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Effect of fortification with baobab *(Adansonia digitata L.)* pulp flour on sensorial acceptability and nutrient composition of rice cookies

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ABSTRACT

In order to fight malnutrition, functional cookies fortified with baobab pulp flour at partial substitution rates of 10, 20 and 30% were evaluated for consumer acceptability and nutritional quality. Consumer acceptability was evaluated in terms of taste, aroma, color and texture (hedonic characteristics) while nutritional quality was evaluated in terms of macro- and micro-nutrient compositions. Results showed that composite flours exhibited good functional properties. Twenty percent fortification cookies produced the most acceptable cookies which were rich in calories (490.24 kcal per 100 g), total fibre (8.65%), and total fat (27.52% DM). According to the National Agency of Sanitary Security recommendations concerning the contribution of each macromolecule to the total energy, crude protein intake was lower, polysaccharide intake was within the recommended value, while total fat intake was largely beyond that value. Mineral profile showed that cookies enriched with 20% of baobab pulp flour were rich in iron (15.6 mg/100 g), calcium (30 mg/100 g), magnesium (20 mg/100 g), potassium (930 mg/100 g), and vitamin C (60 mg/100 g). Thus, incorporation of baobab pulp flour at 20% improved sensory and nutritional qualities of rice cookies. Baobab fortified cookies can therefore be an alternative non costly and accessible snack to alleviate malnutrition in general and micronutrient deficiencies in particular.

Introduction

The endemic poverty on the Africa continent is characterised, among others, by food insecurity [1,2]. This is particularly severe in Sub-Saharan Africa where population growth is higher than resources [3]. In this area, food availability is low

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and the majority of the population is undernourished and live on less than a dollar per day. This lack or insufficiency of resources generates significant poverty and malnutrition among populations: women and children being the most exposed [1]. Malnutrition results from insufficient energy consumption and inadequate nutrients intake. The most common nutritional deficiencies in sub-Saharan Africa are vitamins (vitamin A, vitamin C, group B vitamins, etc.) and minerals (iron, zinc, fluoride, calcium, copper, etc.) [1]. Stunted growth of infants and children, an excess of morbidity and mortality of adults and children are consequences of this malnutrition. It is therefore important to find low cost and accessible alternatives that can help alleviate malnutrition within the population.

Cookies are small bakery products [4] characterised by high levels of sugar and fats, on one hand, and low levels of moisture [5] on the other hand. Thanks to their low moisture content and thinness, cookies are characteristically hard and crunchy, properties that are much appreciated upon eating [5]. Cookies are widely consumed snacks and can thus be used as the matrix for food fortification. The intake of target nutrients could therefore be enhanced through incorporation in cookies.

The African baobab (*Andansonia digitata L*), characteristic of Sahelian areas, is a multi-purpose species recognized and widely integrated by rural communities [6–8]. It plays an important role in local traditional cultures [6]. Despite many traditional uses and the wide distribution of baobab on the African continent, there is no data on its production. Several studies have been carried out on the botanical [7], agronomic [8] and biochemical characteristics [6,9] of baobab. From these biochemical studies, it has been shown that the pulp of baobab is rich in dietary fiber [9,10], carbohydrates [11,12] and vitamin C [8,9] and could then be used in the formulation of beverages such as nectar [10,13], fruit juice, jam, syrup and alcohol [14]. The pulp is also used in many cereal preparations, such as porridge or couscous ("mutchoyan" in Benin or "ngalakh" in Senegal), sauces or creams of accompaniment (sweet cream based on grilled and ground peanuts in Senegal [10,15,16]. Baobab leaves have undergone therapeutic valorization in the treatment of dysentery [6,17–21]. However, the valorisation of baobab pulp in pastry has not yet been documented.

The objective of this work was to enrich the widely consumed snack (cookies) with the nutrients of baobab pulp, as a step to boosting alleviation of malnutrition and micronutrient deficiencies.

