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CASE STUDY

Determination of health and nutritional benefits of jackfruits *(artocarpus heterophyllus)*

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Abstract

Jackfruit *(artocarpus heterophyllus)* is one of the tropical fruits uncommonly consumed in Ghana. In this study, the nutritional and health benefits of the jackfruit pulp, together with its bark and leaves, were assessed. The methodology was centred on determining the macro- and micro-nutrient composition and some potential health benefits of the jackfruit pulps, barks, and leaves. The proximate analytical methods of the Association of Official Analytical Chemists (AOAC) were used to quantify the macronutrients. The micronutrient contents were determined using spectrophotometric and non-spectrophotometric methods. The total phenolic content (TPC), total flavonoids content (TFC), and the β-carotene contents were determined using spectrophotometry as a means of measuring the health benefits of the samples. The crude protein, carbohydrates, and fibre content of the pulp were 1.05±0.06, 17.40±0.36 and 0.46±0.15 g/100 g of fresh fruit sample, respectively. The K, Ca, and P contents of the jackfruit pulps were 422.36±9.60, 69.91±1.66, and 61.17±0.01 mg/100 g of fresh fruit sample, respectively. The TPC, TFC, and β-carotenes content of the pulps were 65.9302±0.0163 mg GAE/100 g, 5.7620±0.0291 mg QE/100 g, and 2.43±0.06 mg/100 g, respectively. The results showed that jackfruit is rich in nutrients including minerals, phytochemicals, and in relatively higher amounts compared with other fruits.

Keywords: Jackfruit, Antioxidants, Phytochemicals, Spectrophotometry, Proximate Analysis, Pharmacological Properties

Introduction

Jackfruit, botanically known as *Artocarpus heterophyllus*, thrives in tropical and subtropical regions throughout the world. It is in the same plant family as figs and mulberries and belongs to the family Moraceae. Jackfruit is the largest tree-borne fruit in the world, and it can weigh approximately 50 Kg or more (Arora and Parle, 2016). It is sometimes called the poor man's food because it is a relatively inexpensive and widely available nutritious fruit in many tropical and subtropical regions of the world (Khan *et al.*, 2021). Jackfruit is an extremely versatile and sweet-tasting fruit that possesses high nutritional values, and its taste is described as a cross between mango and pineapple. Due to its fibrous texture, people often use jackfruit flesh as a meat substitute in vegetarian dishes. Research has shown that jackfruit is rich in nutrients such as carbohydrates, proteins, vitamins, minerals, and phytochemicals. Also, it has been noted that the entire jackfruit plant, comprising the leaves, fruits, and bark, has been extensively used in the production of traditional medicine (Ranasinghe *et al*., 2019).

Previous studies have revealed numerous health benefits of jackfruit, including anticarcinogenic, antimicrobial, antifungal, anti-inflammatory, wound healing, and hypoglycemic properties. These observed pharmacological properties may be attributed to the presence of various phytochemicals such as phenolics, flavonoids, and carotenoids (Baliga *et al.*, 2011; Khan *et al.*, 2021; Shafiq *et al.*, 2017; Arora and Parle, 2016; Saha *et al.*, 2022). Apart from these health benefits, jackfruit can also help improve digestion and strengthen bones (Swami *et al.*, 2012). However, it is considered an underutilized fruit on a commercial scale, mainly due to the higher percentage of inedible portions, which leads to larger waste generation, difficulty in peeling and separation of edible bulbs from the rind, lack of knowledge on proper postharvest practices, and inadequate processing facilities in regions where they are grown (Kumar *et al*., 2017). In addition, it is rarely grown on a regular plantation scale due to its short shelf life, as well as being an unknown fruit within the Ghanaian community. Jackfruits are however highly patronized by foreign nationals, particularly Indians, Chinese, and the people of Bangladesh, compared to their counterparts in Ghana. The reason for this is unclear and uncertain yet; however, it could be due to its unfamiliarity (unknown fruit) or the lack of availability in the local markets in Ghana.

Similarly, the jackfruit leaves are rich in various nutrients and bioactive compounds that can provide several health benefits to humans if extracted. Jackfruit leaves are considered agro-industrial waste, and only a minimal percentage of the total biomass is used as fodder for cattle as well as for asthma, diarrhea, anemia, and dermatitis treatments by the local people. The bioactive compounds include phenolics, flavonoids, terpenoids, stilbenoids, and others. The phenolic compounds are mainly characterized by their antifungal and antibacterial activities (Vázquez-González *et al*., 2020).

