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Compositional, Elemental, Phytochemical and Antioxidant Characterization of Jackfruit (*Artocarpus heterophyllus*) Pulps and Seeds from Selected Regions in Kenya and Uganda

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Authors' contributions

This work was carried out in collaboration between all authors. Author RAO designed the study together with authors EKM, DOO and BNM. Author RAO performed the laboratory and statistical analysis, wrote the protocol and first draft of the manuscript. Authors BKN and RAO managed the analyses of the study. Author RAO managed the literature searches. Authors EKM, DOO and BNM helped in drafting the final manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The number of people affected by nutrition insecurity worldwide in 2016 was 815 million, according to the Food and Agriculture Organization (FAO) of the United Nations. This has been attributed to starvation and overdependence on a few crops for nutritional needs. There is therefore need to find alternative nutrition sources. This study sought to determine the nutritional profile, mineral composition, phytochemical and antioxidant properties of Jackfruit seeds and pulps, collected from

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selected regions in Kenya and Uganda. The moisture contents were found to be higher in the edible pulp region (62.67-70.42%), compared to the seeds (44.76-50.54%). The ash, lipid, carbohydrate and protein contents of fresh weight, on the other hand, were found to be higher in the seeds than in the edible pulp region. The ash contents were (1.12 -1.64%) and (0.34 -0.48%), the lipid contents were (0.41-0.50%) and (0.09-0.12%), the protein contents were (14.11 to 16.26%) and (10.56 to 13.67%) and the carbohydrate contents were (31.41%-34.95%) and (21.65 to 24.91%) for the seeds and pulps respectively. The mineral analysis showed that Jackfruit seeds and pulps were rich in essential minerals. The seeds and pulps, were found to both rich in potassium, sodium, calcium, magnesium, zinc and iron minerals. The phytochemical composition and antioxidant activities, were also found to be higher in the seeds than in the pulps. The phenolic contents were (17.37 to 18.69 mg/g) and (12.10 to 14.55 mg/g), while flavonoids contents were (0.5 - 0.89 mg/g) and (0.18 -0.29 mg/g) for the seeds and pulps respectively. The DPPH scavenging activities were (21.70 - 24.44%) and (15.49 - 17.47%), while the reducing powers were (51.05 - 58.00 µg/ml) and (43.54-45.38 µg/ml) for the seeds and pulp respectively. Jackfruit seeds and pulps are therefore highly nutritious, rich in minerals and can be used as natural antioxidants.

Keywords: Nutritional profile, phytochemical composition, mineral analysis, antioxidants.

1. INTRODUCTION

Food and nutrition insecurity is considered one of the world's greatest challenges that results from the ever-growing food demand, due to increase in population [1]. One problem that is directly linked to under-nutrition is starvation [2]. It is estimated that a total of 800 million people in the world today suffer from starvation. This means that one out of every nine people in the world today is hungry [2]. The World Health Organization puts at 1.9 billion, the number of individuals worldwide, who suffer from malnutrition. People from developing countries are the most affected by under nutrition, which accounts for 45% of deaths for children under the age of five years [3]. This has been attributed to the fact that majority of the people from these countries, have no access to balanced diet, while some have no food at all and end up dying of starvation [2]. In Kenya, UNICEF puts at 3.5 million, the number of people who are nutritionally insecure [4].

Improved nutrition and food security, are part of the Sustenance Development Goals (SDGs) of 2030. Only three plant species, namely maize, rice and wheat, account for half of the daily calories, consumed by the world's population [2]. In Kenya, there is over dependence on a few crops for nutrition, with maize accounting for over 70% of the populations' calorie needs. There is need to find alternative nutrition sources [5]. Terms such as neglected, underutilized, promising amongst others are usually used to describe potentially useful plant species that have not been fully exploited [1]. These crops are normally viewed as great potential contributors to the improvement of food and nutrition security [6]. Jackfruit (*Artocarpus heterophyllus*) has been listed as one of the plants that is 'underutilized.' The knowledge of its nutritional profile, is beneficial to countries where it can be potentially cultivated and are affected by malnutrition and economic depression [7,8, 9].

Jackfruit tree belongs to the genus *Artocarpus*, the fruit of the plant is considered to be the largest in the world, with a mass of up to 50 kg [10,11]. The consumption of the plant is low in Kenya and its cultivation, is mostly done in small scale. In Uganda the consumption of Jackfruit is moderately high, however limited studies have been done on characterization of the plants from that region [12]. Studies from other regions, have shown that Jackfruit pulps and seeds contain carbohydrates, proteins, lipids and minerals [11,12,13]. Studies on characterization of Jackfruits in Kenya and Uganda, have been done on the seed lipid profile and phytochemical analysis of the bark, leaves and roots [12,14]. There is however, no attempt that has been made so far, to study the nutritional profile, mineral composition, phytochemical and antioxidant activities of the seeds and pulps from these regions. This study sought to determine the nutritional profile, mineral composition, phytochemical and antioxidant activities of Jackfruits seeds and pulps, found in selected regions of Kenya and Uganda. Results obtained will be used to promote the use of Jackfruit, as an alternative nutrition and natural antioxidant source.

2. METHODOLOGY

2.1 Fruit Sampling

A total of 30 fruits were collected from Mombasa, Kwale and Ugenya counties of Kenya and Kampala, Mukono and Jinja districts of Uganda. The fruits were then sliced and the seeds and pulps removed and analysed. The samples were analysed in triplicate and the results were expressed as percentage weight of fresh samples except for mineral analysis, where dry weight was used.

