

Full Length Research Paper

## Lipid profile and levels of omega-3 polyunsaturated fatty acids present in jackfruit (*Artocarpus heterophyllus*) Lam. (Moraceae) seeds and variation in different treatments

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The intake of polyunsaturated fatty acids especially omega-3 is projected to be way below the recommended intake in Kenya. Thus, there is need to find other sources of polyunsaturated fatty acids (PUFAs). This study screened for the lipid profile and levels of omega-3 PUFAs in jackfruit and explored the variation in lipid profile of jackfruit seeds in different areas and treatments. The extracted lipids were characterized and analysis done using gas chromatography. The lipid content was found to be  $0.45 \pm 0.24\%$ , iodine number was  $60.76 \pm 3.25$ , saponification number was  $353.65 \pm 14.21$ , and levels of omega-3 and of omega-6 PUFAs were also found to be  $9.94 \pm 0.99\%$  and  $31.19 \pm 0.82\%$ , respectively. Boiling and drying of seeds were found to greatly decrease the levels of polyunsaturated fatty acids such omega-3 and omega-6 and thus, not suitable methods for processing or preservation of jackfruit seeds.

**Key words:** Jackfruit, omega-3 polyunsaturated fatty acids, lipid profile.

### INTRODUCTION

Jackfruit (*Artocarpus heterophyllus*) is one of the most significant trees in tropical home gardens and perhaps the most widespread and useful tree in the important genus *Artocarpus*. Jackfruit tree belongs to the family Moraceae and is believed to have originated from the rainforests of the Western Ghats. It is mostly found in Asia, mainly in India, China and Philippines. In Africa, it is

found in Kenya, Uganda and Zanzibar (Morton, 1987). The tree is easily recognized by its fruit, which is considered to be among the largest in the cultivated plants and the fruit's weight ranges from 2 to 30 kgs. The succulent, aromatic, and flavorful fruit is eaten fresh or preserved in numerous ways (Elevitch and Manner, 2006). Jackfruit has been reported to contain high levels

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of protein, starch, calcium and thiamine (Mukprasirt and Sajjaanantakul, 2004) as well appreciable levels of lipids (Ajayi, 2008). One fruit contains about a 100 to 500 seeds, which are processed in different ways before consumption.

The seeds can be boiled, roasted or preserved in syrup like chestnuts. Roasted, dried seeds are ground to make flour, which is blended with wheat flour for baking (Morton, 1987). This fruit is always termed as a 'neglected fruit' as little research has been done on it and is also considered to be for the lower socioeconomic class in Asia, where the fruit is most dominant (Ocloo et al., 2010). Studies on jackfruit seeds have shown that it has appreciable levels of lipids and knowledge on lipid profile, will help in determining the nutritive content of the fruit (Ajayi, 2008).

Fatty acids exist in two main categories namely: saturated and unsaturated fatty acids. Most saturated fatty acids are synthesized by the body, while the unsaturated fatty acids need to be provided in the diet. The most important polyunsaturated fatty acids are the omega-3 and omega-6 PUFAs. Clinical studies have established that the omega-6 fatty acid and omega-3 PUFAs collectively protect against coronary heart disease (Vasuki and Hayes, 2004).

Omega-3 PUFAs also improve vascular endothelial function and help lower blood pressure, platelet sensitivity and the serum triglycerides (Vasuki and Hayes, 2004). Studies show that fatty acids are among the most crucial molecules that determine one's brain integrity and ability to function well (Chang et al., 2009). Epidemiological studies suggest that diets rich in omega-3 polyunsaturated fatty acids reduce the risk of cancer (Berquin et al., 2007).

It is projected that the intake of omega-3 PUFA falls below the recommended amount of 250 to 500 mg daily for individuals without cardiovascular heart diseases (Lee et al., 2009). The main source of omega-3 fatty acid in the diet is fish (Christian et al., 2007). However, due to over fishing, there is need to find an alternative dietary source of omega-3 PUFAs. The vegetarians on the other hand, solely rely on plant sources to obtain all the important fatty acids. Knowledge of plants lipid profile will enable them to make informed choices, so that they can also meet the daily recommended intake of PUFAs (Lee et al., 2009).