Jackfruit barks are rich sources of prenylated flavonoids, stilbenoids, triterpenoids, and steroids. Some of these compounds have exhibited interesting biological activities, such as cytotoxicity, antioxidative activity, anti-inflammatory activity, antimalarial activity, inhibition of tyrosinase and melanin biosynthesis, and inhibition of 5α-reductase (Wang *et al.*, 2017). According to Swami *et al*. (2012) extracts from the barks and rags (the non-edible portion of ripe fruits) or roots can help cure dysentery.

The main objective of the study is to determine the nutritional values and examine the health benefits of jackfruits, and the specific objectives include: determining the macro and micronutrient contents of fresh jackfruit pulps, leaves, and barks; analysing the antioxidant and anti-inflammatory properties of jackfruit pulps, leaves, and barks; comparing the nutritional compositions of jackfruit pulps, leaves, and barks; and comparing the nutritional and phytochemical compositions of jackfruits and other tropical fruits in Ghana. Ghanaians would therefore be encouraged to patronize them for their health and nutritional needs.

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(a) (b) (c) (d)

Figure 1 The (a) jackfruit plant with fruits, (b) jackfruit pulps, (c) jackfruit leaves, and (d) jackfruit barks

Sample preparation

Materials and Methods

The materials used include fresh jackfruit pulps, leaves, barks, (Figure 1) and chemicals such as 60 % hexane, 1.25 % H_2SO_4, 1.25 % NaOH, 96 % C_2H_5OH, concentrated NH_4OH, 0.02 N EDTA, 20 % $AlCl_3$, 20 % Na_2CO_3, and Folin-Ciocalteu phenol reagent (1:1 with water). The major instruments include furnace, oven, spectrophotometer, and flame photometer.

Sample preparation

Ripe jackfruits obtained from KNUST campus were washed, dissected, or peeled. The pulps and seeds were separated from the entire fruit. The pulps were milled in a blender and then stored in a well labelled clean and airtight nylon bag and kept in a refrigerator, in the food science laboratory, KNUST for the various analysis. Similarly, fresh samples of the leaves and barks of the jackfruit plant were taken from the plant. They were washed, milled, and stored in the freezer for the various analysis.

Macronutrients quantification

The macronutrients -crude proteins, crude fat, crude fibre, carbohydrates, ash, and moisture content- were quantified using the standard methods by Association of Official Analytical Chemists (AOAC) 2000. The moisture content was quantified by the method of difference by 1st weighing a known mass of each sample, drying in an oven at 105 °C for about 3 hours, and reweighing. The crude fat content was determined by Soxhlet extraction (AOAC, 2000), where the known masses of the samples were defatted using hexane and their masses reweighed. Also, the ash content (indicating the amount of inorganic matter) was determined by the method of difference, where known masses of previously dried samples were ashed in a muffle furnace for about 4 hours at 500 °C and reweighed. The crude fibre content was obtained from gravimetric analysis (AOAC, 2000). This involved acid digestion with 1.25 % H_2SO_4 to extract starch and sugar, alkaline digestion with 1.25 % NaOH to remove proteins and some hemicellulose and lignin, and ignition to correct for the ash content. Crude protein content was determined using Kjeldahl's method (AOAC, 2000), which involved the digestion of samples with concentrated H_2SO_4, distillation, and titration. Finally, the carbohydrate content was obtained by using the total fraction concept (AOAC, 2000), where all the macronutrient contents obtained were subtracted from 100 %, ensuring a uniform basis (wet or dry) of calculations.

Detailed description of the proximate analysis

Moisture content determination

Cleaned and dried petri dishes were weighed. About 5g of the jackfruit pulp sample was weighed using the analytical balance. The sample was spread to uniformity in 3 petri dishes (triplicates), and the weight was recorded as W1. The pulp samples were then dried in an oven for 3 hours at 105°C. After drying, the dishes were transferred to the desiccator to cool. The weight of the dishes together with the dried pulp samples were recorded as W2. The procedure was repeated for the leaves sample and the bark sample of the jackfruit. The moisture content was determined using the Eqn. (1).

$$\%\text{Moisture} = \frac{W1 - W2}{W1} \times 100\% \quad (1)$$

Where W1 = weight(g) of the sample before drying.
W2 = weight(g) of the sample after drying.