2.2 Determination of Moisture and Ash Content

Jackfruit seeds and pulp were cut into small pieces and dried in an oven at 105°C for 17 hours. Moisture contents were determined by weighing the samples, before and after drying [15]. The moisture contents were calculated as shown below.

$$\% \text{ moisture content} = \frac{\text{original mass} - \text{oven dried}}{\text{Original mass}} \times 100$$

The ash contents were analysed by weighing the samples before and after burning in a fiery furnace at 500°C for 24 hours [15]. The ash contents were calculated as shown below:

$$\% \text{ ash content} = \frac{\text{original mass} - \text{ash mass}}{\text{Original mass}} \times 100$$

2.3 Determination of Total Nitrogen and Crude Protein Contents

The total nitrogen and crude protein contents determination, was done for both the pulp and seed samples. Determination of the crude protein contents of the the seeds and the pulps was done by biuret and micro Kjedahl according to AOAC 928.08 [16]. The total crude protein was calculated from total nitrogen using the formula

Protein content = Nitrogen content x 6.25

2.4 Determination of Crude Lipid Contents

The fat contents of the samples, were determined using chloroform/methanol as a solvent according to AOAC method 991.36 [16].

2.5 Determination of Total Carbohydrate Contents

Total carbohydrate contents of the seeds and pulps were calculated using the formula:

TC % = {100 – MC% - PC% - LC% - AC%}

Where, TC % is Total carbohydrates content (% fresh weight),
MC% is moisture content (% fresh weight)
LC% is lipid content (% fresh weight)
AC% is ash content (% fresh weight)

2.6 Determination of Mineral Composition

A mass of 1 g of the sample was oven dried and digested using 10 ml of concentrated nitric acid in beaker, while heating in on a hot plate until the solution was clear. The solution was then transferred to a 50 ml volumetric flask and topped up to the mark with distilled water. The mineral composition of Jackfruit seed and pulps, were determined using 'atomic absorption flame emission spectrophotometer' [15]. The elements that were analysed include: Calcium (Ca), Iron (Fe), Magnesium (Mg), Potassium (K), Sodium (Na), Zinc (Zn), and Copper (Cu).

2.7 Phytochemical Analysis

2.7.1 Sample preparation and methanolic extraction

The Jackfruit seeds and pulps were air-dried for a day and then ground into finer particles using mortar and pestle. A mass of 10 g of the samples was then mixed with methanol, to make up to 100 ml volume in conical flasks, plugged with cotton wool and allowed to stand for 24 hours before evaporating the solvents. The crude extracts obtained were stored at 4°C until use.

2.7.2 Total phenolic compound determination

The Folin-Ciocalteu method was used following protocol by Tambe and Bhambar [17] with slight modifications. A volume of 1 ml of the methanolic extract from Jackfruit seed and pulp were mixed separately with 9 ml of distilled water and 1 ml of Folin-Ciocalteu phenol reagent. The mixture was shaken for 5 minutes and 10 ml of 7% Sodium carbonate (Na_2CO_3) was then added. The final volume of the mixture, was made up to 25 ml using distilled water. A set of standard solutions were then prepared using different concentrations of Gallic acid solution (20, 40, 60, 80, 100 µl). Both the samples and the standards

were incubated for 90 minutes at room temperature. The absorbance readings were obtained using an Ultraviolet (UV)/visible spectrophotometer (UV mini 1240, Shimadzu, Japan) at 765 nm with methanol as the blank. The phenolic content was determined and expressed as mg of GAE/g of extract using the following formula.

$$C = \frac{z \text{ mg GAE/ml} \times \text{vol. of chemical used in assay (ml)}}{\text{Mass of sample (mg)}}$$

Where:

Z = concentration value obtained from the calibration curve
GAE = Gallic acid equivalent

2.7.3 Determination of total flavonoids

A volume of about 100 µl of methanolic extract, was mixed with an equal volume of 20% aluminum trichloride and a drop of acetic acid. Methanol was then used to top up the mixture to 5 ml and the samples allowed to incubate for 40 minutes. The absorbance of the samples, were then read at 415 nm against the blanks prepared in a similar way, as the test samples but without aluminum trichloride. Different concentrations of Rutin solution in methanol was used to prepare a standard curve. All samples were analysed in triplicate [18].

2.8 Antioxidant Activities

2.8.1 1,1-Diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity

The DPPH scavenging activity was done according to the Blois [19] method with a few modifications. About 300 µl of extract was mixed by shaking with 3 ml of methanolic solution of 0.02 mM DPPH and incubated at room temperature for 30 minutes before taking absorbance values at 517 nm in a spectrophotometer (UV mini 1240, Shimadzu, Japan). The standard, blank and positive control were ascorbic acid, methanol reagent and DPPH, respectively. The DPPH scavenging activity was determined using the equation below.

$$\text{Scavenging activity (\%)} = \left(\frac{\text{Control absorbance} - \text{Absorbance of sample}}{\text{Control absorbance}}\right) \times 100$$

2.8.2 Reducing power assay

The assay was carried out following protocol by Hossain et al. [20] with a few modifications. A mixture of 1 ml of extract, 2.5 ml of potassium ferricyanide [$K_3Fe(CN)6$] (1%, w/v) and 0.2 M phosphate buffer (pH 6.6) was prepared and incubated at 50°C for 20 minutes, before addition of 2.5 ml of trichloroacetic acid (10%, w/v) to stop the reaction. The samples were then centrifuged at 1000 g for 10 minutes and 2.5 ml of the supernatant, was then mixed with 2.5 ml of distilled water and 0.5 ml ferric chloride (0.1%, w/v). The absorbance of the solution was then read at 700 nm against distilled water as blank and ascorbic acid of different concentrations used as standards.