A few plant oils have been found to contain omega-3 fatty acids. The plant oils include: flaxseed, carola oil, soybean and pumpkin (Coupland, 2008). Despite the fact that the presence of lipids in jackfruits has been documented, no extensive studies have been carried out on the nature of the lipids present (Ocloo et al., 2010). This study seeks to screen the lipid profile and levels of omega-3 PUFAs in Jackfruit seeds and determine if the levels vary in different areas, the effect of boiling and drying, which are both common processing and storage methods used in Kenya, on the total lipid profile.

## MATERIALS AND METHODS

### Research design

Jackfruits were obtained from six regions namely: Nairobi, Mombasa, Malindi, Kakamega, Uganda and Kisumu. The study was done at the Department of Biochemistry, University of Nairobi. Three fruits were obtained per region and seeds extracted from these fruits. This was done by slicing the fruits and removing the seeds, which were approximately 100 to 500 per fruit. The seeds from each fruit were then divided into three groups, where the seeds from the first group were extracted while fresh. The seeds from the second group were dried for one week in sunlight, after which lipid was extracted and the third group was boiled in water for 2 h then lipid extracted. The seeds were crushed using a blender to break it to smaller pieces and further ground using mortar and pestle and then weighed. Thirty grams of the crushed seeds were used in each case for lipid extraction using Folch method. The lipid extracted was then characterized using saponification and iodine number.

The lipid profile of Jackfruit was determined using gas chromatogram (GC) analysis. Prior to G.C analysis, the unsaturated fatty acids were methylated through the derivatization process using methanolic sulfuric acid. The methylation was done to ensure accurate separations during the G.C analysis. The methylated samples were then injected into the GC and the peaks noted. The standard, which consisted of a mixture of fatty acid methylesters were also run in the GC. The retention time of the fatty acid in the analytes were compared to those of the standards to identify the fatty acids present. The levels of fatty acids in all regions was then determined to obtain the Jackfruit lipid profile, comparison of how the levels varied in the different region was also determined using analysis of variance (ANOVA) at  $p = 0.05$  and the variation of the fatty acid profile both in fresh, boiled and dried seeds was also done using ANOVA to determine the effect of boiling and drying on fatty acid profile and levels of omega-3 and omega-6 fatty acids.

### Fruit variety sampling and preparation

Jackfruits were obtained from six different geographical locations namely: Nairobi, Mombasa, Malindi, Kakamega, Uganda and Kisumu. Three fruits were picked from each of the six regions and the seeds extracted from each fruit. Each fruit had seeds ranging from one 100 to 500 seeds. The seeds of each fruit were then subdivided into three groups. The first group was analyzed while fresh, the second group dried in the sun for one week and the last one boiled in water for 2 h prior to analysis. The seeds were then crushed using a blender for 5 to 10 min until they were broken into smaller pieces and further ground using mortar and pestle prior to lipid extraction.

### Lipid extraction and quantification

Thirty grams of crushed seeds from each group were homogenized with chloroform/methanol (2/1) of volume 600 ml. The whole mixture was agitated for 1 h in a magnetic stirrer at room temperature. The homogenate was then centrifuged to recover the liquid phase (Folch et al., 1957). The solvent was washed with 120 ml volumes of 0.9% NaCl solution. The mixture was then centrifuged at low speed (2000 rpm) to separate the two phases. Upper phase was removed by siphoning after centrifugation and the lower chloroform phase containing lipids was evaporated under vacuum in a rotary evaporator. The lipid extract was then weighed after it had dried completely and stored at  $-20^{\circ}\text{C}$  in a freezer (Folch et al., 1957).

**Table 1.** Percentage weight of lipid content in g per 100g, Saponification (mg of KOH/ g of lipid and Iodine number (g of I/ 100 g of lipid) of fresh samples from all regions.