Crude fat content determination using soxhlet extraction

Dry filter papers were folded into a form that could contain the samples. Each folded filter paper was placed on an analytical balance and tared. 2.0 g of the previously dried jackfruit pulps was weighed into one of the folded filter papers. The above steps were conducted in triplicates for all the 3 samples (pulps, bark, and leaves). All the samples were sealed and arranged in the Soxhlet apparatus and hexane was used as the solvent of extraction. The setup was left to stay for about 6-hours. The defatted samples were dried and their masses reweighed. The crude fat content of each sample in the dry basis was determined using the Eqn. (2).

$$\%\text{Fat(dry basis)} = \frac{Wb - Wa}{W} \times 100\% \quad (2)$$

Ash content determination

The samples were dried in an oven at 105 °C for about 3 hours. Clean crucibles were also dried in the oven and cooled in a desiccator (for about 30 min). The initial, masses of the crucibles were weighed. About 1.0 g of sample was weighed into the dried crucible and placed in a muffle furnace for about 4 hours at 500 °C. The ashed samples were then cooled in a desiccator and their masses reweighed. The ash content was calculated using Eqn. (3).

$$\text{Ash (\%)} = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100\% \quad (3)$$

Crude fibre determination using the gravimetric method

About 2.00 g of the sample (pulps) was weighed into a 750ml Erlenmeyer flask. 200ml of 1.25 % H_2SO_4 was added and the flask was immediately set on a hot plate, with the condenser connected. After about 30 minutes, the flask was removed and immediately filtered through a linen cloth in funnel and washed with a large volume of water. The filtrate (containing sample from acid hydrolysis) was washed back into the flask with 200ml 1.25 % NaOH solutions. The flask condenser was connected, and the sample was boiled for exactly 30 minutes. It was filtered through a Fischer's crucible, washed thoroughly with water and 15ml 96 % ethanol was added. The crucible and its content were dried for about 2 hours at 105 °C, cooled in a desiccator and weighed. The crucible was Ignited in a furnace for 30 minutes, cooled and reweighed. The same procedure was repeated for the remaining samples, and Eqn. (4) was utilized.

$$\% \text{ Crude fibre} = \frac{\textit{weight of crude fiber}}{\textit{weight of sample}} \times 100\% \quad (4a)$$

$$\% \text{ Crude fibre (dry basis)} = \frac{\textit{weight of crucible + sample (before-after) ashing}}{\textit{weight of sample}} \times 100\% \quad (4b)$$

Protein content determination by the Kjeldahl's method

About 2 g of the sample (pulp/bark/leaves) was weighed and transferred into a Kjeldahl's flask. Then 2 g of catalyst containing K_2SO_4, $CuSO_4$ and SeO_2 was weighed and transferred into the flask containing the sample. 20 ml of concentrated Sulphuric acid was added to the sample flask using a pipette. The flask was shaken slowly to mix the acid with the sample and catalyst, and it was then placed on a digestion unit and heated to about 230°C. The digester was run for 2 hours. The end of digestion was indicated by a green clear solution. The flask was cooled at room temperature for 2 hours. 20 ml of water was added to the flask and shaken. The solution was then transferred to a 100 ml volumetric flask and topped up to the mark with distilled water. 30 ml of 4 % Boric acid was added to a conical flask. The conical flask was placed on the distillate collection unit. 10 ml of digested sample was transferred into the distillation flask using a pipette. 50 ml of 40 % NaOH and 50 ml of distilled water were added to the distillation flask. The distillation setup was run at a temperature of 200 °C and was turned off after collecting 100 ml of the distillate. A 0.1N of standard HCL was placed in a burette. Few drops of methyl indicator solution were added to the conical flask containing the distillate. The distillate was titrated with 0.1N standard HCl. The titration was stopped at a colour change to orange. The final burette reading was recorded.

Carbohydrates content determination

Carbohydrate content was determined using the difference method, given as:

$$\text{Total carbohydrates (\% wet basis)} = \{100 - \text{moisture (\%)} - \text{protein content (\% wet basis)} - \text{crude fat (\% wet basis)} - \text{total ash (\% wet basis)} - \text{\% Crude fibre (wet basis)}\} \quad (5)$$

Micronutrients quantification

The minerals analyzed were K, P, Mg, Ca and Na. The samples preparation and dry digestion procedure by Jones and Case (1990) were adopted, where dried samples were ashed in a muffle furnace at 500 °C for about 4 hours. The ashed samples were dissolved with distilled H_2O and the crucibles further rinsed with aqua regia (Jones and Case, 1990).

Determination of potassium and sodium using flame photometer

Calibration or standard curves for potassium (K) and sodium (Na) were obtained from the soil science laboratory, KNUST. The flame photometer was 1st set to 'K mode' and tested with the blank. The probe of the photometer was then placed in each sample solution and the absorbance readings were taken. The same procedure was repeated for Na by setting the photometer to 'Na mode'. From the standard curve, the concentrations of K and Na were calculated using the particular absorbance observed for the sample using Eqn. (6) (Motsara and Roy, 2008)

$$\text{K or Na content (g, DB) in 100 g plant sample, } \textit{(\%) K or \% Na} = \frac{c}{100} \quad (6)$$