2.9 Statistical Analysis

The means and standard deviations of the data were calculated from three independent experiments of each sample from the different regions. One Way Analysis of Variance (ANOVA) was used to analyze the means obtained at significant *P=.05* in the different regions. The data analysis was carried out using SPSS 16 statistical tool and Microsoft excel 13.

3. RESULTS

3.1 Nutritional Profile

3.1.1 Moisture content and ash content

The moisture content was found to be higher in the edible pulp region (62.67-70.42%), compared to the seeds (44.76-50.54%) as shown in Fig. 1. There was no significant variation at (*P=.05*) in moisture content of pulp and seeds from different regions. However, there was a significant variation in composition of moisture content of seeds and pulp at (*P=.05*). The percentage ash content of the seeds (1.12 -1.64%) was significantly higher than that of the pulp (0.34 - 0.48%). The levels were however found to have no significant variation at (*P=.05*) across the regions as shown in Fig. 2.

3.2 Lipid Content

The jackfruit seeds were found to have a significantly higher lipid contents (0.41-0.50%) compared to the pulps (0.09-0.12%) as shown in Fig. 3. The variation in lipid contents were however not significant at *P=.05* in pulps and seeds from the different regions.

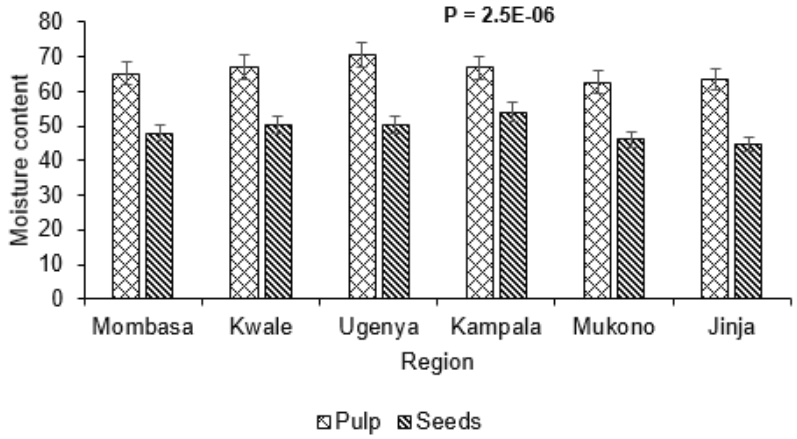

Fig. 1. Percentage moisture content of seeds and pulp (fresh weight)

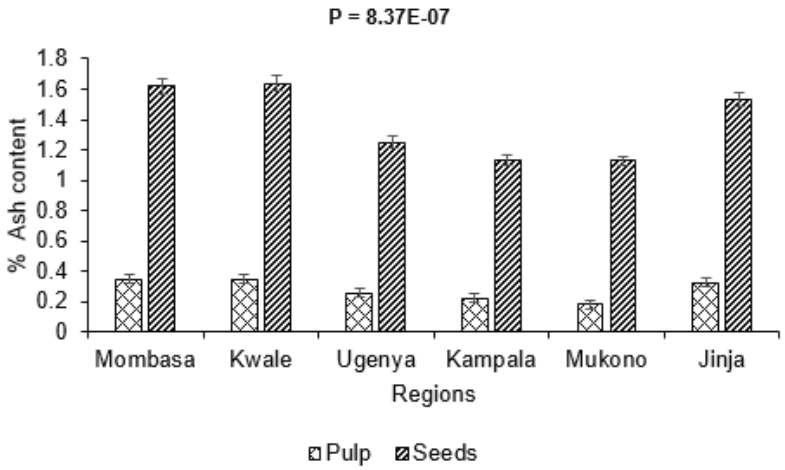

Fig. 2. Percentage ash content of seed and pulp

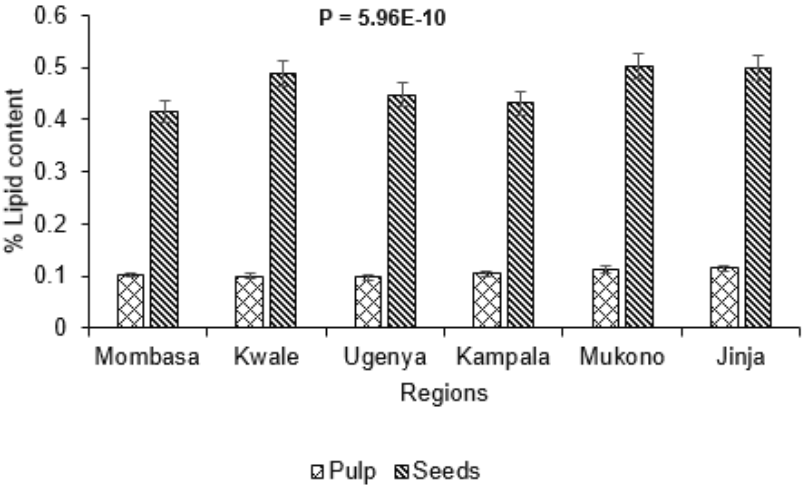

Fig. 3. Percentage lipid content of seeds and pulp (fresh weight)

3.3 Protein and Carbohydrate Contents

The protein and carbohydrate content of the pulp, ranged from 10.56 to 13.67% and 21.65 to 24.91%), respectively, while that of the seeds ranged from 14.11 to 16.26% and 31.41% - 34.95%, respectively as shown in Figs. 4 and 5. The seeds had the highest carbohydrates and proteins content, while the pulps had the least. There was a significant variation at *P=.05* in levels of proteins in the seeds and pulps. There was also a significant variation (*P=.05*) in levels of carbohydrates present in both the pulp and the seeds as shown in Fig. 5.