Region	Lipid content (% weight)	Saponification number (mg of KOH/ g of fat)	Iodine number (g of I <sub>2</sub> / 100g of fat)
NBI FRESH	0.45 ± 0.25	346.8 ± 4.95	62.91 ± 2.39
UG FRESH	0.46 ± 0.22	346.17 ± 21.92	63.55 ± 2.32
MSA FRESH	0.45 ± 0.21	347.43 ± 9.00	60.54 ± 4.71
MLD FRESH	0.44 ± 0.15	362.28 ± 17.48	61.81 ± 4.05
KSM FRESH	0.44 ± 0.34	350.60 ± 12.09	61.29 ± 4.62
KKMG FRESH	0.47 ± 0.26	368.59 ± 19.79	53.88 ± 1.41
MEAN	0.45 ± 0.24	353.65 ± 14.21	60.76 ± 3.25

### Characterization of the lipid extracts

Saponification number is defined as the amount in milligram of KOH required to saponify one gram of fat. In order to determine the saponification number of the lipid extracts, 200 mg of lipid extract was mixed with 2 ml of chloroform. 0.2 ml of the mixture was boiled with 2.5 ml of 0.3 M potassium hydroxide under a reflux condenser in a 250 ml flux. The mixture was then removed and allowed to cool. Two drops of phenolphthalein indicator was added to the mixture, after which it was titrated with 0.3 M hydrochloric acid until endpoint. Titration of blank KOH was also done and the value was noted. To obtain the volume that was saponified, the volume of HCl used to titrate the mixture was subtracted from volume of HCl used to titrate the blank. The number of moles of KOH in this volume was then determined and the results expressed in mg of KOH per 1 g of fat (Masukawa et al., 2010). Iodine number is the mass of iodine in grams that is consumed by 100 g of lipid. Iodine number was determined by a drop wise addition of iodine and mercuric chloride solution to 200 mg of lipid dissolved in 2 ml chloroform, until the lipid solution turned brown. The solution consisted of 26 g iodine and 30 g of mercuric chloride in 250 ml ethanol, which were mixed and made up to 1 L by addition of ethanol. The solution was made in such a way that, 1 ml of the solution, contained 26 mg of iodine. The iodine number was calculated by multiplying the volume in (ml), of iodine and mercuric chloride solution used to titrate the lipid solution by 26 and results were expressed in grams of iodine per 100 g of lipid (Gupta and Kanwar, 1994).

### Gas chromatogram analysis of the lipid extracts

Fatty acid methyl ester (FAME) was prepared following the method described by (Mbatia et al., 2010). 20 mg of lipid sample was mixed with 2 ml of toluene and 2 ml of 1.5% sulphuric acid in dry methanol. The mixture was then vortexed to mix and incubated at 55°C for the whole night. 4 ml of saturated NaCl solution was then added and the mixture vortexed to mix. 2% of NaHCO<sub>3</sub> was also added and mixed well until the lower phase had a pH of 7. The mixture was centrifuged for 10 min at 2000 r.p.m and the upper phase collected through siphoning and stored for gas chromatography (Mbatia et al., 2010). The fatty acid analysis was carried out using Varian CP 3800 GC system equipped with a flame ionization detector (FID). Supelco wax 10 capillary column (60metres by 0.32 mm by 25 µm film thickness; Supelco, Bellefonte, PA, USA) was used to separate the FAME. The carrier gas was Helium at 1.79 \* 10<sup>-1</sup> MPa. The temperature programmed for separation was as follows: initial temperature of 50°C was held for 5 min, increased to 220 at 25°C/min and held for 21 min. The temperature was then increased to 240°C at 15°C/min and held for 10 min. The injector temperature was maintained at 60°C/min and held for 2 min. The detector temperature was kept constant at 250°C.