Materials and methods

Production of rice and baobab fruit pulp flours

Two crop commodities were used for this study:

- Rice: The rice used was Nerica rice, a rainfall variety cultivated on the experimental fields of the Institute of Agricultural Research for Development (IRAD) Nkolbisson. The rice was ground using mill and sieved using a 200 μm sieve to obtain a bread making flour according to Benkadri [22].
- Baobab: The baobab fruit pulp flour was produced according to the protocol of Diop et al. [6]. The fruit of baobab (*Andansonia digitata*) was delicately crushed in a mortar to avoid breaking the seeds and to enhance the separation of fibres from seed and pulp. The pulp thus obtained was subsequently grounded, vigorously sieved using a 200 μm mesh sieve to obtain baobab pulp flour [22].

Preparation of composite flours

The rice and baobab pulp flours were blended to form composite flours. The substitution level was determined according to Górecka et al. [23]. Three substitution levels of rice flour with the baobab pulp flour at 10%, 20% and 30% were studied. No replacements were done at the control level.

RFB10%: 10% substituted rice flour with baobab flour.
RFB20%: 20% substituted rice flour with baobab flour.
RFB30%: 30% substituted rice flour with baobab flour.
Percentages were based on weight.

Production of rice cookies

The rice cookies were produced (Fig. 1) according to a basic recipe developed by Kiger [24]. This recipe comprised of the following raw materials and ingredients, with percentage based on weight: rice or composite flours (52.9%), vegetable fat (20%), sugar (11%), egg (7.3%), vanilla sugar (1.3%) and salt (0.1%).

Hedonic characterisation of cookies

The sensory analysis was carried out according to the method described by Lefebvre [25]. Cookies samples were assessed by 30 panellists aged between 26 and 43 years old and made up of 8 students, 10 researchers, 7 farmers and 5 agribusiness men.

A 6-point hedonic scale was used to evaluate overall acceptability: 1 = Very unpleasant, 2 = Unpleasant, 3 = not pleasant, 4 = Indifferent, 5 = Pleasant and 6 = Very pleasant

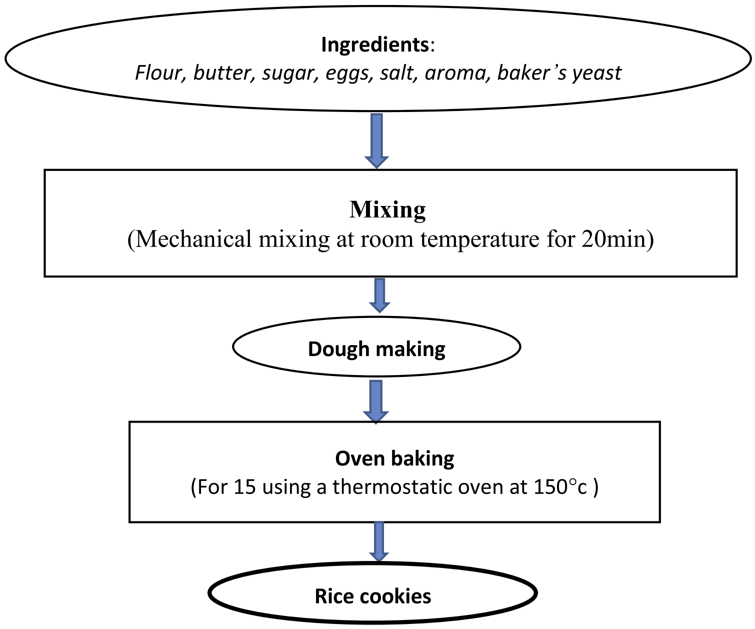

Fig. 1. Production pathway of rice cookies.

But before that, water content of samples were checked according to the Association of Official Analytical Chemists (AOAC method 950.46B [26] method. Differential weighing before (M1) and after (M2) oven drying (103 °C for 16 h) of 2 g of ground sample permitted to evaluate samples humidity. The amount of water present in each sample based on the initial mass of sample as a percentage gives the water content (M). $M = [(M1\text{-}M2)/M1]*100$.

