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Nutritional composition of neglected seeds of jackfruit (*Artocarpus heterophyllus*) cultivated in Burundi

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Abstract

Malnutrition comprises overnutrition and undernutrition. Undernutrition, which stands for insufficient consumption of required calories and nutrients, is a global concern because it can result in diseases such as kwashiorkor and marasmus observed in children. Undernutrition is partly associated with excessive dependence on foods made of few crops. This dependence is widely ascribed to people's ignorance of the nutritional importance of unfamiliar crops, including Jackfruit (*Artocarpus heterophyllus* Lam.). Jackfruit is considered as a non-widespread plant in Burundi where only few people eat its pulps while seeds are discarded as waste. In this study, we determined the nutritional value of jackfruit seeds for the sake of valorization. The results showed that 100 g of fresh material contain 47.44 g of water, 6.32 g of proteins, 0.41 g of fats, 0.46 g of total sugars, 0.27 g of reducing sugars, 2.5 mg of vitamin C, 0.17 g of calcium, 67.5 mg of magnesium, and 1.06 mg of iron. Compared with values from some foods commonly eaten in Burundi, these results highlighted the richness of jackfruit seeds in some nutrients such as proteins and minerals, namely calcium, iron and magnesium, required for a balanced human diets. Therefore, the consumption of jackfruit seeds could improve food security.

1. Introduction

Malnutrition, which comprises both overnutrition and undernutrition, is of serious global health concern. Consisting in excessive uptake of food and nutrients, overnutrition can potentially lead to obesity, a health condition generally linked to chronic diseases, such as cancer, hypertension, cardiovascular disease, and type-2 diabetes. Undernutrition, which denotes insufficient intake of required calories and nutrients, can also result in diseases including kwashiorkor and marasmus observed in children. According to the World Health Organization (WHO), 462 million of world population are underweight, whereas 45% of deaths among children under five are attributed to undernutrition [1]. In 2008, 93% of 8.8 million deaths in children under five were due to underweight in Africa and Asia [2]. In addition to food shortage, excessive dependence on diets made of few crops mostly results in undernutrition [3,4]. This dependence, which is due to ignorance of the nutritional importance of unfamiliar crops, predominantly occurs in Africa where diets are mainly based on cereals [5]. The decreased nutritional value of the resulting foods contributes to food insecurity [6]. It is therefore of importance to find alternative food sources that can improve food security.

Artocarpus heterophyllus Lam. is a tropic tree carrying green to yellow-brown fruit, the jackfruit. This fruit is made of up to 500 light brown to brown seeds [7]. Jackfruit, which is mainly eaten either as pulps or seeds [8], has been reported to be rich in nutrients, including carbohydrates, proteins, vitamins, minerals and phytochemicals [9-12]. However, the chemical composition of jack fruit depends on various factors, such as soil quality, plant genetics, stage of maturity, and climatic conditions [13-16], calling for a systematic assessment of its nutritional value.

A. heterophyllus is a non-widespread plant in Burundi. Only few people eat its pulps, whereas seeds, which represent 10 to 15% of the total mass of the fruit [17], are discarded due to ignorance of their nutritional value. The aim of this study was to determine the nutritional value of jackfruit seeds for the sake of valorization. The results revealed the nutritional importance of neglected jackfruit seeds as source of nutrients required for a balanced diet.

2. Methodology

2.1 Plant material and sample preparation

Five ripe jackfruits were harvested from five trees randomly selected in Bugabira, Kirundo province, northern Burundi. Fruit were characterized by measuring their weight, length, and diameter. 120 seeds were randomly collected and divided into two groups of 60 seeds each. Seeds were then transported to the laboratory for chemical analysis. One group was directly grinded for the evaluation of nutrients in fresh material while the other one was oven-dried and reduced to powder for the determination of nutrients in dry material. Sample analysis was carried out in triplicate and the collected data were averaged.