The instrument was calibrated with one-point calibration method, using a standard mixture of fatty acid methyl esters of known proportions and an internal standard used to spike the samples to monitor the detector response. 1 µ of both the standards, which were made of different concentrations and the samples, which were injected into the GC. Individual methyl esters were identified by comparison of retention times to those of known standards. The peak areas of the standards obtained from the chromatograms were used to calculate the detector response. This was done by division of all standard peak areas, by their corresponding internal standard peak areas. The detector response of the standards, which were of different concentrations, were then used to plot seventeen calibration graphs of the fatty acid methyl esters present in the standards. The calibration graphs were then used to determine the levels of each fatty acid present in the samples (Ackman, 1980). A ratio of the peak areas of the standards to the internal standards were calculated and a calibration graph of the ratio of the detector response against concentration, plotted for each of the seventeen fatty acids (Ekeberg et al., 2006). The concentration of each fatty acid was determined by multiplying the concentrations, which were in p.p.m (mg/L) present, by the percentage weight of the fatty acids in the standard.

### Data analysis

The mean and standard deviation of the lipid content and fatty acid values were determined, and one-way analysis of variance was used to detect variation in means at significance level of p = 0.05.

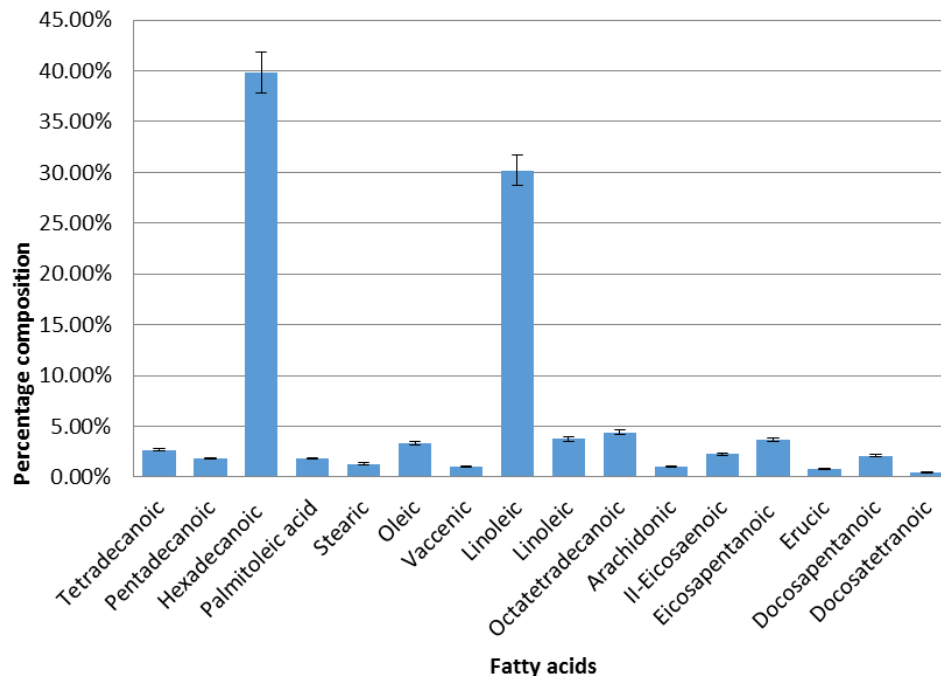
## RESULTS

### Lipid content and characterization of Jackfruit seeds

The samples from each region were done in triplicates, and the mean and standard deviation per region determined were as shown in Table 1, the lipid content of samples from all regions showed no variation at significance p = 0.05. The average lipid content for the fresh seeds was found to be 0.45 ± 0.24 g per 100 g of crushed seeds. The mean saponification and iodine values were also found to be 353.65 ± 12.51 and 60.76 ± 3.25, respectively, as shown in Table 1.