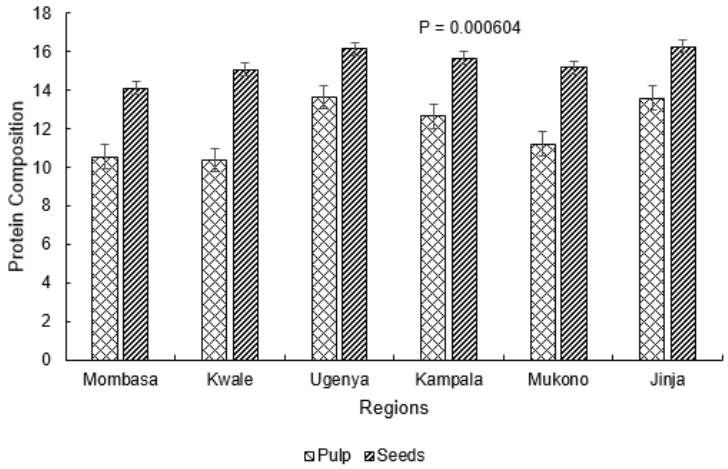

Fig. 4. Percentage protein content of seeds and pulp (fresh weight)

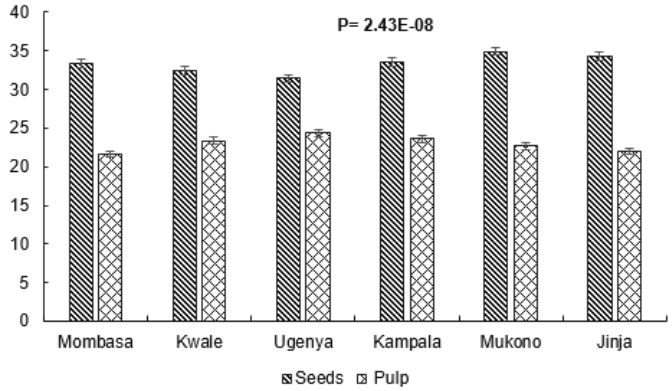

Fig. 5. Percentage carbohydrate content of seeds and pulp (fresh weight)

Table 1. Jackfruit seeds and pulp nutritional profile in Kenya and Uganda

		Kenya	Uganda
%Moisture	Pulp	66.55±2.63	64.40±2.24
	Seeds	49.24±1.45	48.27±5.01
%Ash	Pulp	0.32±0.05	0.24±0.07
	Seeds	1.50±0.22	1.26±0.21
%Lipid	Pulp	0.10±0.002	0.11±0.005
	Seeds	0.45±0.037	0.47±0.04
% Protein	Pulp	11.53±1.86	12.50±1.19
	Seeds	14.04±19	16.19±1.75
%Carbohydrates	Pulp	22.43±1.80	19.38±1.19
	Seeds	32.39±0.98	34.15±1.18

3.4 Jackfruit Seeds and Pulps Nutritional Profile

The moisture content had the highest composition in both the seeds and pulps, followed by carbohydrate, which had the second highest and then protein. Lipid and ash contents, were the least as shown in Table 1. The seeds generally had a higher nutritional composition compared to the pulp region.

3.5 Elemental Analysis

In the mineral analysis of Jackfruit seeds and pulps, potassium had the highest composition, which was 10 times greater than those of those of all the other minerals, while Cu and Zn had the least concentrations. The elemental analysis of the both seeds and pulps, had the following trend. K>Na>Ca>Mg>Fe with Cu and Zn having the least concentrations as shown in Table 2. The composition of sodium, calcium, magnesium, zinc, copper and iron in the pulp, were lower compared to those of the seeds. However, the composition of potassium was higher in the pulps, compared to the seeds. Generally, the seeds had a higher mineral composition compared to the pulps.

Table 2. Mineral contents of seeds and pulp in mg/100 g of dry weight

	Pulp	Seeds
Sodium	185.33±21.02	193.75±17.60
Calcium	141.67±28.40	176.73±30.16
Iron	14.05±1.40	23.09±1.60
Magnesium	76.28±12.64	84.25±6.63
Potassium	2836.66±193.58	2297.5±129.44
Zinc	5.31±1.64	7.12±2.27
Copper	2.21±0.16	2.84±0.58

3.6 Determination of Phytochemical Composition

3.6.1 Phenolic content

The phenolic content of jackfruit pulps were lower than those of seeds. The contents obtained ranged from 12.10 -14.55 mg/g and 17.37-18.69 for pulps and seeds respectively, as shown in Fig. 6. There was no significant difference at (*P=.05*) in the phenolic content of the seeds and pulps across the different regions. However, there was a significant difference at (*P=.05*) in the phenolic composition of the seeds and pulps.