2.2 Determination of the dry material and moisture content

Dry material and moisture were determined at the Laboratoire d'Analyse des Sols et Produits Agro-alimentaires (LASPA) of the Institut des Sciences Agronomiques du Burundi (ISABU). 2 g of powder were placed in a pre-tared silica crucible and weighed using an analytical balance (Ohaus Corporation, Parsippany, NJ, USA). The crucible was placed in an oven (Memmert, Germany) set at 105 °C for 24 h. The crucible was removed and stored at room temperature in a desiccator prior to reweighing. The operation was repeated until the mass of the dry sample become constant. The percentage of dry material (DM) was given by **Eqn. 1**.

$$DM\ (\%) = \frac{P_2}{P_1} \times 100 \qquad \textbf{Eqn. 1}$$

where P_1 and P_2 respectively represent the masses (g) of fresh and dry samples. The moisture (M) is obtained by **Eqn. 2**.

$$M(\%) = 100 - DM(\%) \qquad \textbf{Eqn. 2}$$

2.3 Determination of protein content

The content of protein was determined in LASPA using the Kjeldhal method [18]. 25 ml of concentrated sulfuric acid and a mixture of catalysts (potassium sulfate, copper (II) sulfate pentahydrate, selenium, iron (II) sulfate heptahydrate) were added to 2 g of powder in 1000 ml-Kjeldhal flask. The mixture was gently heated in a hood until the appearance of pink color. The mixture was then cooled at room temperature prior to the addition of 300 ml of distilled water. 25 ml of the obtained solution was basified with sodium hydroxide (50%) and distilled. The extremity of the condenser was immersed in a flask containing 50 ml of boric buffer. A fixed ammonia was then titrated with sulfuric acid (0.1N) to determine the amount of total nitrogen in the sample. A control was similarly prepared without the addition of the powder. The percentage of total nitrogen was calculated according to **Eqn. 3**.

$$Total\ nitrogen\ (\%) = \frac{(V_1 - V_2)xNx0.014xFxf}{M}x100 \quad \textbf{Eqn. 3}$$

where V_1 and V_2 respectively represent the volumes in ml of sulfuric acid solution used to titrate the sample and the control, N the normality of the sulfuric acid solution (0.1N), 0.014 the equivalent mass of nitrogen per ml of solution, F the conversion factor for proteins [19], M the mass of the test portion of the sample, and f the correction factor. f was determined by titrating 3 ml of the solution of sodium carbonate (meq/l) with a solution of sulfuric acid (0.05 N) and calculated using the **Eqn. 4**.

$$f = \frac{3x0.1}{Vx0.05} \quad \textbf{Eqn. 4}$$

where V is the volume in ml of sulfuric acid used to titrate sodium carbonate. The protein content in percentage was calculated according to the **Eqn. 5**.

$$Proteins\ (\%) = Total\ nitrogen\ (\%)x6.25 \quad \textbf{Eqn. 5}$$

2.4 Determination of sugar content

The content of sugar was determined in LASPA according to the Luff-Schoorl method [20]. 150 ml of distilled water was added to 12.5 g of powder contained in a 250 ml-flask. The mixture was stirred for 30 min using a magnetic stirrer (HJ1, Anzeser, Shenzen, Guangdong, China) to solubilize the sugars. 5 ml of CARREZ A solution and 5 ml of the CARREZ B solution were then added to the mixture while stirring. The mixture was brought to 250 ml with distilled water, homogenized, and filtered. 25 ml of the filtrate were placed in 250 ml-flask, brought to 250 ml using distilled water, and then homogenized. The obtained solution was used for the determination of the content of reducing and total sugars.

To ascertain the concentration of reducing sugars, 25 ml of Luff-Schoorl's reagent and three pieces of pumice stone were mixed with 25 ml of the solution contained in a 250 ml-flask. After 2 min, the mixture was heated under reflux for 10 min and cooled. 1 g of potassium iodide dissolved in distilled water and 25 ml of sulfuric acid solution (25%) were carefully added. The molecular iodine thus released was titrated with sodium thiosulfate (0.1 N) in the presence of starch indicator. To determine the total sugars content, 4 drops of methyl orange, 5 drops of hydrochloric acid (3.7 N), and 10 ml of hydrochloric acid (0.1 N) were added to 25 ml of the sample in a 50 ml-flask. The obtained mixture was heated and cooled to room temperature prior to the addition of 10 ml of sodium hydroxide solution (0.1 N). The volume was brought to 50 ml using distilled water. 25 ml of the obtained solution were then used to determine the content of the reducing sugars as described above. The content of non-reducing sugars was calculated using the **Eqn. 6:**

$$NRS = TS - RS \quad \textbf{Eqn. 6}$$

where *NRS*, *TS*, and *RS* represent the non-reducing sugar content, the total sugar content, and reducing sugar, respectively.