### Lipid profile of jackfruits seeds

The lipid profile was found to contain sixteen fatty acids. The fatty acids were namely tetradecanoic acid (C 14:0),



**Figure 1.** Percentage composition of Jackfruit seeds fatty acid profile of fresh samples from all the six regions.

pentadecanoic acid (C15:0), Hexadecanoic acid (C16:0), palmitoleic acid (C16:1), stearic acid (C18:0), oleic acid (C 18: 1), vaccenic acid (C18:1), linoleic acid (C 18:2), linolenic acid (C18:3), octadecatetraonic acid ( C18:4), 11-eicosanoic acid (C20:1), arachidonic acid (C20:4), eicosapentanoic acid (C22:5), erucic acid (22:1), docosatetraonic acid (C22:4) and docosapentanoic acid (C22:4) as shown in Figure 1. Hexadecanoic acid recorded the highest relative percentage composition of  $39.85 \pm 2.68\%$ . Linoleic acid, which is an omega-6 fatty acid, equally recorded in high values and was also among the most dominant fatty acids, with the relative percentage of  $30.18 \pm 0.59\%$ . The other saturated fatty acids that were consistently present were tetradecanoic acid (C14:0), pentadecanoic acid (C15:0) and stearic acid (C18:0), whose percentages ranged from 1 to 3%, which implies that they were present in low levels. The total levels of saturated fatty acids were found to be  $45.64 \pm 4.90\%$ . The monounsaturated fatty acids present were palmitoleic acid, oleic acid, vaccenic acid and 11-eicosanoic. The total percentage of monounsaturated fatty acids is  $6.55 \pm 2.32$ . The polyunsaturated fatty acids present are linoleic acid, linolenic acid, octadecanoic acid, arachidonic acid, eicosapentanoic acid, erucic acid, docosatetraonic and docosahexanoic acid. They constituted the greatest percentage composition of 46.37%. The total monounsaturated and polyunsaturated fatty acids is 52.92%, which implies that Jackfruit mostly consists of polyunsaturated fatty acids. The omega-3 fatty acids were found to be linolenic acid,

eicosapentanoic acid, docosapentanoic acid and docosatetraonic acid. Linoleic and eicosapentanoic acid were found to be the most abundant omega-3 fatty acids, with the least being docosatetraonic acid and docosapentanoic acid as shown in Table 2. The total percentage levels of omega-3 polyunsaturated fatty acids were found to be  $9.94 \pm 0.99\%$ . The levels of omega-6 fatty acids were found to be  $31.26 \pm 0.82\%$ , this could be attributed to the fact that linoleic acid was among the most dominant fatty acids.

#### **Lipid content, profile and levels of omega-3 fatty acids in Jackfruit seeds from different areas**

The levels of fatty acids from all the six regions showed no significant variation at significance  $p = 0.05$ . The percentage composition of the fatty acids of the saturated fatty acids such as tetradecanoic acid, pentadecanoic acid, hexadecanoic acid, and stearic acid showed a lower variation compared to the values of unsaturated fatty acids such as oleic acid, vaccenic acid (11 – Octadecenoic acid), linoleic acid, linolenic acid, octadecatetraenoic acid, 11-eicosenoic acid, arachidonic acid, eicosapentanoic, (erucic acid 22:1), docosatetraonic and docosapentanoic acid as shown in Figure 2. There was also a variation in percentage composition of omega-3 PUFAs at significance  $p = 0.05$ , which included eicosapentanoic acid, docosapentanoic acid, linolenic acid and docosatetraonic acid. The seeds were also

**Table 2.** Overall percentage fatty acid composition of saturated, monounsaturated and polyunsaturated fatty acids from all regions.

