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A LITERATURE REVIEW OF CASHEW APPLE PROCESSING

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ABSTRACT

The cashew tree, a tree adapted to tropical areas was introduced in Africa by European explorers. Its cultivation in some African countries has been done to stop the advancing Sahara desert and to reduce soil erosion. The cashew fruit consists of a nut being the real fruit, and a fleshy apple which is considered the pseudo-fruit. The nut represents the major point of interest in cashew tree cultivation. Despite being a commodity of international trade, cashew apple suffers from low commercial interest. As a result, millions of tons of cashew apple rot in orchards without any form of processing every year. Gradually, its excellent properties are attracting the attention of the scientific world and industrialists with a view to enhancing its commercial and food value. This review reports different methodologies of transforming cashew apple. Some potential products include juice and potential cocktails. Juice clarified by tangential microfiltration was almost cleared of tannins, giving good clarity and a pleasant taste. A stabilized cocktail of cashew apple and pineapple juices using 10% ginger aqueous extract was judged good as it retained prime quality for 7 days at 4 - 5 °C, with significant improvement of vitamin C and protein content ($p \leq 0.05$). Obtaining an amber dry wine of 12.6% alcohol with no significant difference ($p < 0.05$) from commercial grape wine was demonstrated using Saccharomyces cerevisiae as a fermenting agent. Ethanol of 97.8% purity was also obtained by immobilized cells of S. cerevisiae on silica gel. Edible vinegar of 4% acidity with similar characteristics as commercial varieties was produced from the juice. Jam and a viscous syrup of 80 °Brix which was found to be rich in glucose and fructose was also produced. A generator powered by 6% cashew apple biofuel with the rest being gasoline revealed reduced fuel consumption compared to the use of gasoline alone, though engine behavior during its operation was a concern. Also, cashew apple flour has been used for the manufacture of composite biscuit formulated with or without wheat flour. Thus, cashew apple could become a source of additional incomes for peasants by being the origin of creation of companies through these various developed technologies.

Key words: cashew apple, processing, juice, alcohol, vinegar, jam, syrup, flour, biofuel

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INTRODUCTION

The cashew tree (Anacardium occidentale L.) is a fruit tree of Brazilian origin adapted to tropical areas that was introduced in the 16th century by Portuguese explorers into their African colonies. It is an Angiosperm belonging to Dicotyledonous class of plants, of the Sapindal order and Anacardiaceae family [1,2]. Its cultivation in some African countries was done in order to halt desert advance and to fight against soil erosion. It produces a fruit called cashew consisting of two parts: the nut or real fruit and the apple or pseudo-fruit. The cashew nut represents the major interest of cashew cultivation because it is an item of international trade [3]. Côte d'Ivoire has remained the world's leading producer and exporter of raw cashew nuts since 2015, with an average annual production estimated at 700,000 metric tons [4]. As for the cashew apple which is 9 to 10 times the nut weight, its average annual production is estimated at more than 6,300,000 tons. Unfortunately, almost all of this biomass remains untapped. According to Ogunjobi and Ogunwolu [5], this situation is not only due to its perishability and the lack of a processing industry, but also to its characteristic astringency [3]. Various studies show that cashew apple has a high vitamin C content, a significant amount of minerals, sugars, carotene and amino acids such as niacin, thiamin or riboflavin [6,7,8,9]. Also, cashew apple is an excellent source of bioactive compounds, in particular the polyphenols [10].

Natural polyphenols give fruits many properties which would be useful in the prevention and treatment of many illnesses. Thus, consumption of fruits rich in polyphenol is associated with hypoglycemic [11], antidiabetic [12], anticancer [13], antimicrobial and antioxidant effects [14,15]. Polyphenols can also be used in skin care [16]. In view of the beneficial effects of polyphenols on health, several studies have focused on their extraction for application in cosmetic, pharmaceutical and food industries. The work of Koffi et al. [17] shows that ethanol would be the solvent with the potential to extract the maximum amount of polyphenols. Similarly, other works have focused on optimizing extraction of polyphenols using experimental design [18,19,20].

Due to its physicochemical and biochemical composition, cashew apple should be processed for added value. Based on the results of several studies, this bibliographical synthesis will focus on the various ways of adding value to cashew apple.