2.5 Determination of fat content

The content of fat was determined in LASPA using the Soxhlet method [21]. 5 g of powder were put in a cartridge covered with a cotton ball that was placed inside the Soxhlet apparatus. A flask containing a few pumice stones was tared prior to being filled with 300 ml of carbon tetrachloride (CCl_4). Flask, Soxhlet apparatus, and condenser were mounted and heated using a heating mantle at a siphon rate of 10 times per hour. A solvent containing lipids was recovered after 4 h and cooled to room temperature. Residual CCl_4 was evaporated from a flask containing the mixture of oil and pumice stones. The content of fat was then determined using the **Eqn. 7.**

$$Fat\ content\ (\%) = \frac{m_2 - m_1}{m_0}x100 \quad \textbf{Eqn. 7}$$

where m_1, m_2, and m_0 respectively represent the mass of the flask containing the pumice stones before extraction, the mass of the flask containing the pumice stones and oil after extraction and evaporation, and the mass of the sample.

2.6 Determination of the content of mineral elements

The determination of the content of mineral elements (Ca, Mg, and Fe) was carried out using atomic absorption spectrometry (AAS) under a UV spectrum, flame air-acetylene, and a slit of 0.7. Working solutions of 100 ppm $CaCl_2$, 100 ppm $FeCl_3.6H_2O$, and 10 ppm $MgCl_2.6H_2O$ were prepared from stock standards of 1000 ppm to obtain calibration curves. All the standards were prepared from analytical grade reagents (VWR Chemicals, Leuven, Belgium). 5% Lanthanum chloride ($LaCl_3$) was added to 5, 15, and 30 ml of 100 ppm solution contained in 100 ml-flasks. The volume was then brought to 100 ml with a solution of 3.7 N HCl. The blank was prepared in the same way, but without analyte. The analyzes of Ca, Mg and Fe were carried out at wavelengths (λ) of 422.7, 285.2, and 248.4 nm and a current of 10, 6, and 30 mA, respectively.

2.7 Determination of the content of vitamin C

The content of vitamin C was determined in the Centre National de Technologie Alimentaire (CNTA). A standard solution of vitamin C (0.2 g/l) was prepared by dissolving 0.05 g of ascorbic acid in 60 ml of metaphosphoric acid (20%). The volume was brought to 250 ml using distilled water. 40 ml of 20 % metaphosphoric acid was added to 10 ml of the extract of jackfruit seeds for the sake of stabilization. Half of the obtained volume was poured into an Erlenmeyer flask, mixed with 2.5 ml of acetone, and then titrated with 2,6-dichlorophenolindophenol (DCPIP) solution.

2.8 Data conversion

For the sake of ease comparison, the nutrient values, which were determined relative to the dry material, were converted to fresh material-based equivalents (R) except for vitamin C and moisture using the **Eqn. 8**:

$$R\ (\%) = \frac{R_{FM\ (\%)} x DM\ (\%)}{100} \qquad \textbf{Eqn. 8}$$

R_{FM} and DM represent the results obtained from the fresh material and the dry material, respectively.

3. Results and Discussion

3.1 Characteristics of the harvested jackfruit

The ripe jackfruits were harvested and characterized by measuring their weight, length, and diameter. As shown in **Figure 1**, fruits were cylindrical, oblong, and their length varied from 31 to 47 cm with a diameter ranging from 47 to 68 cm. The weight of each fruit varied between 11 and 24 kg. Brown in color, the rounded seeds had a length of 2.1 to 2.9 cm and a diameter ranging from 0.9 to 1.7 cm. All characteristics were found to be in ranges that have been reported in *A. heterophyllus* grown in different regions over the world [9,22-25], evidencing that jackfruit could be beneficially grown in Burundi.

3.2 Moisture content

The value of a product is often overestimated on the basis of its content in moisture. However, the moisture content of food can considerably influence its shelf life and quality [26]. Thus, the knowledge of moisture content not only informs on food quality but also permits the prediction of the deterioration risk during its storage. The moisture content of our sample (47.44 g of water per 100 g of fresh material) was less than half of the total composition (**Table 1**).