Where C = concentration of K or Na, (µg / ml) read from the standard curve**.**

Determination of calcium and magnesium content

The calcium (Ca) and magnesium (Mg) content of each sample were determined by complexometric titrations with 0.01 M EDTA with EBT indicator (Motsara and Roy, 2008; Moss 1961) as follows:

$$\text{Calcium in mg} = \text{Titre value of EDTA} \times 0.4008 \quad (7a)$$

$$\text{Calcium (DB)} = \frac{\textit{mass of Ca (mg)}}{\textit{sample wt x volume}} \times 100 \quad (7b)$$

where 0.4008 M is the amount of Ca in mg that is complexed by 1 mL of a 0.01 M solution of EDTA

$$\text{Magnesium in mg} = \text{Titre value of EDTA} \times 0.243 \quad (8a)$$

$$\%\text{Mg} \frac{\textit{mg Magnesium}}{\textit{sample wt x volume}} \times 100 \quad (8b)$$

where 0.243 M is the amount of Mg in mg that is complexed by 1 mL of a 0.01 M solution of EDTA

Determination of phosphorus content

The analytical method by Motsara and Roy (2008) were adopted. Calibration or standard curve for phosphorus (P) was obtained from the soil science laboratory, KNUST. A 10 ml of the sample solution was transferred into a 100 ml volumetric flask. 10 ml of vanadomolybdate reagent was added and volume made up to 100 ml. The sample was kept for 30 minutes for colour development. A stable yellow colour was developed. The sample's absorbance was read on a Spectronic 20 spectrophotometer at 420 nm. The observed absorbance was used to determine the P content from the standard curve. The % P was calculated as:

$$\text{P content (g) in 100 g sample (\% P)} = \frac{c}{10} \quad (9)$$

Where C = concentration of P (µg /ml) as read from the standard curve (Motsara and Roy, 2008)

Vitamin C and phytochemical content

The vitamin C content of the jackfruit samples was determined by iodometry where sample solutions were titrated with 0.05M KI/KIO_3 using 1 ml of starch solution as indicator, until an endpoint (blue-black colour) was obtained (Helmenstine, 2020). The phytochemicals or bioactive compounds that were analyzed in the samples are the total phenolics content (TPC), total flavonoids content (TFC), and β-carotenes.

Total flavonoid determination using aluminium chloride

Using an analytical balance, 100 mg of each sample was weighed into three different test tubes. 20 ml of 80 % of ethanol was added to each test tube. The samples were vortexed for about 5mins. 100 µL of each vortexed sample was pipetted using a micropipette into test tubes. 10 test tubes were used together with the blank because the analysis was done in triplicates for all the 3 samples. 100 µL of 20 % of $AlCl_3$ was added to each of the test tubes using a micropipette. The samples were incubated for about an hour. The absorbances were measured at 420 nm against the blank sample. The total flavonoid contents of the samples were determined from the calibration curve equation ($R^2 = 0.8801$) (Nirmala *et al*., 2020) given as:

$$TFC = \frac{A + 0.0663}{349.26} \left(\frac{mg\ QE}{ml}\right) \quad (10)$$

Where A is samples absorbances, 349.26 and 0.0663 are the slope and intercepts from the calibration curve, and QE is Quercetin equivalent.

Total phenolic determination

Using an analytical balance, 100 mg of each sample was measured in three different test tubes. 20 ml of distilled water was transferred into each of the test tubes. The mixture was vortexed for five minutes for each of the test tubes. 100 µL of each of the sample was measured in triplicate into various test tubes. 20 mL of distilled water was used as a blank. 100 µL of 20 % Na_2CO_3 solution was added to each test tube with the help of a micro pipette. 20 µL of FC reagent was transferred into each test tube using a micropipette. The 10 test tubes were incubated in the dark for 30 minutes. The absorbances were measured at 760 nm against the blank using a Spectrophotometer. The total phenolic content in the extracts was determined from the calibration curve equation ($R^2 = 0.9926$) (Vernon *et al*., 1999) given as:

$$TPC = \frac{A - 0.0061}{103.24} \left(mg\ \frac{GAE}{ml}\right) \quad (11)$$

where GAE is Gallic acid equivalent.

β-Carotene content analysis

1g of each of the samples was weighed into 3 different test tubes. The test tubes were covered with muskin tape to reduce the evaporation rate of acetone. 100 ml of 1:1 acetone-hexane mixture was added to each of the samples in the test tube and vortexed for about 5 minutes. The absorbances were measured using a spectrophotometer at 453 nm, 505 nm, 645 nm and 663 nm. Composition of β-Carotene was calculated as:

$$\beta\text{-Carotene(mg/100L)} = 0.216A_{663} - 1.220A_{645} - 0.304A_{505} + 0.452A_{453} \quad (12)$$

where A_{663}, A_{645}, A_{505}, and A_{453} are the absorbances at wavelengths of 663, 645,505 and 453 nm respectively (Rosario *et al*., 2021).

