thermopressing technique; the fields of application could also be agriculture, construction or furniture [18].

9. Conclusions

Cashew apple has a high nutritional potential. It is rich in antiscorbutics, carotenoids, dietary fibre, vitamins, sugars and mineral elements essential for human nutrition. The edible part of the fruit is superior to that of other traditional tropical fruits and its juicy, sweet flesh is seedless and stone-free. In addition, very large volumes are available. Moreover, its physical and chemical characteristics are influenced by several parameters, notably the variety, the climatic conditions of the growing area and the stage of ripening.

Cashew apples can be processed into beverages or used as a substrate for the production of bacterial cells, bioethanol, biosurfactant, dextran, lactic acid, mannitol, etc. It is also used as an additive in the food and pharmaceutical industries and in the production of agro materials.

In view of its many advantages and interests, the valorization of cashew apples is becoming an imperative in order to take advantage of this abundant raw material and increase the income of producers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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