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Potential of Cashew Apples as Valuable Raw Materials in Food Industry and Biotechnology in Africa: A Review

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ABSTRACT

The possibility for biomass valorization, using biotechnological processes, is an ideal solution for the use of agricultural products with low commercial value. Cashew apple is an agricultural resource available in many African countries. Unfortunately, this agricultural resource is abandoned in the fields by the producers and decayed each year in large quantities, because of the astringency of the juice, and the consumption of cashew apples with milk, would be considered incompatible in several African countries. However, there are a lot of ways to upgrade the value of this resource as a raw material in food industry or in the production of renewable bioenergy. Technical methods used involve biotechnological processes using enzymatic biocatalysis, fermentation and fractional distillation.

Introduction

The many nuisances associated with the use of fossil fuels have led most developed countries, to set up research and development programs for renewable energy sources. Among these alternative sources of energy, bioenergy in general, and agrofuels in particular, are more targeted [1]. Indeed, the energy policies of the ethanol-producing governments are explicit and aim to counter the dependence on petroleum products, which are currently at record prices. Taking about its characteristics, the bioethanol is in the long list of alternative energies whose development is motivated by a vision that converges towards energetic availability.

However, in many African countries, the biofuel sector is still embryonic or almost non-existent. It would therefore be advisable, in the perspective of development of this sector, to first consider the production of biofuel from non-convential agricultural products, or starchy and neglected lignocellulosic biomass.

In many African countries, such as Benin, Togo, Cote d'Ivoire, etc., cashew is one of the main agricultural export products [2-3-4]. However, apart from nuts, the other cashew by-products are not valued. Indeed, the cashew apples which represented on average 3 to 4 times the weight of the annual production of the nut, are abandoned in the fields by the producers and decayed each year in large quantities, because of the astringency of the juice. Moreover, the consumption of cashew apples with milk, would be considered incompatible in several African countries. This consideration, transmitted from generation to generation and which remains to be scientifically verified, explained why cashew apples have low value for commercial use in Africa [5].

Several researches have reported the high nutritional potential of cashew apples: it is rich in vitamin C [6], in polyphenolic compounds [7], in carotenoids [8]. In an African socio-economic context, characterized by food and energy crises, the exploitation of this available but little exploited agricultural resource would have a great importance for the development of African countries. Thus, the present review aims to make a deep analyses on the scientific research in the different valorization field of cashew apple as raw material in food industry and in the field of the production of renewable bioenergy.

1. Cashew in Africa: agronomic and socio-economic aspects

Cashew (*Anacardium occidentale* L.) belongs to the anacardiaceae family. It is a tree that can reach ten meters and whose trunk diameter can vary between 1.2 to 1.5 m [9]. It grows prefers at altitudes of less than 1000 m, in hot tropics with alternating dry and wet seasons. It adapts to various soils, but prefers light, sandy, deep, well-drained soils with 25% clay content. Its lifespan is about 30 years. It produces two fruits: the cashew nut (real fruit) and the cashew apple (false fruit). It is when the cashew nut reaches a maximum size (30 to 35 days) that the peduncle, which until then was normal, begins to grow considerably and quickly. It becomes fleshy and turns into a cashew apple [3]. Meanwhile, the nut loses moisture and decreases in volume and hardens. These two types of fruit reach maturity at the same time. Sometimes, harvesting because of the height and width of the foliage of the tree. Fruits are therefore often collected manually after having fallen to the ground [9].

The cashew tree is often subject to parasitic attacks. These parasites attacked fruit inflorescences and directly affected production. The most commonly encountered insect pests are leaf-eating and leafing caterpillars, mealybugs, thrips, flatids and three species of Helopeltis (*H. anacardii, H. shoutedeni* and *H. antonii*) [3]. *Acrocercops syngramma* also can caused losses in production by causing leaf fall [9].

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The growth of cashew tree has developed in Africa because of its great rusticity and its many products. Besides the fruits (nut and cashew apple), the plant provides a range of side products. The bark rich in tannin is used in tannery. It is used to prepare indelible inks and black powder. The cashew gums, exudates that flow from the trunk and branches of old trees, are used to prepare insect-proof adhesives (for binders) [3].