Nutritional composition of baobab pulp flour

The nutritional composition of baobab pulp has been studied by several authors, with results not always in accordance: macromolecules content of 100 g of baobab pulp consisted of 60.6 ± 15% of carbohydrates, 2.3 ± 0.8% of proteins and very little lipids (0.27 ± 0.6%) [13,27]. Baobab pulp is known for its high content of Vitamin C. A mass of 100 g of pulp can indeed contain up to 300 mg of vitamin C, a quantity 6 times greater than that present in one orange [10]. It also contains significant amounts of other essential vitamins, such as thiamine, riboflavin, and niacin. Baobab pulp is also rich in certain minerals and essential fatty acids. In fact, 100 g of baobab pulp contain 293 mg of calcium, 231 mg of potassium, 118 mg of phosphorus and alpha-linoleic acid (27 mg of acid for each g of dry product) [28,29].

This important nutritional value of baobab pulp motivated its selection as an enrichment substance of rice's cookies.

Physicochemical characterisation of fortified cookies

- *Ash content*: the ash content was evaluated according to AOAC method 920.153 [30]. This method was done by sample incineration in a muffle furnace at 550 °C during 24 h. A mass of 3 g of milled sample was incinerated. Differential weighing before and after incineration allowed determination of ash content of sample.

- *Crude protein content*: The crude protein content was estimated using Kjeldahl procedure according to AOAC method 955.04 [30]. This method consisted of transforming the organic nitrogen of the sample into mineral nitrogen (ammoniacal form) by the oxidizing action of concentrated sulphuric acid (H_2SO_4) in the presence of a catalyst. The crude protein content was calculated using the conversion factor 6,25.

- *Determination of total lipids*: The total fat content was done by Soxhlet Extraction according to AOAC method [26]. It consisted of extracting fat in 3 g of dry sample with an organic solvent (petroleum ether) at 60–80 °C by refluxing for 6 h. After that, the distillate was dried at 100 °C in an oven for 1 h and cooled in a desiccator for 30 min. The difference in weight of empty container to that containing fat allowed the calculation of total fat content.

- *Determination of total sugars*: The total carbohydrate content was determined by an indirect method [31]. It was determined according to the following formula:

Carbohydrate (%DM) = 100- [Moisture (%) + Ash (%DM) + Protein (%DM) + Fat (%DM)].

- *Determination of total energy value*: The total energy value of the cookies was estimated according to the method of Merrill and Watt [32]. It is an indirect method which allows calculation by multiplying the proportions of the food groups (carbohydrates, proteins and lipids) by the energy coefficients of 4 kcal/g, 4 kcal/g and 9 kcal/g, respectively.

Calorific Value (Kcal/100 g) = [(%*Protein* × 4) + (%*Carbohydrate* × 4) + (%*Fat* × 9)]

- *Mineral elements titration*: The basic cations: calcium (Ca), magnesium (Mg), potassium (K), copper (Cu), zinc (Zn), manganese (Mn), iron (Fe) and phosphorus (P) were determined by the method of Onwuliri and Anekwe [33]. This method consisted of determining the mineral content by atomic absorption spectroscopy after solubilisation of cookie ashes in an acid medium. The ash (1 g) was dissolved in 10 mL of hydrochloric acid and then 100 ml of distilled water added to it. The apparatus used was an AAS 1100 atomic absorption spectrometer (Perkin-Elmer, USA) fed by an air-acetylene flame. For the extraction of Ca and Mg, 10 mL of lanthanum chloride (18 g of lanthanum oxide + 250 mL of concentrated HCl in 100 mL of distilled water) were added before completing the 100 mL flask to the gauge line with distilled water. Calcium was read at 422.7 nm, magnesium at 285.2, potassium at 766.5 nm, copper at 324.8 nm, zinc at 213.9 nm, manganese at 279.5 nm, iron at 248.3 nm, and phosphorus at 860 nm.