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Cashew apple processing into juice

The main way of adding value to cashew apple is its transformation into juice. However, three major difficulties must be overcome, in particular the juice astringency that is linked to tannins, its heat sensitivity both on its nutritional and sensory properties and the presence of sugars, which are responsible for the Maillard reaction [21]. For these reasons, various studies have been undertaken. Soro *et al*. [21] and Dedehou *et al*. [22] studied different cashew apple juice clarification processes. According to Soro *et al*. [21], after cashew apple pressing, the juice obtained was clarified by tangential microfiltration (TMF), then concentrated under vacuum at different temperatures (40, 60 and 80 °C). Their results show that clarification caused the total elimination of tannins, while retaining up to 94% of vitamin C content (15 $g.kg^{-1}$ SDE before TMF to 14.1 $g.kg^{-1}$ SDE after TMF). However, this clarification method could have an impact on the nutritional property of the juice, since, according to Abreu *et al*. [23], TMF induces almost total elimination of the bioactive compounds. Also, during the concentration of juice, the high evaporation temperature caused a drop in vitamin C content from 13% to 21%, proportionally with temperature rise. Nevertheless, elimination of tannins helped to give a pleasant taste to the juice.

The work of Dedehou *et al*. [22] led to the optimization of cashew apple juice clarification using starch from cassava and rice as clarifying agents. Their results showed that juice clarification by rice starch at 1% for 193 minutes gave good clarity and a more desirable juice. In fact, this treatment led to the elimination of 42% of tannins, and produced a juice of 94.8% clarity. However, given the remaining tannin content in the juice, it might be somewhat astringent. According to Castro *et al*. [24], microfiltration and ultrafiltration are methods that induce elimination of up to 96% of condensed tannins and an increase in the brightness of clarified juice. Indeed, work of de Andrade *et al*. [25] showed that TMF of juice induces the concentration of some volatile compounds with pleasant odor notes. Comparing these two studies, it appeared that TMF is more effective for cashew apple juice clarification due to the complete elimination of tannins.

Another method of clarification of juice is described by Preethi *et al*. [26]. These authors used polyvinylpyrrolidone at 1‰ level. Sodium benzoate or citric acid was used as a preservative.

Adou *et al*. [27] and Ouattara *et al*. [28] studied the storage of cashew apple juice and a cocktail made from cashew apple juice and pineapple juice (25:75, v:v), respectively. While Adou *et al*. [27] used pasteurization as a stabilizing treatment, Ouattara *et al*. [28] used aqueous extract of ginger. An acceptability test was carried out at the end of 7 days of storage at refrigeration temperatures (4 – 5 °C) to evaluate juice and cocktail stability. Results of the work of Adou *et al*. [27] showed that pasteurization resulted in the loss of high levels of vitamin C. The 75 °C for 5 min and 90 °C for 30 sec scales induced 48.3% and 59.8% loss of vitamin C, respectively. Ouattara *et al*. [28] showed that the stabilization of the cocktail with 10% ginger aqueous extract helped to increase vitamin C content by 44.7% compared to the raw untreated cocktail. The increase of vitamin C content is probably due to the adding of ginger whose content would be 2.5 to 9 mg/100 g DW as shown by Sharaf and Ayad [29] and Sarker *et al*. [30]. Also, the protein content in cocktail stabilized with ginger extract was significantly ($p \leq 0.05$) improved (1.2% to 2.6%) with the gradual increase of ginger extract. This could be due to added protein coming from ginger since Akter *et al*. [31] and Ajayi *et al*. [32] showed that protein content of some ginger varieties range from 6 to 12%. Similarly, Kausar *et al*. [33] reported a protein content improvement when they produced biscuits from a mixture of wheat flour with ginger powder up to 10%. Mohammadi *et al*. [34] also reported that the common carp (Cyprinus carpio) food supplemented with 0.2% ginger extract improved the protein content up to 9% of the carp muscle compared to the control ($p < 0.05$).

Consumer acceptability testing revealed that the pasteurized cashew apple juice obtained a lower score than the control fresh juice. On the other hand, the cocktail treated with ginger aqueous extract obtained a score higher than the control cocktail, indicating that it was very well appreciated by panelists. Comparing the two stabilization methods used, it appears that ginger aqueous extract is effective and beneficial.

A cocktail based on cashew apple juice combined with passion fruit (Passiflora edulis) juice was produced by Adou *et al*. [35]. The 90:10 (v:v) passion juice / cashew apple juice formulation was judged the most enjoyable with a high acceptability score.

Alcohol from cashew apple

Cashew apple can also be used for production of alcoholic beverages. As was mentioned by Ozturk and Anli [36], wine is a beverage resulting from sweet must fermentation by yeasts, and usually with over 9% alcohol content. Awe and Olayinka [37] produced wine from cashew apple juice. These authors used the yeast Saccharomyces cerevisiae SIL 59703 as the fermenting agent in aerobic fermentation for 6 days, then in anaerobic fermentation for 42 days. They report having obtained wine of 10% alcoholic concentration. A study conducted by Lowor *et al*. [38] produced wine of 12.6% alcohol content. These authors also used

Saccharomyces cerevisiae (Lallemand), a commercial fermenting agent to produce wine. Fermentation lasted a week in an aerobic environment, and four weeks in anaerobic environment. They report having obtained an amber dry wine with a marked cashew aroma and a high content of phenolic compounds. They also specified that their wine presented no significant difference ($p < 0.05$) compared to commercial grape wine in terms of taste, color, clarity, astringency and aftertaste. However, panelists did not like the aroma. According to authors, it could be because most of the panelists were not familiar with the natural cashew apple smell.