Results and Discussions

The proximate or macronutrients analysis

Figure 2 illustrates the proximate analysis results, providing a visual representation of the approximate composition of the jackfruit pulps, barks, and leaves. From Figure 2, the moisture content was higher in all the samples, followed by carbohydrates. Also, the pulps have the highest amount of H_2O, and the bark has the highest amount of protein, carbohydrates, fat, and fiber.

The ash content is the measure of the inorganic materials present in the fruit, which are minerals in most cases (Ojwang *et al.*, 2018). The determination of the ash content also facilitated the analysis of the carbohydrate content in this project. The ash content in the leaves was similar to the one obtained by Amadi and Ihemeje (2018) , thus a value of (2.53±0.06) % on a wet basis. There was an inconsistency of the ash value with that of Goswami *et al*. (2015), who reported the pulp ash content between (0.7 - 1.0) % in Bangladesh (South Asia). This inconsistency may be due to the difference in geographical locations. Thus, the environmental conditions in West Africa and South Asia affected the consistency of the results.

Proteins are important nutrients in the body, as they help repair worn-out tissues and are a source of amino acids required for protein synthesis. The findings of this study showed that the protein content (% wet basis) of the jackfruit bark, leaves, and pulps were different from each other. The protein content in the

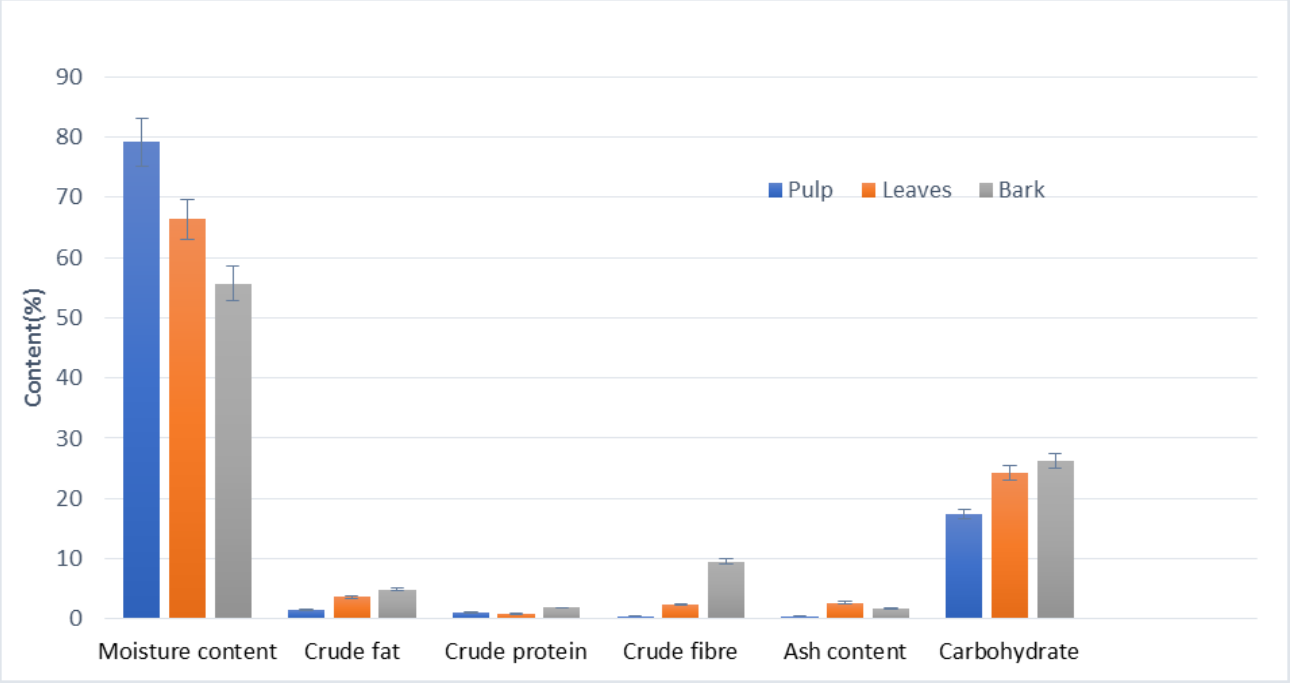

Figure 2 Comparison of the macronutrients content in the jackfruit pulps, barks and leaves