3.6.2 Flavonoids content

The flavonoids content was found to be lower in the pulps (0.29 - 0.18 mg/g) than in the seeds (0.89 - 0.5 mg/g) as shown in Fig. 7. There was no significant difference (*P=.05*) in flavonoid contents of the seeds and pulps, across the different regions. There was however a significant variation (*P=.05*) in levels of flavonoids in the seeds and pulps.

3.7 Determination of Antioxidant Activity

3.7.1 DPPH scavenging activity

A calibration curve for DPPH scavenging activity using ascorbic acid was generated. The DPPH scavenging activity of the pulp (15.49-17.47%) was lower than that of the seeds (21.70-24.44%), as shown in Fig. 8. The variation in scavenging activity of the pulp and seeds from the different regions was statistically significant (*P=.05*). However, the scavenging activity of the seeds, in the different regions showed no significant variation at *P=.05*.

3.7.2 Reducing power

The reducing power of the seeds ranged from 51.05 to 58.00 µg/ml and the pulp ranged from 43.54 to 45.38 µg/ml. The variation in reducing powers was found to be statistically significant *(P=.05)* for the seeds and pulp. There was however no significant variation in reducing power *(P=.05)* of the seeds and pulp across the regions (Table 3).

Table 3. Reducing power of pulp and seeds from different regions

Reducing power	Pulp (µg/ml)	Seeds (µg/ml)
Kwale	43.54[a]±2.19	51.05±2.69
Mombasa	44.58 [a] ± 2.51	52.87± 2.83
Kampala	45.38 [a] ± 1.10	57.57 ± 2.06
Wakiso	44.56 [a] ±1.44	52.56 ± 1.78
Mukono	43.44 [a] ± 1.73	58.00 ± 2.7
Jinja	44.24 [a] ± 1.61	56.12 ± 2.18

[a]*: values in the same column are statistically the same at P=.05*

4. DISCUSSION

4.1 Nutritional Profile

The ash content is the measure of the inorganic material present in the fruit, which are minerals in

