Baobab (Adansonia digitata L.)

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Baobab (*Adansonia digitata* L.), which belongs to the Malvaceae family, is an indigenous African tree widespread in arid savannah regions of Madagascar, mainland Africa, the Arabian peninsula, and Australia, and it was once classified as the “lost crop” of Africa.

Keywords: baobab ; polysaccharide extraction ; techno economic analysis ; scale up ; Nigeria

1. Introduction

Baobab is a multipurpose tree and has attracted research interest from many industries, as most parts of the tree (fruits, leaves, bark, and seeds) can be used for either fodder, medicine, food, or to produce valuable utensils. The bark is soft and can be used to weave rope and clothes, whereas the fruit is one of the modern “superfoods”. Only the baobab leaves remain unexploited and are only being used by the local population as part of their diet. For these reasons, it has been nicknamed as ‘‘the small pharmacy tree’’ or ‘‘chemist tree’’ [1]. In Africa, many parts of the baobab tree are consumed by humans for nutritional purposes. However, in Europe only the baobab fruit pulp is consumed and only since 2008, when the European Commission provided marketing authority as a novel food ingredient (2008/575/EC). Similarly, in the United States of America, it has been approved as a food ingredient since 2009 [2].

1.1. Uses of Baobab

The baobab fruit has an oblong or oval shape and consists of black seeds embedded in a chalky, white pulp [3][4]. The baobab fruit pulp is the most popular food source, as it contains high levels of calcium and is a ten times richer source of vitamin C than oranges [5]. It is usually sold as a dry powder and when dissolved in milk or water, it can be used as a drink, food sauce, substitute for cream-of-tartar in baking, or fermentation agent in local brewing [5]. In addition, it is a significant source of polysaccharides and is low in protein. Because of the presence of saponins, sterols, and triterpenes, it has been traditionally used for analgesic, immuno-stimulant, pesticidal and anti-inflammatory purposes [6]. On an industrial scale, the baobab fruit is already being used in food and cosmetics applications, and there are a few companies that process and trade baobab fruit products worldwide.

On the other hand, baobab leaves are not yet authorised as a novel food in Europe and are only consumed in Africa. More specifically, baobab leaves are used in the preparation of soup and are a staple in Africa, due to the significant levels of minerals (e.g., iron, calcium, potassium, magnesium, zinc, and phosphorus). Young leaves are commonly used fresh or as a dried powder, and consumed as salad, or used to prepare sauces [7]. Furthermore, they are a significant source of essential and non-essential amino acids but also of vitamins C and A. In addition, they consist of mucilage, which explains their traditional use as thickening agent in the African culture, and mostly in the Southern countries [8].

1.2. Importance for the African Countries

Smart and effective utilisation of indigenous agricultural resources is a key area, through which developing African country economies may grow. There is a continuous need to increase the agricultural production and, consequently, the income of farmers, who are pressured by international markets to maintain production at competitive prices. However, one major gap in the African agricultural sector is its inability to create and sustain export chains for agricultural produce, driven by poor knowledge of target markets. To that end, the commercial exploitation of an indigenous crop for the formulation of high value products might have an important economic impact to the local economy.

Baobab fruit is an ideal trade product for villagers, since the crops are light to transport, easily dried, and readily accessible. However, in the majority of countries it goes to waste because of the lack of demand and knowledge of the fruit properties. More specifically, baobab, as an important source of polysaccharides, has not been fully exploited due to limited information on its properties. With the knowledge gained from this research, polysaccharides that improve the performance of food systems could be developed. Furthermore, the application of baobab polysaccharides may not be limited to the food industry and could be expanded to the cosmetics and pharmaceutical industries.

Another significant impact that baobab can have to the local community is to help promote gender equality, since, traditionally, women are in charge of the baobab trees. An Africa-inspired health food brand and social business has been using baobab fruit as a key ingredient for their health and beauty products, in collaboration with Ghanaian partners. The company has been promoting the use of baobab worldwide, by developing an online campaign #MakeBaobabFamous, showcasing the importance of the crop to the local society and economy. They state that over 1000 women have been working with them, either by harvesting the baobab fruits or in the processing centre. This has led to an increase in their annual income from £9 to £119, enabling the women to provide food, education, healthcare, and other basic needs for their families [9].

2. Techno-Economic Assessment of Polysaccharide Extraction from Baobab, Take Nigeria as an Example

Focusing on Nigeria, an area of application for these polysaccharides could be the flour and baking industry. This would strengthen the use of indigenous flours and increase the income of local farmers. Nigeria's agricultural policies aim at accelerating industrialisation through research and development into utilisation and value addition of under-utilised agricultural commodities, such as baobab. This can lead to sustainable economic growth and employment, improved agricultural production and a new income source for small scale food producers or rural population who harvest and sell such commodities in local markets. During the past decade, the Nigerian Government initiated a policy on 10% cassava flour inclusion in bread, as part of efforts to boost the utilisation and create markets for farmers and small/medium scale processors. The program drove the demand for cassava, increasing productivity by approximately 10 million tonnes in six years, making, temporarily, Nigeria a top world producer. Similarly, baobab polysaccharides can be used as a natural improver in wheat-cassava breads and subsequently increase the market demand for baobab.