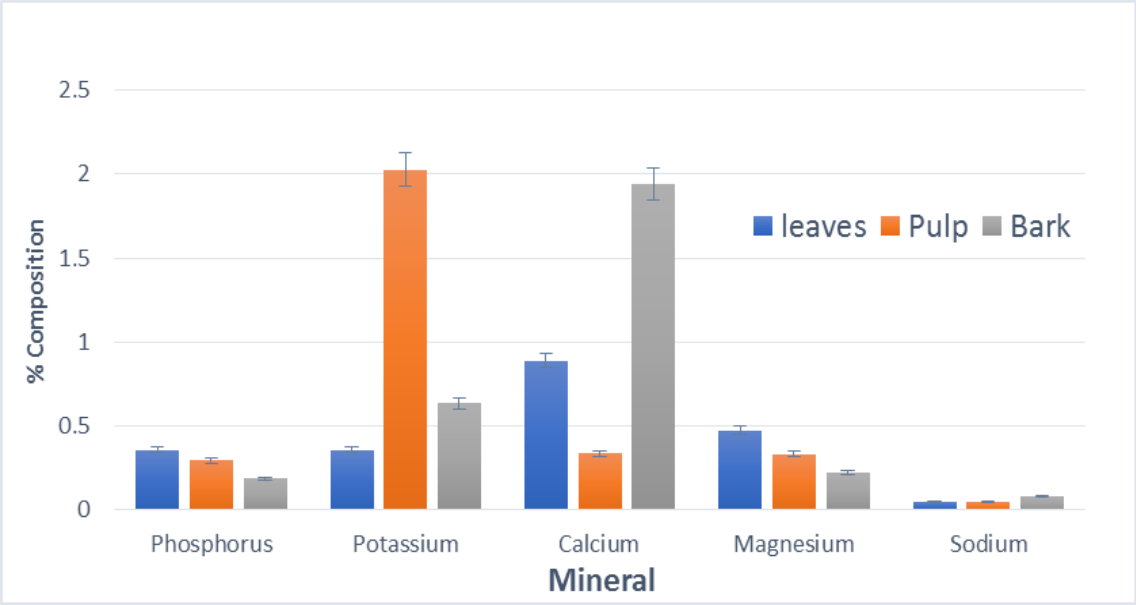

Figure 3 Minerals compositions of the pulp, back and leaves of jackfruit (DB)

leaves was similar to that of Amadi and Ihemeje (2018), who recorded a value of 1.19±0.11 % on a wet basis. The pulp protein composition (1.05 %) did not fall within the range (1.2-1.9) % reported by Ranashinghe *et al*. (2019) in their review paper. This difference could be attributed to variety or species differences, or differences in environmental conditions.

The crude fibre content of the jackfruit pulp (0.46 % wet basis) was significantly lower than the range reported by Khan *et al*. (2021) in their review paper (1.0–1.5 % wet basis). Also, there was a significant difference between the fibre content of the pulps and leaves and the results of Amadi and Ihemeje (2018). Fibre helps to improve the digestion of food and produce smooth bowel movements when consumed. Crude fibre also offers protection to the colon mucous membrane by removing carcinogenic chemicals from the large intestine, thereby preventing colon cancer.

Jackfruit pulp contains the highest amount of moisture or water compared to the bark and leaves. Also, the moisture content in the jackfruit pulps was consistent with the range reported by various researchers and review papers (Khan *et al.*, 2021; Swami *et al*., 2012). However, the moisture content of the leaves (66.37±0.29 %) was significantly lower than the value (85.33±0.45 %) reported by Amadi and Ihemeje (2018). Eating fruits with a higher moisture or water content has several benefits. They help regulate body temperature, prevent developing infections, keep joints lubricated, allow nutrients to get delivered to your cells, improve sleep and mood, and many more. Fruits with high water content are low in calories and rich in minerals, vitamins, antioxidants, and fibre that are important for good health (Brianna, 2023).

The crude fat content of the jackfruit pulps (1.47±0.04 %) was higher than the range (0.1-0.4 %) reported by Ranasinghe *et al*. (2019) in their review paper. Similarly, the crude fat content in the jackfruit leaves (3.62±0.17 %) was higher than the results (0.73±0.05 %) of Amadi and Ihemeje (2018). This shows that Ghanaian jackfruit is relatively rich in fat. A small amount of fat is an essential part of a healthy and balanced diet. Fat is the source of essential fatty acids, which the body cannot make itself, and it helps the body absorb vitamin A, vitamin D, and vitamin E (fat-soluble vitamins). The crude fat in the jackfruit samples consists mainly of monounsaturated fats. Monounsaturated fats from plants may lower bad cholesterol and raise good cholesterol.