- *Total fibre content*: The total fibre content of cookies was determined according to A.O.A.C method [26]. This method consisted of heating samples with sulphuric acid and sodium hydroxide. A mixture of 2 g of delipidated sample and 100 ml of 0.26 N sulphuric acid was heated at 100 °C for 30 min, then filtered and washed several times with distilled water. Subsequently, 100 ml of 0.23 N KOH (GROSSERON, P1767-500 g) was added and the mixture was again heated at 100 °C for 30 min, then washed and dried at 100 °C for 8 h and finally mineralized in an oven (brand CARBOLITE LHT 5/60) at 500 °C for 3 h.

- *Vitamin C content*: The vitamin C content of cookies was determined by titrimetric method of Harris and Ray [34]. This method was realised by acid extraction and determination of vitamin C by 2,6-ichlorophenol indophenol at pH < 3. Five grams of cookies sample was crushed and 10 ml of 90% (v/v) acetic acid added. The mixture was filtered and the supernatant recovered in a 50 ml flask. The operation was repeated three times with 10 ml of 90% acetic acid. The flask was filled to gauge line with 90% acetic acid in order to obtain the extract of cookies containing vitamin C. The Vitamin C content of the extract was then obtained by titration with 2,6-dichlorophenol indophenol.

Statistical analyses

All analyses were done in triplicate. The data were subjected to analysis of variance (ANOVA) using EXCEL (Microsoft 2013) and STATGRAPHICS. The Duncan test allowed analysing of differences between means at 95% confidence interval.

Results

Hedonic text of cookies

The effect of baobab pulp flour on the consumer acceptability of cookies is represented in Fig. 2.

The enrichment of rice cookies with baobab flour improved taste, aroma and overall quality. Taste and aroma were the most important sensorial descriptors that influenced the overall appreciation of rice cookies. In general, rice-baobab pulp cookies were more appreciated than simple rice cookies (control cookies). The overall acceptability of control cookies were lower than that fortified with baobab pulp flour. Cookies enriched with 20% baobab flour were the most appreciated with highest overall acceptability (5.53) when compared to the other rice cookies (control cookies or alternative levels of substitution). Cookies enriched with 30% baobab scored lowest and were completely rejected in all sensory attributes by panellists.

Sensory evaluation is an important criterion in the development of new products [35]. It meets consumer requirements in terms of organoleptic quality. Several studies have been carried out on the fortification of cookies with various substances improving their sensorial characteristics: Górecka et al. [23] investigated the consumer acceptability of cookies enriched with raspberry pomace. These authors did not find any negative impact of the fruit enrichment on the organoleptic characteristics of cookies. The same findings were obtained by Khouryieh and Aramouni [36] who investigated the consumer acceptability of cookies prepared with flaxseed. These authors noted an improvement in sensory attributes and overall acceptability with flaxseed flour incorporated in cookies as a partial replacement of wheat flour up to 12%. With cookies fortified with chestnut flour, samples with 20% of chestnut flour presented highest score for overall sensory impression [37]. Moreover, the determination of water content of cookies samples showed that those of fortified cookies doubled that of control cookies; 10.27% against 4.94%. This sparks the question whether water content can improve taste attributes of cookies?

According to Knuckles et al. [38], cookies that have been developed are of good quality because whatever the formulation, the overall acceptability is greater than 5. With Acceptability Index greater than 70%, these cookies can also be marketed [39]. Indeed, the most liked cookies were those enriched at 20% baobab pulp flour because they had the best sensory attributes, overall acceptability, and acceptability index. Therefore, physicochemical and nutritional analyses were only focused on the 20% baobab pulp flour cookies.

Nutritional profile of baobab-enriched rice cookies

Intake of macromolecules and energy

The composition of macromolecules and energy intake of 20% enriched cookies with baobab pulp flour are presented in Table 1.