Fatty acid	Percentage composition	Type of fatty acid
Tetradecanoic acid (C14:0)	2.66±0.51	Saturated
Pentadecanoic acid (C15:0)	1.83±1.21	Saturated
Hexadecanoic acid (C16:0)	39.85±2.68	Saturated
Stearic acid (C18:0)	1.30±0.50	Saturated
Oleic acid (C 18: 1)	3.30±1.38	Monounsaturated
Vaccenic acid (C18:1)	1.01±0.44	Monounsaturated
11-Eicosanoic acid (C20:1)	2.24±0.02	Monounsaturated
Linoleic acid (C 18:2)	30.19±0.59	Polyunsaturated
Linolenic acid (C18:3)	3.73±0.25	Polyunsaturated
Octadecatetraoic acid ( C18:4)	4.38±0.53	Polyunsaturated
Arachidonic acid ( C20:4)	1.07±0.23	Polyunsaturated
Eicosapentanoic acid (C22:5)	3.66±0.65	Polyunsaturated
Erucic Acid (22:1)	0.79±0.02	Polyunsaturated
Docosatetraoic acid (C22:4)	0.47±0.04	Polyunsaturated
Docosapentanoic acid (C22:4)	2.08±0.06	Polyunsaturated
Total saturated fatty acids	45.64±4.90	
Total monounsaturated fatty acids	6.55±2.32	
Total polyunsaturated fatty acids	46.37±2.12	

found to contain a high levels of omega-6 fatty acids, namely the linoleic acid and arachidonic acid. Linolenic acid was the most abundant Omega-3 fatty acid followed closely by eicosapentanoic acid as shown in Table 3.

### The effect of boiling and drying on the lipid content and lipid profile

The boiled seeds had the lowest lipid content in most regions compared to the fresh and dried seeds. There was a significant variation in iodine values in the fresh, dried and boiled seeds at significance of  $p = 0.05$ . There was no significant variation in saponification values for fresh seeds, boiled and dried seeds in all regions at  $p = 0.05$ . Hexadecanoic acid showed a small variation in fresh, dried and boiled seeds though the values of the boiled seeds were slightly lower. Tetradecanoic acid, hexadecanoic acid, palmitoleic acid and stearic acid were also found to show slight variations in the levels of both fresh, boiled and dried seeds and they are all saturated fatty acids as shown in Figure 3. The difference in fresh and boiled seeds was however higher in oleic, vaccenic acid, linolenic, linoleic acid and octadecatetraoic acid, which are all unsaturated fatty acids. Linoleic acid was also found to be in high levels in fresh fruits and lower in boiled and dried seeds. Octadecatetraoic acid was found to be present only in fresh fruits and the levels in both boiled and dried seeds were found to be below the GC detection limit, which is the lowest concentration of

an analyte that can be detected by the GC. The levels of eicosapentanoic acid were relatively high in fresh seeds but below the G.C detection limit in both dried and boiled seeds. arachidonic, erucic and docosapentanoic acid were also found to be present in fresh seeds but below G.C detection limit in both dried and boiled seeds except for docosapentanoic acid, which was present in small quantities in dried seeds as shown in Figure 4.

### DISCUSSION

The average mass of the oil content per 100 g was  $0.45 \pm 0.24$  g. This implies that the oil content of Jackfruit seeds constitutes  $0.45 \pm 0.24\%$ . This value is different from those found in other studies, as the oil content was found to be 11.39% (Ajayi, 2008). The value was also different from the findings of Sign et al. (1991) whose value was 3.2, 0.91% by Mukprasirt and Sajjaanantakul (2004) and Tulyathan et al. (2002), who recorded 0.99% lipid content in Jackfruit. The value was however, close to (Madrigal-Aldana et al., 2011), which was 0.71%. The saponification number was  $353.65 \pm 14.21$  mg of KOH per 1 g of fat, which is above 250 upper limit for lipids with long chained fatty acids, implying that Jackfruit fatty acids mainly consists of short chained fatty acids (Dosumu and Ochu, 1995). The iodine number was  $60.76 \pm 3.25$ , which is relatively high, implying that the oil contains an appreciable level of unsaturated bonds (Akubugwo and Ugbogu, 2007). The polyunsaturated