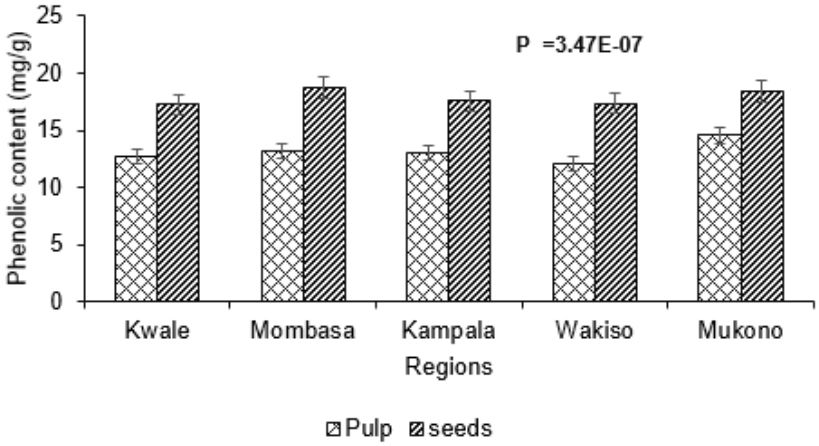

Fig. 6. Phenolic composition of seeds and pulp

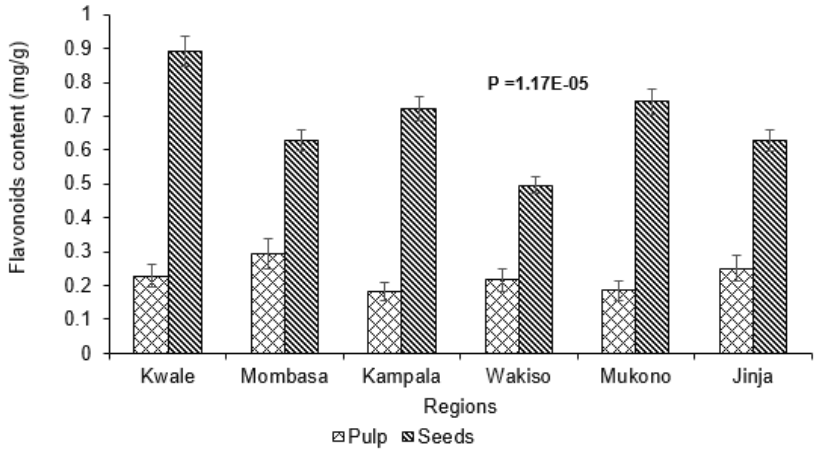

Fig. 7. Flavonoid composition of seeds and pulp

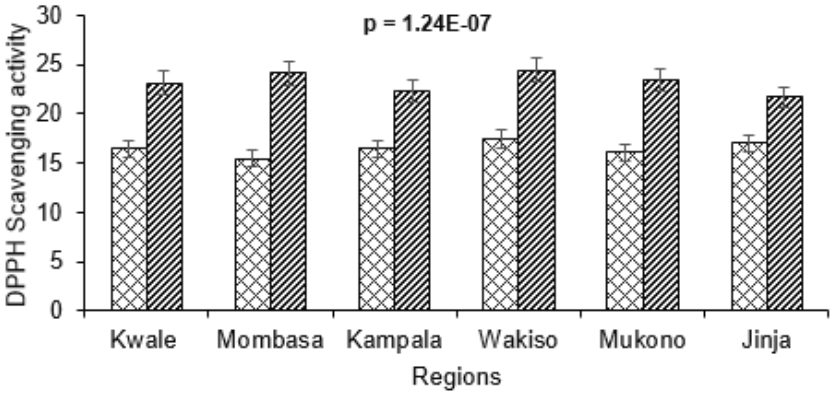

Fig. 8. DPPH scavenging activity of seeds and pulp

most cases. The percentage ash content of the seeds (1.12 -1.64%) and pulp (0.34 -0.48%) of Jackfruit, indicate they are rich in minerals. The composition of ash content in the seeds was however higher than that of the pulps region. These findings are consistent with those of Ejiofor & Owuno [21], who also found that the ash content of Jackfruit pulps is 0.43% and inconsistent with that of Goswami et al. [22], who got pulp ash content of 0.7 - 1.0%. The ash content of the seed is consistent with that of Awal et al. [23], who found the ash content to be 1.8%. The lipid content was found to be (0.41-0.50%) in the seeds and (0.09-0.12%) in the pulp region. There are a number of health benefits of lipids in the body such as synthesis of cell membranes, which ensures integrity of the cell and enables it to carry out a number of vital body processes. The consumption of lipids is therefore important to ensure proper functioning of the body [12]. The jackfruit was found to have moderate lipid content with values similar to those of Madrigal-Aldana et al. [24].

High moisture content reduces the shelf life of fruits as moisture increases the microbial activity. The moisture content of the pulp and seeds of Jackfruit were ranged from 62.67-70.42% and 44.76-50.54% respectively, implying that both fresh Jackfruit seeds and pulps, cannot be stored for long in fresh state. Jackfruit therefore needs to be preserved by techniques, such as drying amongst others to increase their shelf life.

Proteins are important nutrients in the body, as they help in repairing worn out tissues and are a source of amino acids required for protein synthesis. The findings of this study showed that the pulps region and the seeds had 10.56 to 13.67% and 14.11 to 16.26% fresh weight respectively, indicate and seeds are good sources of protein. These findings are consistent with those of Abedin et al. [25], who found Jackfruit seeds protein contents were 13 -18% and close to those of Gupta et al. [15], who obtained 11.85%. Both Jackfruit seeds and pulps have very high carbohydrate levels (31.41% - 34.95%) and 21.65 to 24.91%) for seeds and pulps respectively. This means that both Jackfruit seeds and pulp are good sources of energy. The values obtained are close to those of Gupta et al. [15], who obtained 26.2% for the seeds.

4.2 Mineral Composition

Jackfruit was found to be rich in essential minerals, with potassium having the highest composition. The mineral helps in strengthening of bones and teeth in the human body. They also facilitate the contraction and relaxation of muscles in the body. Potassium together with other electrolytes, such as Mg, Ca and Na also conduct electricity in the body, which is important for proper functioning of the heart and other body organs [26]. Calcium was also in high composition and it also helps in strengthening of bones and teeth. Inadequate intake of Ca has been associated with illnesses such as osteoporosis [26].

Magnesium levels were also found to be moderately high. The mineral plays a role in the regulation of blood sugar levels. It is used as a cofactor by many enzymes such as insulin in glucose metabolism [27]. The fruit was found to contain moderate levels of iron, which is an important mineral that is used by the body to synthesize hemoglobin. The concentration of red blood cells in the body is highly determined by the presence of iron [26]. Zinc on the other hand, is required by the body in small quantities and also plays a major role in a number of metabolic processes. It is also used as a cofactor by a number of enzymes [26].

Copper was also found to be in low levels in the seeds and in the pulp. The mineral is required in the body in small quantity and it is crucial in formation of connective tissues. It is also used alongside iron, in the formation of red blood cells [26]. The findings of this study, were consistent with those of Gupta et al. [15], who also found that Jackfruit seeds had very high potassium contents in the seeds. The study also found that Jackfruit seeds had high calcium and sodium contents. The study was however inconsistent with that of Ejiofor & Owuno [21], whose calcium levels were very low.

4.3 Phytochemical Composition

The pulp had the least phenolic content (14.5 - 12.10 mg/g) and the seeds had the highest (18.69 - 17.37 mg/g). The flavonoids content was found to be lower in the pulp (0.29 - 0.18 mg/g) than in the seeds (0.89 - 0.5 mg/g). Phytochemicals are important in the body, because they react with oxygen species and hence prevent the formation of free radicles in the body. The free radicles have been associated with the damage of proteins in the body including DNA [28]. The difference in composition of seeds and pulps, may be attributed to genetic factors. The genes that express the phenolic and

flavonoid contents, may have been higher in the seeds than in the pulp [29]. These current findings are consistent with that of Shanmugapriya et al. [30], who found flavonoids content of 4.05 mg/ml using ethanolic extract. The phenolic content (4.16 mg/g) was however lower compared to the ones obtained in this study. This may be due to difference in the extraction solvents, as methanol and ethanol have been found to have different efficiencies in extraction of phytochemicals [31]. The study therefore shows that the seeds are richer sources of phytochemicals compared to the pulps.