Furthermore, the pulp's carbohydrate content (17.41 %) was consistent with the results (16.0-25.40 %) by Goswami and Chacrabati (2015). However, the leaf's carbohydrate content was significantly higher than (5.33±0.40 %) by Amadi and Ihemeje (2018). Carbohydrates provide the primary source of energy for the human body, supporting various bodily functions and fuelling physical activities. However, there was little to no literature available on the jackfruit barks for comparison.

Micronutrients analysis

Micronutrients play pivotal roles in supporting various physiological functions essential for human health, and their presence in diets is critical for maintaining the overall well-being. Micronutrients, comprising of vitamins and minerals, are integral components contributing to the nutritional values of jackfruit. Understanding the distribution and concentration of these micronutrients in different parts of the jackfruit, such as the pulps, barks, and leaves, provides valuable insights into its potential health benefits. Figure 3 shows the compositions of some minerals in the jackfruit samples.

From Figure 3, the K content in the pulp was higher than that of the leaves and barks. The bark was seen to contain the highest amounts of Ca and Na, and the leaves contained the highest amounts of P and Mg. It can be observed from Table 1 that the jackfruit pulps are relatively richer in minerals than most tropical fruits.

Potassium is needed by the human body for proper fluid balance, nerve transmission, muscle contraction, suitable maintenance of blood pressure, and waste elimination (Gharibzahedi and Jafari, 2017). The potassium content in the pulp was consistent with the range reported in the review article by Swami *et al*. (2012).

Calcium is important for healthy bone and tooth formation, relaxation and contraction of muscles, nerve functioning, blood clotting, and blood pressure regulation (Gharibzahedi and Jafari, 2017). The Ca content value obtained was consistent with the reviewed results of young jackfruits by Ranasinghe *et al.* (2019).

Sodium is needed for appropriate maintenance of electrolyte and fluid balance, heart function, and specified metabolic activities (Gharibzahedi and Jafari, 2017). The Na content obtained was consistent with the range reviewed by Ranasinghe et al. (2019).

Magnesium is needed for the formation of protein, muscle contraction, immune system health, and nerve transmission. It also helps to avoid constipation (Gharibzahedi and Jafari, 2017). The Mg content obtained for the pulps was inconsistent with the review by Swami *et al*. (2012).

Vitamin C is a H_2O soluble vitamin, and its content in the pulps was higher compared to the leaves and barks. The human body is unable to synthesize vitamins, so their intake through diet is necessarily vital.

There was little to no information on the jackfruit bark and leaves for further comparisons. Also, most of the results obtained for the leaves were inconsistent with those of Amadi and Ihemeje (2018); hence, more research needs to be conducted on the leaves for effective comparisons.

Health benefits analysis from the phytochemicals content

The health benefits of the jackfruit samples were analysed by quantifying some phytochemicals present. Figure 4 shows the phenolic and flavonoids contents in the jackfruit samples and indicates that the leaves contain the highest amounts of phenolics and flavonoids. The TPC and TFC of the pulps were lower than the values reported by Shafiq *et al.* (2017) for aqueous extract (84.86±0.57mgGAE/100g) and 44.72±1.03 mgQE/100g respectively. There was no literature available on the leaves and bark for comparison. These bioactive or phytonutrients exhibit numerous health benefits, including antioxidant, anti-inflammatory, anti-allergic, anti-carcinogenic, antihypertensive, cardioprotective, anti-arthritic, and antimicrobial activities.

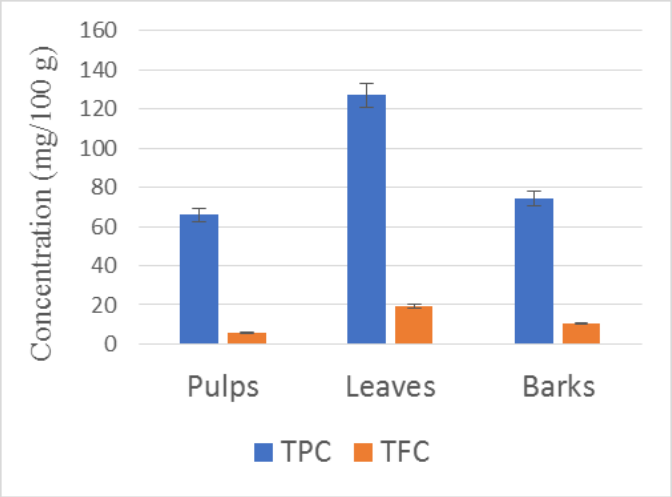

Figure 4 TPC and TFC of the jackfruit (wet basis)

Therefore, it is beneficial to eat plant foods with high antioxidant content because antioxidants cut down the incidence of certain chronic diseases, such as diabetes, cancer, and cardiovascular diseases, through the management or reduction of oxidative stress.