Macromolecules content

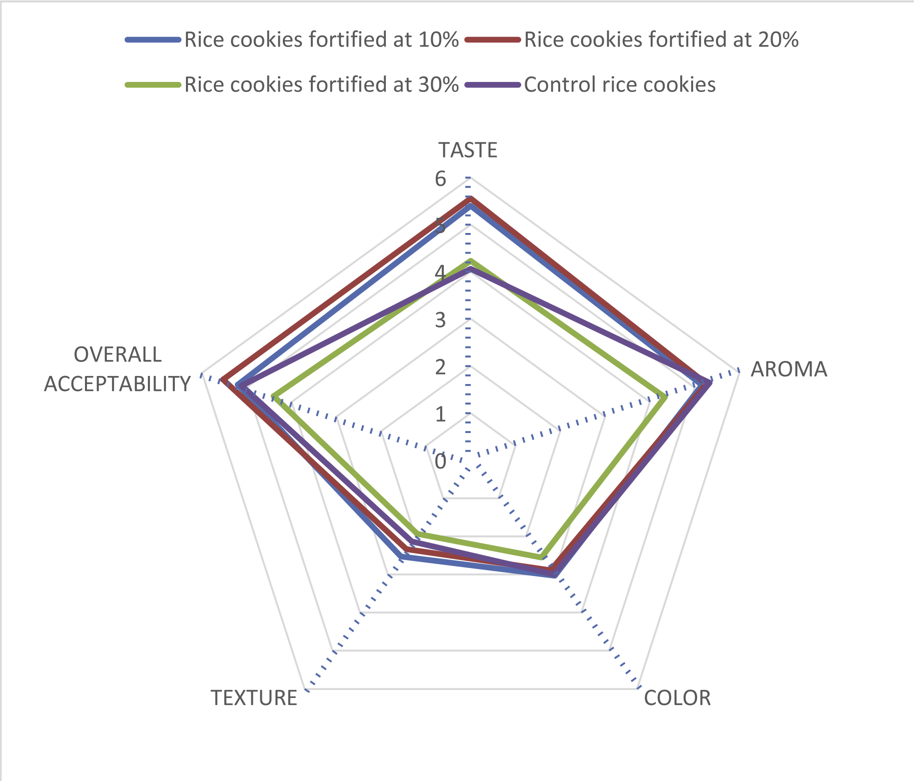

Fig. 2. Hedonic evaluation of cookies.

Table 1
Macromolecular and energy content of experimental cookies.

Samples	Control rice cookies (0% baobab)	Enriched rice cookies (20% baobab)
Crude protein (% DM)	9.18[a] ± 0.02	6.29[b] ± 0.03
Total fat (% DM)	25.72[a] ± 0.60	27.52[b] ± 0.25
Carbohydrates (% DM)	59.26[a]	54.35[b]
Energy value (Kcal/100 g)	505.24	490.24

[a,b] Means with different superscripts in same line indicate significant difference ($P < 0.05$).
Source: authors.

Results showed that baobab-enriched cookies exhibited a macromolecular nutrient intake which was superior to the control. This result was in accordance with that of literature which showed that the nutritional composition of fortified cookies depends on the fortification rate and the nature of the composite flour or substituted flour [40–42].

-*Crude protein content*: Table 1 showed that unlike the other macromolecules, crude protein content decreased with fortification with baobab pulp flour when compared to the control cookies.

Proteins are macromolecules that are involved in all the major physiological functions of the body (tissue structure, enzymatic activities, hormones, antibodies…) and are indispensable components of nutrition. According to the report of AFSSA in 2007 [43], the standard nutritional intake of proteins for a healthy adult is 0.83 g/kg/day. The significant decrease in protein content of baobab-fortified cookies could result from a dilution effect given that rice flour is richer in protein than baobab pulp flour [44]. The obtained baobab fortified cookies had a protein content similar to that of rice cookies fortified with 9% apple fruit powder [44], as well as sorghum cookies substituted with 18% orange-fleshed potato flour [42], and 'Maria' cookies [45].

- *Total fat content*: Results showed that unlike crude protein content, introduction of baobab flour to rice cookies increased lipid content when compared to the control cookies.

Lipids play essential roles in the body such as energy suppliers (they must bring 35 to 40% of the total calories per day) and are essential elements of cell membranes. The increase in lipid content of baobab pulp - fortified rice cookies may be due to the high oil retention capacity of baobab flour during cooking [44]. This total fat content is higher (27.52% DM) than that of fortified wheat cookies with rice flour [41], “Maria” Cookies [45], or wheat cookies fortified with buckwheat flour [40].