4.4 Antioxidant Activity

Antioxidants help in reducing the damage that results from the action of free radicles in the body. The free radicles have been associated with symptomatic characteristics of diseases such as cancer, hypertension, diabetes mellitus and neurodegenerative illness [10]. The current study found the DPPH scavenging activity of the jackfruit pulp and seeds ranged from 15.49-17.47% and 21.70-24.44%, respectively. The study was consistent with that of Abu Bakar et al. [10], who found that the pulps of various *Artocarpus* plants had moderate DPPH activity. The seeds and the pulp had relatively lower DPPH activity, compared to those of the barks, roots and leaves of Jackfruits [14]. This could be attributed to the fact that the leaves, roots and barks are more exposed to the environment and therefore require more phytochemicals to help them fight pathogens compared to the seeds and pulp that are enclosed inside the fruit. The reducing power of the seeds was (51.05 ± 2.69 µg/ml) and that of the pulp was (43.54-45.38 µg/ml). The reducing power obtained for both the seeds and roots were relatively high. The values were much higher compared to those obtained by Gupta et al. [15], who found the reducing power to be (14.02 -16.68 µg/ml). The variation may be attributed to difference in the extraction solvent as the study used acetone and dichloromethane: methanol (1:1).

5. CONCLUSION

The compositional analysis of Jackfruit seeds and pulp reveal that there is a significant variation in composition of the two tissues. The two parts are however both rich in proteins and carbohydrates. The fruit can therefore be used as an alternative source of both carbohydrates and proteins. The fruit was also found to be rich in minerals such as potassium, calcium, sodium and iron, which are essential in the body. Jackfruit is therefore a good source of essential minerals. Jackfruit seeds and pulps, were also found to have moderate levels of phytochemicals and antioxidant activities, hence a potential source of natural antioxidants. The knowledge of Jackfruit nutritional profile, may contribute to reducing the overdependence on a few crops for nutritional needs. It may also help in the popularization of Jackfruit in Kenya, where it is underutilized. This will reduce the cases of under nutrition in Kenya and in turn contribute towards the Sustainable Development Goals (SDGs) of 2030, of ensuring food and nutrition security. The information on phytochemical and antioxidant activity, may also help in providing alternative sources of natural antioxidants.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENT

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Fanzo J. Strengthening the engagement of food and health systems to improve nutrition security: Synthesis and overview of approaches to address malnutrition. Global food security. 2002;3(3-4):183-192. DOI:https://doi.org/10.1016/j.gfs.2014.09.001
2. FAO, IFAD, UNICEF, WFP and WHO. The state of food security and nutrition in the world 2017. Building resilience for peace and food security. Rome, FAO; 2017. Available:http://www.fao.org/3/a-I7695e.pdf (Accessed on 10th March 2018)
3. World Health Organization (WHO). Malnutrition; 2017. Available:http://www.who.int/mediacentre/factsheets/malnutrition/en/

(Accessed on 10th March 2018)
4. UNICEF. (2018) Kenya; 2017. Available:https://www.unicef.org/appeals/kenya.html (Accessed on 10th March 2018)
5. Madegwa YM. Modelling nutrient dynamics and yield of finger millet (*Eleusine Coracana*) in semi-arid eastern Kenya, using the agricultural production systems simulator model (APSIM). Department of Land Resource Management and Agricultural Technology, Faculty of Agriculture, University of Nairobi, Nairobi. Thesis; 2015. Available:http://erepository.uonbi.ac.ke/bitstream/handle/11295/90224/Madegwa,Yvonne%20M_Modelling%20nutrient%20dynamics%20and%20yield%20of%20finger%20millet%20(eleusine%20coracana)%20in%20semi%20arid%20eastern%20kenya,%20using%20the%20agricultural%20production%20systems%20simulator%20model%20(apsim).pdf?sequence=4
6. Frison EA, Cherfas J, Hodgkin T. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. Sustainability. 2011; 3(1):238-53. Doi: 10.3390/su3010238
7. Jagtap UB, Bapat VA. Artocarpus: A review of its traditional uses, phytochemistry and pharmacology. Journal of ethnopharmacology. 2010;129(2):142-166. DOI:https://doi.org/10.1016/j.jep.2010.03.031
8. Swami SB, Thakor NJ, Haldankar PM, Kalse SB. Jackfruit and its many functional components as related to human health: A review. Comprehensive Reviews in Food Science and Food Safety. 2012;11:565–576. DOI:10.1111/j.1541-4337.2012.00210.x
9. Morton JF. Fruits of warm climates. Florida Flair Books, Miami; 1987.
10. Abu Bakar MF, Abdul Karim F, Perisamy E. Comparison of phytochemicals and antioxidant properties of different fruit parts of selected Artocarpus species from Sabah, Malaysia. Sains Malays. 2015; 44(3):355–363. DOI:http://dx.doi.org/10.17576/jsm-2015-4403-06
11. Mukprasirt A, Sajjaanantakul K. Physico-chemical properties of flour and starch from jackfruit seeds (*Artocarpus heterophyllus* Lam.) compared with modified starches. International Journal of food science & technology. 2004;l39(3): 271-276. DOI:https://doi.org/10.1111/j.1365-2621.2004.00781.x
12. Ojwang RA, Runo SM, Ben M, Ogoyi DO. Lipid profile and levels of omega-3 polyunsaturated fatty acids present in jackfruit (*Artocarpus heterophyllus*) Lam. (Moraceae) seeds and variation in different treatments. African Journal of Biotechnology. 2015;14(16):1409-1417. DOI: 10.5897/AJB2014.14345
13. Ajayi IA. Comparative study of the chemical composition and mineral element content of *Artocarpus heterophyllus* and *Treculia africana* seeds and seed oils. Bioresource technology. 2008;99(11): 5125-5129. Available:https://www.sciencedirect.com/science/article/pii/S0960852407007717
14. Ojwang RA, Muge EK, Mbatia B, Mwanza B, Ogoyi DO. Comparative analysis of phytochemical composition and antioxidant activities of methanolic extracts of leaves, roots and bark of jackfruit (*Artocapus heterophyllus*) from selected regions in Kenya and Uganda. Journal of Advances in Biology & Biotechnology. 2017;16(1):1-13. DOI: 10.9734/JABB/2017/37355
15. Gupta D, Mann S, Sood A, Gupta RK. Phytochemical, nutritional and antioxidant activity evaluation of seeds of jackfruit (*Artocarpus heterophyllus*). International Journal of Pharma and Bio Sciences. 2011;2(4):333–343. Available:http://www.ijpbs.net/vol-2_issue4/pharma_science/38.pdf
16. Intl, A. O. A. C. Official methods of analysis of AOAC International. Arlington, Va.: AOAC Intl. pv (loose-leaf); 1995.
17. Tambe V, Bhambar R. Estimation of total phenol, tannin, alkaloid and flavonoid in *Hibiscus tiliaceus* Linn. wood extracts. Research and Reviews: Journal of Pharmacognosy and Phytochemistry. 2014: 2(4):42-45. Available:https://www.rroij.com/open-access/estimation-of-total-phenol-tanninalkaloid-and-flavonoid-in-hibiscus-tiliaceuslinn-wood-extracts-.php?aid=34291
18. Kumaran A, Karunakaran J. *In vitro* antioxidant activities of methanol extracts of five Phyllanthus species from India. LWT-Food Sci. Technol. 2006;40:344-352.