Another antioxidant present in jackfruit is the β-carotene. From Table 2, it can be observed that the jackfruit leaves are enriched in β-carotenes. The β-carotene is a provitamin A carotenoid that the body converts into vitamin A. It is a natural antioxidant that protects eye, skin, brain, and arterial health and, hence, helps prevent eye diseases.

Ghanaian jackfruits content versus other tropical fruits

Table 1 compares the nutritional compositions of Ghanaian jackfruits with other tropical fruits. From the results, it is evident that jackfruit is very nutritious and it is worthy of consideration for cultivation and consumption by the Ghanaian community. For instance, the energy (87 kcal), protein (1.05 g), potassium (422 mg), calcium (69.91 mg) and magnesium (68.87 mg) contents of the jackfruit pulps are significantly higher than those of pineapple and mango, which are the most commonly consumed tropical fruits in Ghana. These nutrients are known to contribute to the growth, maintenance and the overall wellbeing of the human cells and body.

Table 2 presents the nutritional and phytochemical content of the jackfruit pulps, leaves and barks. It is observed that the pulps, leaves and bark of the jackfruit contain significant amounts of nutrients and phytochemicals, that can be extracted and used for the preparation of various drugs formulations.

Conclusion

Jackfruit bark, leaves, and pulps are all found to contain a significant amount of nutrients and phytochemicals. These phytochemicals contribute to various health benefits, including; antioxidant activity, anti-inflammatory properties, and anti-aging properties. The jackfruit bark and leaves were seen to contain relatively higher amounts of most of the nutrients and phytochemicals compared with the pulps.

Also, the nutritional profiles of the jackfruit samples were seen to depend on various factors including geographical dif-

Table 1 Jackfruits nutritional content against other tropical fruits (Waghmare *et al*., 2019)

Nutrients (/100g)	Jackfruit	Pineapple	Mango	Banana	Fig
Energy (kcal)	87	50	60	89	74
Carbohydrate (g)	17.40	13	15	22.84	19.18
Water (g)	79.19	86.00	81.81	74.91	79.06
Dietary fibre (g)	0.46	1.4	1.6	2.6	2.9
Fat (g)	1.47	0.12	0.38	0.33	0.30
Protein (g)	1.05	0.54	0.82	1.09	0.75
Vitamin C (mg)	18.20	47.8	36.4	27	2.0
Calcium (mg)	69.91	13	11	8.7	35
Magnesium (mg)	68.87	12	10	0.26	17
Phosphorous (mg)	61.17	8	14	22	14
Potassium (mg)	422.36	109	168	358	242
Sodium (mg)	9.99	1	1	1	1

Table 2 The nutritional and phytochemicals content of fresh jackfruit samples (100 g)

Nutrients (/100g)	Pulp	Bark	Leaves
Energy (kcal)	87.01 ± 2.07	156.51 ± 3.08	132.41 ± 2.45
Carbohydrate (g)	17.40 ± 0.36	26.25 ± 0.48	24.16 ± 0.43
Water (g)	79.19 ± 0.34	55.70 ± 1.13	66.37 ± 0.29
Crude fibre (g)	0.46 ± 0.15	9.53 ± 0.72	2.35 ± 0.28
Fat (g)	1.47 ± 0.04	4.90 ± 0.16	3.62 ± 0.17
Ash (g)	0.43 ± 0.02	1.77 ± 0.05	2.71 ± 0.05
Protein (g)	1.05 ± 0.06	1.84 ± 0.07	0.81 ± 0.08
Vitamin C (mg)	18.20	10.57	8.22
Calcium (mg)	69.91 ± 1.66	858.82 ± 8.92	299.57 ± 3.86
Magnesium (mg)	68.52 ± 0.6	99.23 ± 5.96	159.88±1.36
Phosphorus (mg)	61.17 ± 0.01	82.41 ± 1.17	120.86±0.19
Potassium (mg)	422.36 ± 9.60	281.45 ± 7.93	328.61 ± 9.49
Sodium (mg)	9.92 ± 0.12	12.55 ± 0.25	17.04 ± 0.48
Total Phenolic (mg GAE)	65.9302±0.0163	74.0759 ± 0.0039	127.0495 ± 0.2377
Total Flavonoids (mg QE)	5.7620 ± 0.0291	10.5113 ± 0.1303	19.1415 ± 0.1522
β-carotene (mg)	2.43 ± 0.06	0.50 ± 0.11	±0.09

ferences, differences in the variety, and extraction methods used. Jackfruit pulp contains relatively higher nutritional values and health benefits when compared with other tropical fruits, and hence recommended for consumption in greater amounts than it is currently in the Ghanaian community.

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Conflict of Interest Declaration

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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