Table 2
Comparison of macromolecular contents of cookies to nutritional intake standards.

	Macromolecules content (%DM)	Energy intake (kcal)	Contribution to total energy intake (%)	Standards of NASS (%) [47]
Crude protein	6.29	25.16	5.14	15
Carbohydrates	54.35	217.4	44.34	45–50
Total fat	27.52	247.68	50.52	35–40
Total energy intake (kcal)	/	490.24	100	/

Source: authors.

Table 3
Average composition (mg/100 g DM) of minerals and vitamin C of cookies.

Samples	Control rice cookies (0% baobab pulp flour)	Enriched rice cookies (20% baobab pulp flour)
Calcium	$20^{a} \pm 0.01$	$30^{b} \pm 0.01$
Magnesium	$10^{a} \pm 0.02$	$20^{b} \pm 0.03$
Potassium	$610^{a} \pm 0.03$	$930^{b} \pm 0.18$
Zinc	$1.07^{a} \pm 0.001$	$1.054^{a} \pm 0.02$
Copper	$0.091^{a} \pm 0.09$	$0.18^{b} \pm 0.01$
Manganese	$0.318^{a} \pm 0.00$	$0.4^{a} \pm 0.02$
Iron	$3.976^{a} \pm 0.03$	$15.6^{b} \pm 0.01$
Vitamin C	nd	$60^{a} \pm 0.06$
Phosphorus	$80^{a} \pm 0.01$	$220^{b} \pm 0.09$

[a,b] Means with different superscripts in same line indicate significant difference ($P < 0.05$).
nd: not detectable.
Source: authors.

- *Carbohydrate content*: Just like crude protein, carbohydrate content of cookies reduced with fortification: the value dropped from 59.26 to 54.35% DM.

Carbohydrates, essential for the functioning of the muscles and the brain, are the energy source that can be used quickly by the body and are involved in anabolism of proteins. The carbohydrate content of the substituted cookies was lower than that of the control cookies. The carbohydrate content obtained (54.35% DM) was higher than that of sorghum cookies enriched with moringa flour [44], but lower than millet cookies enriched with chenille powder [46] and 'Maria' cookies [45].

Energy value: Rice cookies enriched with baobab pulp flour had an energy intake of 490.24 kcal/100 g.

The energy value of these rice cookies enriched with baobab pulp flour was more calorific than sorghum cookies enriched with 21% of orange-coloured potato flour [44] and 'Maria' cookies [45]. According to the National Agency of Sanitary Security (NASS) [47], the Recommended Nutritional Intake (RNI) for adults between the ages of 20 and 40 years, as part of normal activity is 2700 kcal for men and 2200 kcal for women. Rice cookies enriched with baobab pulp flour are therefore calorific as they provide up to 22% of the RNI in women and 18% in men.

The contribution of each macromolecule to the total energy intake was 5.13% for crude protein, 44.34% for carbohydrates and 50.52% for total fat (Table 2). These results showed that only the contribution of carbohydrates to the total energy intake fell within the recommendable value range of NASS [47]. That of crude proteins was lower while that of total fat was higher than the recommended value. These results showed that although the studied cookies are highly caloric, their fat content is higher than the recommended value, thus making them fatty cookies.

Mineral and vitamin C intake of cookies

Baobab-enriched cookies had total mineral content (ash content) higher than that of the control cookies: 0.9% and 1.57% with control cookies and enriched cookies respectively. Trace and major elements of baobab-enriched rice cookies were represented in Table 3. This Table reflected a significant mineral content of fortified cookies. When compared to the control, fortification with baobab pulp flour improved copper, iron, calcium, magnesium, phosphorus and potassium contents of the fortified cookies, while the zinc and manganese contents remained unchanged. This may be due to the fact that baobab flour is highly rich in minerals such as iron, calcium, and magnesium [44].