Other authors produced ethanol. Djossou *et al*. [39] led to optimizing the production of ethanol using palm wine (Elaeis guineensis, Jacq.) as ferment. They assessed the influence of three factors which are proportion of fermenting agent supplied, duration of fermentation and duration of distillation according to a Box-Behnken plan. Ethanol of a concentration of 11.3% alcohol was obtained following this condition: supply of 0.79% of ferment for a fermentation time of 4.7 days and a distillation time of 113.15 min. Arumugam and Ponnusami [40] produced pure ethanol of 97.8% from cashew apple juice. Juice was inoculated using immobilized cells of Saccharomyces cerevisiae MTCC 170 on silica gel, followed by a distillation. This pure alcohol produced would be useful for medical uses or laboratory work. However, the density (16.2 g/L) of ethanol produced was found to be low compared to commercial ones which is 0.805 kg/L.

Vinegar from cashew apple processing

Wine produced from cashew apple juice by Lowor *et al*. [38] was used to produce edible vinegar. According to the authors, the vinegar presented the same characteristics as the standard commercial vinegar. Similar work has been reported by Sobhana and Mathew [41], and Silva *et al*. [42]. Sobhana and Mathew [41] reported to have added no chemical ingredients to cashew apple juice and using sago, sugar and microorganisms (Saccharomyces cerevisiae and Acetobacter aceti for alcoholic and acetic fermentations, respectively), they obtained vinegar of 4.7% acidity. Silva *et al*. [42], experimenting for 5 days, also used the same microorganisms, and in addition, gelatin, ammonium sulfate, potassium phosphate and potassium metabisulfite, and obtained vinegar of 4% acidity. From these two studies, one can notice that adding or not adding chemicals resulted in vinegar of acidity in the range of recommended values (4 – 10% acidity).

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Cashew apple processing into jam

The work of Manjusha and Seema [43] showed that jam is obtainable from cashew apple. They report preparing the pulp by steaming apples after pickling in 5% salt solution for 3 consecutive days, with daily changes of the salt solution. Sugar and citric acid were then added, mixed and cooked by continuous stirring until jam was obtained. Sensory evaluation of jams from ten cashew apple varieties revealed that "Dhana" variety was rated good in terms of appearance, color, flavor, taste, texture, sweetness/saltiness and overall acceptability.

Syrup from cashew apple

Work of Nwosu *et al*. [44] in Nigeria led to syrup production by boiling cashew apple juice above water boiling point. No significant difference occurred concerning microbial load and proximate composition, when stored for six months at ambient conditions. Work of Ramos *et al*. [45] carried out in Brazil, produced cashew apple syrup by rotary evaporation system (bath set at 50 and 60 °C, pressure set at 20 mbar) of clarified cashew apple juice with gelatin. More viscous syrups of 80 °Brix with higher fructose and glucose concentrations than a reference food-grade syrup was obtained. At the end of these two studies, it was noted that a cashew apple syrup with high sugar content can be produced for long term conservation. Yet, its stability study was not done.

Cashew apple processing into flour

Use in bread-making

Consumption of bread in developing countries continues to increase due to changes in dietary habits [46]. Unfortunately, wheat, which is the main raw material in manufacturing of bread, is not grown in these countries, particularly in sub-Saharan Africa. Given the high import costs of wheat flour, the Food and Agriculture Organization of the United Nations (FAO) as early as the 1960s, encouraged these countries to add value to their local food production of baked goods by using composite flours [47]. To this end, several studies have been undertaken in which tubers, roots, leaves, legumes, or even fruits have been used in bread-making. Table 1 summarizes the different formulations of composite breads designed and deemed acceptable within the last six years.

Cashew apple flour has not yet been cited in composite bread production. However, Offia and Onwubiko [48] studied physicochemical and functional properties of wheat / cashew apple composite flour. They showed that partial substitution of durum wheat flour by that of cashew apple helped to improve its characteristics particularly fiber, vitamin C and mineral contents. They suggest that it could be used for baking.