2. Cashew apples: morphological characteristic

Several authors reported that mainly two types of morphotypes of cashew apples, are often encountered in Africa. These are the yellow and red morphotypes [3-10]. However, in Benin, Gbohaida et al. [11] reported the presence of a yellow-orange morphotype in some cashew plantations (Figure 1). Morphological characterization studies of the two main morphotypes of cashew apples revealed that there are significant variability in the morphological characteristics, including mass, height and diameter at the equator of cashew apples [11]. The genetic characterization of these different morphotypes currently encountered, will led to know whether these observed variabilities are genetic or phenotypic.

1. Red morphotype 2. Yellow morphotype

Figure1. Some morphotypes of cashew apples growing in Benin

3. Food valuation of cashew apple

As with many fruits, the main way of valuing that is relevant is to transform into juice. However, in the case of cashew apple, this transformation is confronted with three main problems: the astringency of the juice due to the presence of condensed tannins, the high sensitivity of the product in terms of nutritional and sensory value and the high sugar content is responsible for Maillard reactions observed during heat treatments. The processes to be used must therefore be developed by integrating these specific constraints linked to the product. Thus, the scientific studies carried out in Africa, with a view to a valorization of cashew apple in food industry, are on one hand focused on the clarification of juice extracted from the apple through the elimination of tannins. On the other hand, researches are focused on the field of animal production. Then, the use of cashew apples in improving the quality of the animal feed ration was investigated [12].

Studies carried out by Soro [3] revealed that juices extracted from the two morphotypes of cashew apple have significant differences in several nutritional compounds. According to this author, red varieties are richer in polyphenols and vitamin C but less in sugars compared to yellow varieties. The high content of total polyphenols, can explain the astringency of cashew apple juice, which limits its consumption.

However, its richness in vitamin C is a major factor for its valorization. Thus, several methods have been investigated in order to improve the nutritional and organoleptic quality of apple juice. These include clarification techniques using tangential microfiltration, nanofiltration, reverse osmosis preconcentration, concentration by osmotic evaporation [3]. The use of local clarifying agents, including cassava starch and rice groats [10], has also been developed in some African communities to improve the quality of cashew apple juice.

In order to improve the extraction yield of cashew apple juice, Padonou et al. [13], investigated the effectiveness of the various pressing juice extraction methods used in African communities. Thus, the results obtained indicated that, only the use of the "Moulinex" mixer coupled with the hydraulic press, made it possible to obtain the best juice extraction yields. However, other constraints remain to be eliminated throughout the process of transformation for a better valuation of the apple cashew.

4. The bioethanol

Bioethanol is the main biofuel that is experiencing significant industrial development, with production being more environmentally friendly. Indeed, it is obtained from an anaerobic fermentation process of natural sugars. This fermentation is also used in the production of wine, beer and other alcoholic beverages [14]. It is a colorless, volatile, hygroscopic product, miscible with water and other alcohols, and recognized for its solvent qualities for fats and plastics [15]. Bioethanol is chemically stable and possesses all the properties which characterize alcohols, in particular, an oxidation reaction when it is kept in the open air to form acetic acid. Under extreme oxidation conditions, it converts to carbon dioxide (CO_2) [16].

Today, industrial applications using bioethanol are numerous. Beyond the fact that bioethanol is used for lighting and heating, it is the basic active ingredient of alcoholic beverages and is used in the synthesis of many chemicals in the pharmaceutical, cosmetics, brewing, perfumery and medicine [16].

4.1. Different types of bioethanol

In the production of bioethanol, the usable raw materials are very varied and functions of the progress made in research in recent years. The choice of each is not depends only to the cost and profitability of the process, but also on the fermentation capacity of the microorganisms associated with the bioconversion process. In general, bioethanol production chains are traditionally divided into four generations, depending on the raw materials and the technologies used [4]. Thus, the production of first-generation bioethanol uses conventional technologies to convert only the food portion of crops rich in sugars or starch, into bioethanol. The production of second-generation of bioethanol aims the full valorization of plants and specially the lignocellulosic part of the biomass, in bioethanol using advanced technologies. The production of third-generation of bioethanol aims to exploit the potential of algae, using more advanced technologies. Finally, the production of fourth generation of bioethanol envisages the conversion of phytoplankton (microalgae) to bioethanol using very high processing technologies.

4.2. Importance of biomass in bioethanol production

The research for biomass for renewable energy production, without competition for food, and no harmful effects on the environment, and no competition with the using of agriculture land for food production, is also combined with climate change led to consider new resources and Innovated processes. From this perspective, the conversion of neglected biomass into biofuels is a solution of choice to overcome these problems. Indeed, bioethanol is the biofuel produced by fermentation frombiomass rich in sugar or starch.