Trace elements. *Zinc content*: baobab pulp fortified cookies was not significantly different when compared to the control. This content corresponded to 9% of the daily dose (11 mg/day maximum for an adult) recommended by Codex Alimentarius [48]. Zinc deficiency is responsible for many diseases including sterility and night blindness. However, the baobab pulp fortified rice cookies had zinc content (1.4 mg/100 g) lower than that of sorghum cookies enriched with orange-coloured potato flour [44].

Copper content: Cookies made with 20% baobab pulp flour had a copper content twice as high (0.18 mg/100 g vs. 0.09 mg/100 g) as that of the control cookies.

Copper is an essential trace element for many enzymes and is involved in the maintenance of cartilage and bone, and is also essential in the fight against infections and the proper functioning of the heart. Copper deficiency disturbs connective tissue formation and significantly weakens the body's immune system. The values obtained for enriched cookies were lower when compared to the FAO recommended doses for 7 to 12 month-old infants, which is 0.34 mg/day and about 1 mg/day for adults [48]. Cookies made with 20% baobab pulp flour had a copper content similar to that of whole bread [47].

Manganese content: The manganese content of cookies made with 20% baobab pulp flour remained almost identical to that of the control.

Manganese is an essential trace element, not synthesized by the organism. It intervenes in many vital mechanisms of the body such as the enzyme system by limiting the action of free radicals, fat metabolism, and production of sex hormones. Manganese deficiency can cause growth retardation and dermatological problems such as dermatitis. The manganese content of the enriched cookies corresponded to 25% of the recommended nutritional intake value of the Codex Alimentarius [48] which is 2 mg/day for an adult.

Iron content: Cookies made with 20% baobab pulp flour were very rich in iron. The iron content of the enriched cookies was 3 times higher than that of the control cookies: the obtained value was 15.6 mg/100 g, against 3.976 mg/100 g for the control rice cookies.

Iron is a major constituent in the manufacture and function of haemoglobin, a red blood cell protein that transports oxygen from the lungs to the cells. It also enters into the constitution of myoglobin, which is the protein responsible for muscle oxygenation [47]. Iron deficiency causes anemia. It is the most common nutritional deficiency in the world and particularly affects the female population. The consumption of 100 g of enriched rice cookies already covers the body's iron requirement which is 16 mg/day for women, 14 mg/day for men and 10 mg/day for children [47]. This high content in iron of enriched cookies is probably due to the fruit of baobab whose iron content is 7 mg/100 g [49]. Cookies made with 20% baobab pulp flour were significantly richer in iron than sorghum cookies enriched with red meat flesh (3.7 mg/100 g) [44].

Major minerals. *Calcium content*: Cookies made with 20% baobab pulp flour had higher calcium content when compared to the control.

Calcium contributes to the edification and renewal of the skeleton and participates in muscular and cardiac contraction, blood coagulation, cell exchange, membrane permeability, hormone release and nerve impulse transmission. Calcium deficiency can cause chronic diseases such as osteoporosis, as well as joint and cardiovascular problems. The recommended calcium intake is 950 mg/day for an adult and 700 mg/day for a 4 to 6-year-old child [47]. This difference may be due to the high content of calcium (300 mg/100 g) of baobab calcium [49].

Magnesium content: fortification with baobab pulp flour doubled the magnesium content of enriched cookies when compared to the control.

Magnesium is one of the most abundant minerals in the body. Its main property is its soothing action, which helps to fight against stress. It also has a relaxing action on the muscles, stimulates the immune system and regulates carbohydrate and lipid metabolism of the muscular, cardiac and nervous tissues [47]. Magnesium deficiency may cause muscle problems (cramps, contractures,..), tachycardia, headache and high blood pressure. The recommended intake for children likewise adults is 6 mg per kg of weight per day. The high magnesium content observed in enriched cookies (20 mg/100 g) could be due to the high content of magnesium in baobab [6].

Potassium content: The potassium content of cookies made with 20% baobab pulp flour was 930 mg/100 g.