2.1. Technical Assessment

Polysaccharides have been isolated from different varieties of baobab fruits and leaves (*Adansonia digitata L.*) under a range of extraction conditions (at pH 6.0 or 2.0)[10]. The polysaccharides were examined by means of sugar composition analysis, NMR spectroscopy, size exclusion chromatography (SEC) and dilute solution viscometry. It was found that fruit polysaccharides are xylogalacturonans, whereas leaf polysaccharides are homogalacturonans and rhamnogalacturonans.

The extracted polysaccharides from the fruits and leaves of the baobab tree were assessed for their emulsifying capacity. Emulsions were formed at acidic pH (pH 2.0 and ϕ = 0.1) and were investigated by means of droplet size distribution analysis, ζ-potential measurements, and interfacial composition analysis. Despite the macromolecular differences of baobab polysaccharides all emulsions were formulated at concentrations resulting in comparable zero shear viscosity of the continuous phase allowing structure *vs.* function relationships to be made. Emulsions made with fruit polysaccharides formed finer droplets and exhibited good long term stability than those formulated with leaf polysaccharides. Stability was achieved by formation of thick interfacial layers, as evidenced by the large polysaccharide interfacial loading ($\Gamma_{\text{polysaccharide}}$ 13.8 or 20.7 mg m^{-2}) that created an effective steric barrier against droplet growth, whereas proteins did not seem to play central role. Fruit polysaccharide emulsification performance at acidic pH was attributed to their compact conformation at the interface that is linked to their structure. Conversely, the presence of rhamnogalacturonan segments in leaf polysaccharides resulted in chain desorption and poor emulsion stability. Overall, it has been shown that baobab fruit polysaccharides could be suitable emulsifiers for a range of technological applications that require low pH stability[11].

The structure and rheology of baobab polysaccharides were characterised by using linkage analysis and rheometry. The results demonstrate that leaf polysaccharides are comprised mainly of an RG-I-type backbone, with two predominant domains: one branched at O-4 of the →2)-Rhap-(1→residues with typical neutral arabinan, galactan and type II arabinogalactan side-chains; the other branched at O-3 of the →4)-GalpA-(1→backbone to single GlcpA-(1→residues, similar to that found in polysaccharides extracted from several other members of the *Malvaceae* family. On the other hand, the fruit polysaccharide was mostly xylogalacturonan, with co-extracted α-glucan. Regarding the rheological characterisation leaf polysaccharides did not show unusual rheological behaviour in response to changes in pH or temperature. In contrast, the relaxation dynamics of fruit polysaccharides after constructing master curves of viscoelasticity revealed a strong dependency of rheological behaviour on pH. More specific, polysaccharide dispersions present liquid-like viscoelasticity at acidic pH, whereas, at neutral pH a weak gel network formation was observed that destabilised rapidly under the influence of flow fields. These unique rheological characteristics may point to new directions in food and pharmaceutical formulation[12].

2.2. Economic Assessment

An economic viability assessment was performed for the isolation and extraction of baobab polysaccharides on a large scale and the potential market for such products were examined. As the extraction process uses large amounts of ethanol for the polysaccharide precipitation (accounting for 62% of the total cost), this allows the opportunity to investigate two alternative scenarios: a base case (without ethanol recycling) and a circular scenario with ethanol recycling. For this reason, a preliminary economic analysis for both scenarios (with/without ethanol recycling) was performed to determine the economic viability of the process, based on the bench scale extraction and considering all the capital and operating costs. The results showed that the average cost per 100 g of extracted polysaccharide was estimated to be 33.9£/100 g, for the base scenario, and 22.5£/100 g, for the ethanol recycling scenario by combining the operating cost with the average polysaccharide yield. The values were similar to the price of commercial pectin; however, they were higher compared to the actual production cost of commercial pectin. In addition, a scale up analysis was evaluated for a 15-year project lifetime, to assess if the overall cost would drop, and, thus, the potential profit of an industrial extraction plant would be higher, rendering such an investment viable.

However, as the polysaccharide extraction from baobab is a novel process, it was difficult and uncertain to assume a specific price for the final product in order to calculate the expected revenues and, thus, assess the economic viability of the investment. For that purpose, the production cost of the polysaccharide was calculated for a minimum acceptable economic result, as expressed by the payback period. The minimum profitable selling price was estimated to be between £22 and £34 per 100 g of polysaccharide, which was comparable to the commercial selling price of high purity polysaccharides. Since the two major components of the total annual variable costs were the raw materials and the labour cost, a scale-up analysis with the ethanol recycling scenario was examined under Nigerian conditions, as it was the most profitable.

In addition, a sensitivity analysis was performed to estimate the overall range of the final product price. The major component that affects the final product prices and, thus, the viability of the plant, was the cost of utilities and mostly steam. The results revealed that fluctuations in the steam price play a critical role although the best-case scenario showed that the minimum profitable price might even drop below £20/100 g, leaving a bigger margin for profit and making the product more competitive to existing commercial ones. On this basis, a more detailed analysis on a case-by-case basis is necessary to investigate more accurate values for purchase costs as well as alternative options for steam production in order to optimize the baobab polysaccharide extraction process and to establish a profitable price of baobab polysaccharide as a food or pharmaceutical ingredient.

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