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Use in biscuit manufacture

Cashew apple has been the subject of study in the formulation of composite flour for making biscuits. Ogunjobi and Ogunwolu [5] produced composite biscuits from cassava and cashew apple flour. According to these authors, the protein, fiber and ash content and the presence of vitamin C in cashew apple flour could have played an important role in the quality of cookies, because it would allow the increasing of their content in composite biscuits. That result is well illustrated by the sensory evaluation in which the 20% supplemented biscuit with cashew apple flour would have been the best-liked biscuit. Likewise, Ebere *et al*. [49] produced composite cookies based on wheat flour substituted up to 20% by cashew apple residue powder (CARP) as a source of fiber. Their results showed the crude fiber and ash contents of the cookie supplemented with 20% CARP significantly improved ($p < 0.05$). Contrary to Ogunjobi and Ogunwolu [5], Ebere *et al*. [49] found that protein content decreased with the CARP increase. This contradiction can be due to the different treatments undergone by apples before drying. Ogunjobi and Ogunwolu [5] reported to not have pressed apples to remove juice, while Ebere *et al*. [49] soaked apples in hot water for 20 min before pressing them, followed by residue washing which could have resulted in the protein leaching. Nevertheless, they report that the overall acceptability of the control cookie presented no significant difference compared to the cookie 20% supplemented with CARP. These two works show that cashew apple would be a very good ingredient in cookie manufacturing given that it improves biochemical components with health benefit.

Cashew apple processing to produce biofuel

Biorefining is defined as the process of sustainable transformation of biomass into a range of marketable biobased products (additives, biomaterials, molecules for chemical sector, etcetera.) and bioenergy (biofuel, electricity, heat) [50]. Biorefinery concept appeared and continued to gain momentum following the first oil crisis in 1980. In recent years, biofuels industry has developed under two major influences, namely the gradual increase in the price of petroleum and petrochemical products, and their limited availability. To these must be added new environmental concerns, including greenhouse gas emissions and climate change [51] which have encouraged industries and research players to develop alternatives to petroleum products.

Deenanath [52] evaluated the behavior of a “Bundu Power” generator powered with biofuel. The extracted cashew apple juice was clarified using 1% gelatin, followed by inoculation using the yeast Saccharomyces cerevisiae Vin 13 for fermentation. The bioethanol produced was purified by distillation. A bioethanol with a purity of 75% was obtained. A copy of this bioethanol was prepared by

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mixing 75% absolute ethanol to 25% of water. This mimicked bioethanol was used to substitute 6% gasoline, then used as biofuel. The operation and fuel consumption of the generator powered using the biofuel were assessed. Results showed that during 60 min of operation, fuel consumption using the biofuel was low (12%) compared to the use of gasoline (40%). However, a persistent cloud of white smoke was visible during operation. Also, the generator engine switched off abruptly during the run without complete consumption of the biofuel. This could be the result of abnormal combustion due to the poor quality of the biofuel used.

Similarly, Gbohaida *et al*. [53] in Benin focused on evaluating the biofermentative potential of Saccharomyces cerevisiae and Saccharomyces carlsbergensis strains in the production of bioethanol for use as biofuel. These authors pointed out that addition of urea as growth factor improved fermentation, resulting in bioethanol production.

CONCLUSION

By its chemical composition, cashew apple is a nutrient reservoir. It has been converted into various products for use in the energy, food and medical industries. On the one hand, cashew apple juice can be used for biofuel production to run engines. It can be transformed into refreshing beverages (juice or cocktails) of desirable taste, or into alcoholic beverages particularly wine that is comparable to commercial ones. Edible vinegar, syrup and jam are food products that can be made from cashew apple juice. The juice can also be converted into ethanol of 97.8% purity for medical use. Cashew apple has also been converted into flour for manufacturing biscuits. Cashew apple which is the hypertrophied peduncle of cashew represents a promising potential for investors. Juice, cocktail, wine, jam and composite cookies from cashew apple flour in mixing to other flours are products that industrialists could explore to produce foods with new flavors. On the other hand, some cashew apple processing products present some limitations to overcome. Its use as biofuel is a concern for engine running. Deep research must be conducted to reach the commercial analytical ethanol density for its use in scientific researches. Likewise, its use in bread-making would be welcomed.

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Conflict of interest
The authors declare no potential conflicts of interest.

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Table 1: Different formulation of composite breads deemed acceptable

Composite flours	Accepted formulation	Origin	Authors
Sorghum – rice - millet	67.18: 17.87: 15	Iran	[54]
Wheat – fermented cashew kernel	90: 10	Côte d'Ivoire	[55]
Soft wheat – durum wheat – whole barley	77: 17: 6	Algeria	[56]
Wheat – cassava – soybean	80: 10: 10	Botswana	[57]
Wheat – plantain	70: 30	Ghana	[58]
Wheat – pumpkin pulp – pumpkin seed	78.3: 15: 6.7	Romania	[59]

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