Potassium is needed for the regulation of cell water balance, in the use of carbohydrates and the construction of proteins. It acts against the perturbations of the heart rhythm and intervenes in the regulation of osmotic pressure of the cell. Potassium participates in membrane transport and activation of enzymes and plays a role in muscle contraction (increased neuromuscular excitability) [50]. Fatigue is the most common symptom of potassium deficiency. Cramps, myalgia and muscle weakness can be observed during hypokalemia. Nausea, constipation, intestinal bloating are also observed. Compared to the control cookies, fortification improved the potassium content by about 66%. Cookies made with 20% baobab pulp flour thus had a potassium content well above the WHO recommended value of 420 mg/day for an adult male and 360 mg/day for an adult woman.

Phosphorus content: The phosphorus content of cookies improved with fortification. Cookies made with 20% baobab pulp flour had phosphorus content of 220 mg/100 g DM.

Phosphorus is an important component of bones and teeth which help strengthens them and provide good mineral density. It also helps maintain blood acid-base balance. Phosphorus deficiency is found in children in countries where malnutrition and under nourishment are prevalent. It results in loss of appetite, muscle weakness, difficulty in walking coordination, anemia and bone disorders: rickets in children, bone demineralization in adults [51]. The recommended dietary intake is 700 mg/day for adults and 500 mg/day for young children 8 years old. 20% cookies fortified with baobab pulp contribute nearly half of the recommended value.

Vitamin C content. Table 3 showed that cookies made with 20% baobab pulp flour were richer in vitamin C when compare to the control.

Vitamin C is the most effective antioxidant in the class of hydrophilic vitamins. It participates in several essential metabolic processes such as collagen production, connective tissue biosynthesis, neurotransmitters and hormones. Ascorbic acid also increases the assimilation and bioavailability of calcium and iron in the body. It is recognized as a preventive agent for several degenerative and cardiovascular diseases and also arteriosclerosis. Vitamin C deficiency causes scurvy. The vitamin C content of cookies made with 20% baobab pulp flour was higher than the recommended value of WHO/FAO

[52] which is 30 mg/day for infants aged 7–12 months and 45 mg/day for an adult. The obtained vitamin C content of cookies was also higher to that of cookies enriched with other fruits, such as pomace fruit [53]. This high content of cookie's vitamin C could be explained by the incorporation of baobab flour in rice cookies because vitamin C content of baobab fruit is 300 mg/100 g [49].

Total fibre content of cookies

Cookies made with 20% baobab pulp flour had a total fibre which was double the value obtained for the control cookies (8.65±0.10 and 4.37±0.34 mg/100g DM respectively) .

Fibres regulate the intestinal transit and capture some of the lipids and carbohydrates, which allow regulating in part the blood sugar level and avoiding excess cholesterol. Due to their high degree of saturation, these fibres have a positive effect on overweight and metabolic diseases [54]. It is recommended to consume between 25 and 30 g of fibre per day in adulthood [55]. Cookies made with 20% baobab pulp flour had a fibre content that was higher than that of soft wheat cookies [40], cookies enriched with pomace fruit [53], but lower than that of mango-enriched cookies [56]. The high fibre content of rice cookies enriched with baobab may be due to the incorporation of the baobab since the baobab fruit contains 30% fibre in its pulp [49].

Conclusions

The objective of this study was to develop a new functional cookie based on rice and enriched with baobab pulp flour, and to determine its physicochemical, sensory and nutritional properties. Three formulations (10, 20 and 30%) were studied and rice cookies made with 20% of baobab pulp flour was the most preferred formulation for all sensory attributes and also had the best overall acceptability and index of acceptability. This cookies enriched with 20% baobab pulp flour is very rich in minerals such as iron, calcium, potassium, magnesium, total fibre and vitamin C. The valorisation of the baobab in cookies seems to be a very low cost alternative and affordable way to combat micronutrient deficiencies in Africa in general. As a perspective to this study, it will be advisable to complete nutritional analysis (amino and fatty acids profiles), to verify some toxins as aflatoxins for commercial purpose, to study the lifespan of cookies, to determine socio economic, developmental, and ecological impacts.

Declarations of interest

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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