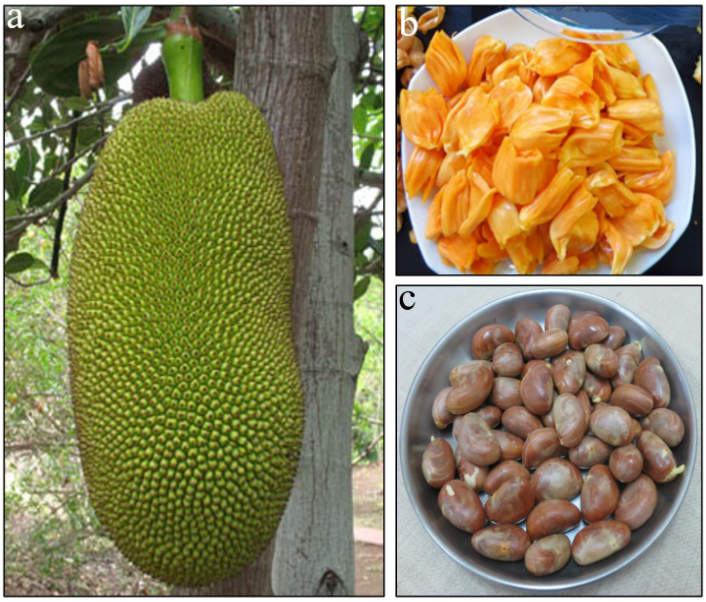

Figure 1. Picture of (a) jackfruit that contains (b) pulps and (c) seeds

Table 1. Nutrient content of jackfruit per 100 g of dry and fresh materials

Nutrient	Dry matter	Fresh matter
Water content (H)	not determined	47.44 ± 3.39
Vitamin C (mg)	not determined	2.5 ± 0.2
Protein content (g)	12.03 ± 0.65	6.32 ± 0.27
Fat (g)	0.78 ± 0.05	0.41 ± 0.03
Total sugar (g)	0.88 ± 0.06	0.46 ± 0.04
Reducing sugar (g)	0.51 ± 0.024	0.27 ± 0.03
Ca (mg)	334.1 ± 17.8	175.6 ± 7.6
Mg (mg)	128.6 ± 10.9	67.5 ± 3.4
Fe (mg)	2.017 ± 0.136	1.06 ± 0.05

With reference to most consumed foods in Burundi, the moisture content of our sample was lower. This observation testified the richness of jackfruit seeds in proteins, Ca, Fe, and Mg (**Table 2**) because nutrient concentration increases when the water content of a food decreases [27]. However, the moisture content found in this study, which was higher than the moisture content for safe storage of 13%, can alter the quality of jackfruit seeds during storage [28]. Therefore, it is highly recommended to dry the seeds to enable their conservation for a later consumption. For the sake of ease comparison, the nutrient values of jackfruit seeds were compared with those of commons foods consumed in Burundi (**Table 2**). The nutritional values of these foods were established on the basis of data taken from the ANSES-CIQUAL website [29] where the values were established per 100 g of fresh material. **Table 2** illustrates the comparison between the nutritional values of jackfruit seeds and some of the most foods commonly consumed in Burundi per 100 g of fresh material.

3.3 Protein content

Proteins constitute one of the major families of macronutrients essential to human body. The protein content of jackfruit seeds was found to be 6.23 g and 12.03 g per 100 g of flesh and dry material, respectively (**Table 1**). This composition has been compared with that of some foods commonly eaten in Burundi (**Table 2**). Although dry beans are mainly consumed in Burundi, we considered the green beans as all values were determined on fresh materials.