However, the competition with food products that it has engendered in pushing industrialists to abandon the use of broad-based food products to turn to new unconventional materials and agricultural and industrial residues, for bioethanol production.

In economical way, the possibility for energy recovery by neglected biomass using biotechnological processes, is an ideal solution to valorize low-value agricultural products, crop residues and agro-industrial waste [17]. Similarly, the promotion of biofuels obtained from neglected biomass contributes to the reduction of fossil energy dependency of countries. It therefore led to create new agricultural sectors and could offer new opportunities for farmers, especially in developing countries. Furthermore, the interest in producing of bioethanol stems from the fact that it is a strategic energetic substance whose use also covers a wide field of industrial activities. Although the second-generation of bioethanol obtained from lignocellulosic biomass is recognized as a promising alternative energy source, **ineffective** pretreatment pathways and the high cost of enzymatic hydrolysis are major causes that could not motivate the commercialization of bioethanol. Thus, attempts to produce bioethanol are often directed towards unconventional agro-resources rich in sugars [18].

4.3. Production of bioethanol using cashew apple

In order to respect the environment and reduce greenhouse gas (GHG) emissions, microbial pathways can be interesting alternatives by using microorganisms to ensure the transformation of vegetable resource into bioethanol.

4.3.1. Microorganisms adapted for the production of bioethanol

The microorganisms most frequently used for the production of bioethanol from fermentable sugars are yeasts from the genus of Saccharomyces [19] and Kluyveromyces [20]. There are also bacteria such as *Zymomonas mobilis* which have good yields in ethanol [21]. However, the major disadvantage of the use of bacteria, is that they often produce other by-products, such as other alcohols, organic acids, polyols, ketones, or gases (methane, carbon dioxide, dihydrogen). Despite this, *Zymomonas mobilis* is considered to be a good ethanol producer. These bacteria have the advantage of making a fermentation in a strict anaerobic medium [22]. It would also be more tolerant to ethanol than *Saccharomyces cerevisiae* [23].

However, *Saccharomyces cerevisiae* is effective in the production of ethanol at low pH, which makes it possible to avoid contamination or parasitic reactions due to the presence of other microorganisms, while sterilization is still necessary before using *Zymomonas mobilis* [24]. Thus, *Saccharomyces cerevisiae* is used on a very large scale both for traditional productions (alcoholic beverages, bread, baker's yeast, bioethanol), as well as for productions with pharmacological or chemical aims, such as vitamins, enzymes or recombinant proteins. Ultimately, all these different features make *Saccharomyces cerevisiae* the most suitable microorganism for the production of bioethanol [25].

4.3.2. Technological advances

Depending on the raw material used and the required purity of the ethanol, one or more steps may be omitted. For example, sugar-containing feedstocks can be directly fermented if sugars are available, whereas starched products must first be hydrolyzed. Indeed, fruit juices or fermentable agro-industrial by-products are directly converted into bioethanol by alcoholic fermentation. However, starch from tubers and cereals, as well as agro-industrial waste are first treated with enzyme or acid substance, before the alcoholic fermentation step. The first hydrolysis processes used were mainly chemical, but nowadays, they are not very competitive, due in particular to the cost of the reagents and the formation of numerous by-products and inhibitor compounds making the hydrolysates less fermentable. They are now competing with more specific enzymatic processes that allow better hydrolysis yields under less severe conditions [26]. Enzymatic hydrolysis is a specific method performed under relatively mild conditions of pH and temperature, and allowing hydrolysis yields greater than those obtained from chemical processes [4]. The valorization of cashew apple using the techniques of alcoholic fermentation of juice or advanced technologies such as the enzymatic hydrolysis of lignocellulosic residues, followed by fermentation using selected yeast strains was investigated. Indeed, the evaluation of the fermentative performance of the yeast Saccharomyces carlsbergensis and three yeast strains of Saccharomyces cerevisiae, in particular the Angel brand super alcohol, the Angel super alcohol and the Angel brand Thermal-tolerant alcohol, in the production of bioethanol from cashew apple juice, yielded good results [27]. Other investigations aiming at the bioconversion of the lignocellulosic residues of the cashew apple, using enzymatic biocatalysis followed by fermentation, also led to obtain bioethanol with interesting fuels characteristics [28].

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