Available:http://www.sciencedirect.com/science/article/pii/S0023643805002227?via%3Dihub

19. Blois M. Antioxidant determinations by the use of a stable free radical. Nature. 1958. 181(4617):1199-1200. Available:http://dx.doi.org/10.1038/1811199a0
20. Hossain MD, Sarwar MS, Dewan SM, Shahid-Ud-Daula A, Islam MS. Investigation of total phenolic content and antioxidant activities of *Azadirachta indica* roots. Avicenna J Phytomed. 2014; 4(2):97–102. Available:https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4103707/
21. Eke-Ejiofor J, Owuno F. The physico-chemical and sensory properties of jackfruit (*Artocarpus heterophilus*) jam. International Journal of Nutrition and Food Sciences. 2013;2(3):149-152.
22. Goswami C, Hossain M, Kader HA, Islam R. Assessment of physicochemical properties of jackfruits' (*Artocarpus heterophyllus* Lam) pulps. Journal of Horticulture, Forestry and Biotechnology. 2011;15(3):26-31. Available:http://www.journalhfb.usabtm.ro/romana/2011/2011%203%204/Lista%20lucrari_2011%20PDF/JHFB_15(3)_PDF/5Goswami_Bangladesh.pdf
23. Awal HM, Gheyasuddin S. Biochemical parameters of jackfruit seed meal. Bangladesh J. Agril. Res. 1991;16(1):17-22.
24. Madrigal-Aldana DL, Tovar-Gómez B, de Oca MMM, Sáyago-Ayerdi SG, Gutierrez-Meraz F, Bello-Pérez LA. Isolation and characterization of Mexican jackfruit (*Artocarpus heterophyllus* L) seeds starch in two mature stages. Starch-Stärke, 2011;63(6):364-372.
25. Abedin MS, Nuruddin MM, Ahmed KU. Hossain AI. Nutritive compositions of locally available jackfruit seeds (*Artocarpus heterophyllus*) in Bangladesh International Journal of Biosciences (IJB). 2012;2(8):1-7. ISSN: 2220-6655 (Print) 2222-5234.
26. Soetan KO, Olaiya CO, Oyewole, OE. The importance of mineral elements for humans, domestic animals and plants-A review. African Journal of Food Science. 2010;4(5):200-222.
27. Takaya J, Higashino H, Kobayashi Y. Intracellular magnesium and insulin resistance. Magnesium research. 2004; 17(2):126-136.
28. Sudha G, Priya SM, Shree IR, Vadivukkarasi S. In vitro free radicle scavenging activity of raw pepino fruit (Solanum muricatum Aiton). Int J Curr Pharm Res. 2011;3(2):137–140. Available:https://www.ijcpr.org/Issues/Vol3Iissue2/332.pdf
29. Andrew R, Wallis I, Harwood C, Foley W. Genetic and environmental contributions to variation and population divergence in a broad-spectrum foliar defence of *Eucalyptus tricarpa*. Annals of Botany. 2010;105(5):707-717. DOI:http://dx.doi.org/10.1093/aob/mcq034
30. Shanmugapriya K, Saravana S, Payal H, Mohamed P, Binnie W. Antioxidant activity, Total Phenolic and flavonoid contents of *Artocarpus heterophyllus* and *Manilkara zapota* Seeds and its reduction potential. Int J Pharm Pharm Sci. 2011;3(5):256–260.
31. Nahak G, Sahu RK. In vitro antioxidative acitivity of *Azadirachta indica* and *Melia azedarach* Leaves by DPPH scavenging assay. Nat Sci. 2010;8(4):22-28.

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