Table 2. Nutritional value of the jackfruit seeds compared with foods commonly consumed in Burundi

Food	Jackfruit	Beans	Rice	Sweet potato	Potato	Banana
Water (g)	47.44	90.00	67.00	78.00	80.00	75.00
Energy (cal)	nd	33	135	79	73	94
Proteins (g)	6.32	1.4	2.5	1.7	2.0	1.2
Total sugar (g)	0.46	5.1	28.7	16.3	15.0	20.5
Fat (g)	0.41	0.2	0.9	0.1	0.1	0.2
Ca (mg)	175.6	56.3	8.2	32.5	nd	4.5
Fe (mg)	1.06	0.6	0.3	0.7	0.5	0.3
Mg (mg)	67.5	22.4	11.4	22.5	20.0	32.8
Vitamin C (mg)	2.5	8.0	0	16.2	10.2	6.5

nd: not determined

The protein content of most eaten foods was lower compared with that of jackfruit seeds, making the jackfruit a valuable source of proteins. Similar compositions have been found in the seeds of *A. heterophyllus* cultivated in different regions over the world [30,31]. Relative to beans (1.4 g per 100g), the most important source of proteins of many Burundians, jackfruit seeds become a highly valuable protein source to be adopted. Therefore, the consumption of jackfruit seeds can be recommended for the prevention of certain malnutrition-associated diseases such as Kwashiorkor, the main cause of infant mortality in Africa and other developing countries [32].

3.4 Sugar content

Sugars constitute an important source of energy. However, an increased intake of sugar can result in health problems, calling for a systematic assessment of food content in sugar. For 100 g of fresh material, our sample contained 0.46 g of total sugars, 0.27 g of reducing sugars and 0.19 g of non-reducing sugars (**Table 1**). The sample was mainly made of reducing sugars, indicating that jackfruit seeds are rich in mono and disaccharides whose excessive intake may lead to adverse food reactions [33]. Fortunately, the total sugar content of seeds cultivated in Burundi was found to be far lower than that observed in some foods frequently consumed in Burundi (**Table 2**) and other *A. heterophyllus* cultivated in different regions around the world [34]. These results show that these seeds could be recommended for people who suffer from diabetes [35].

3.5 Fat content

Fats serve as sources and stores of energy. Fat content of jackfruit seeds was found to be 0.41 g per 100 g of fresh material (see **Table 1**) We noticed that jackfruit seeds have a slightly higher lipid content than other foods commonly eaten in Burundi except for rice (see **Table 2**).

3.6 Content of mineral elements

The contents in certain mineral elements, namely Ca, Mg and Fe, were determined in the seeds of jackfruit. Ca accounted for the major element followed by Mg while Fe level was the least as shown in **Table 2**. Per 100 g of fresh material, their respective compositions were 175.6, 67.5, and 1.06 mg. The results revealed the presence of essential elements in jackfruit seeds yet considered as unusable materials. Compared with some foods commonly consumed in Burundi (see **Table 2**), these mineral elements, particularly Ca and Mg, are present in considerable quantities. The analyzed minerals have been recently found but in lower amount in flowers of Jackfruit [36]. These nutrients are involved in muscle contraction, oocyte activation, building strong bones and teeth, blood clotting, nerve impulse, regulating heartbeat, regulation of osmotic gradients, maintenance of blood pH and blood clotting and fluid balance within cells [37,38]. Thus, the consumption of jack fruit seeds can obviously contribute to the prevention of certain diseases such as osteoporosis in older women and the alleviation of stunting observed in children [1,39].

3.7 Vitamin C content

Vitamin C is an essential dietary component involved in various metabolic processes. Its content in our sample was found to be 2.5 mg per 100 g of fresh material. Except for rice, this proportion is far lower than that found in foods frequently consumed in Burundi as shown in **Table 2**. Therefore, the seeds of jackfruit cultivated in Burundi are not a good source of vitamin C.

Conclusion

The present study was carried out to investigate the nutritional value of jackfruit (*A. heterophyllus*) seeds cultivated in Burundi. Compared with some foods commonly eaten in Burundi, the results showed that, despite the relatively low levels of vitamin C and sugars, the seeds of jackfruit contain significant amounts of protein, and mineral elements, such as calcium, magnesium, and iron. The regular consumption of jackfruit seeds could ensure a normal growth and development of children suffering from Kwashiorkor as well as the rigidity of the skeleton in elderly women suffering from osteoporosis. Due to their lower content in sugar, jackfruit seeds can also be eaten by people suffering from type 2 diabetes. Overall, jackfruit seeds that have been considered so far as wastes, could be an alternative food source to improve nutrition and food security.

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