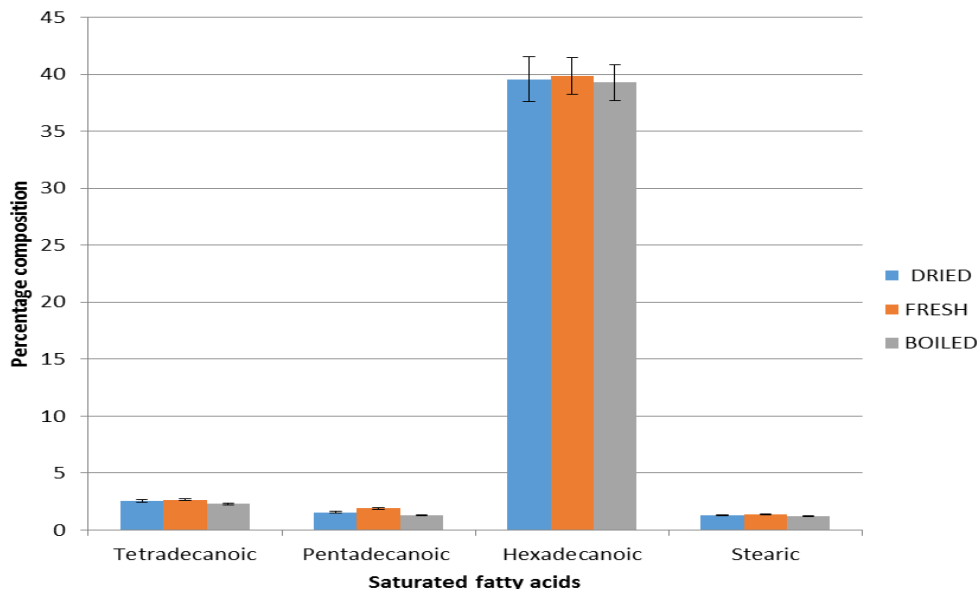


Figure 2. Fatty acids composition of fresh samples of Jackfruit seeds from all the six regions.

Table 3. Overall percentage composition of omega-3 and omega-6 PUFAS in Jackfruit.

Fatty acid	Percentage composition	Type of fatty acid
Linolenic acid (C18:3)	3.73±0.25	omega-3
Eicosapentanoic acid (C22:5)	3.66±0.65	omega-3
Docosatetranoic acid (C22:4)	0.47±0.04	omega-3
Docosapentanoic acid (C22:4)	2.08±0.05	omega-3
Linoleic acid (C 18:2)	30.19±0.59	omega-6
Arachidonic acid ( C20:4)	1.07±0.23	omega-6
Total omega-3 PUFAs	9.94±0.99	
Total omega 6 PUFAs	31.26±0.82	

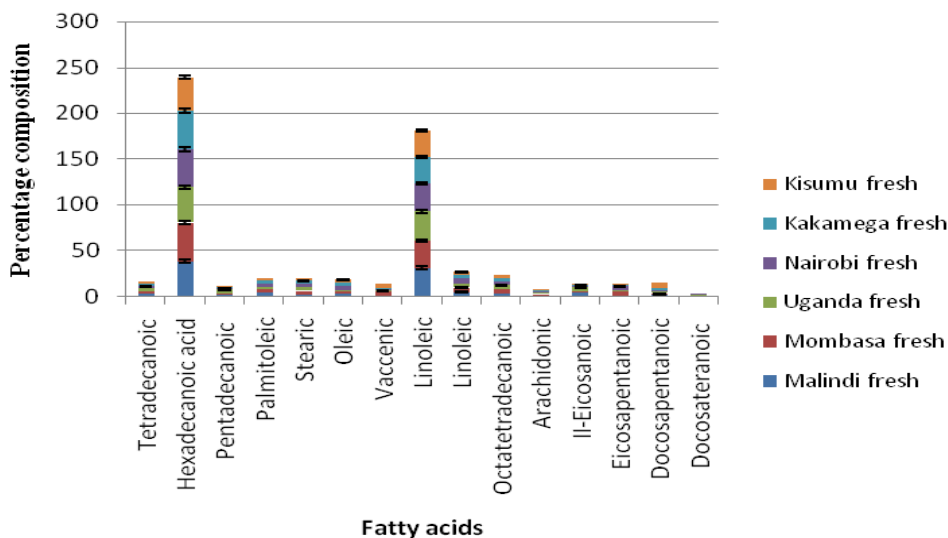
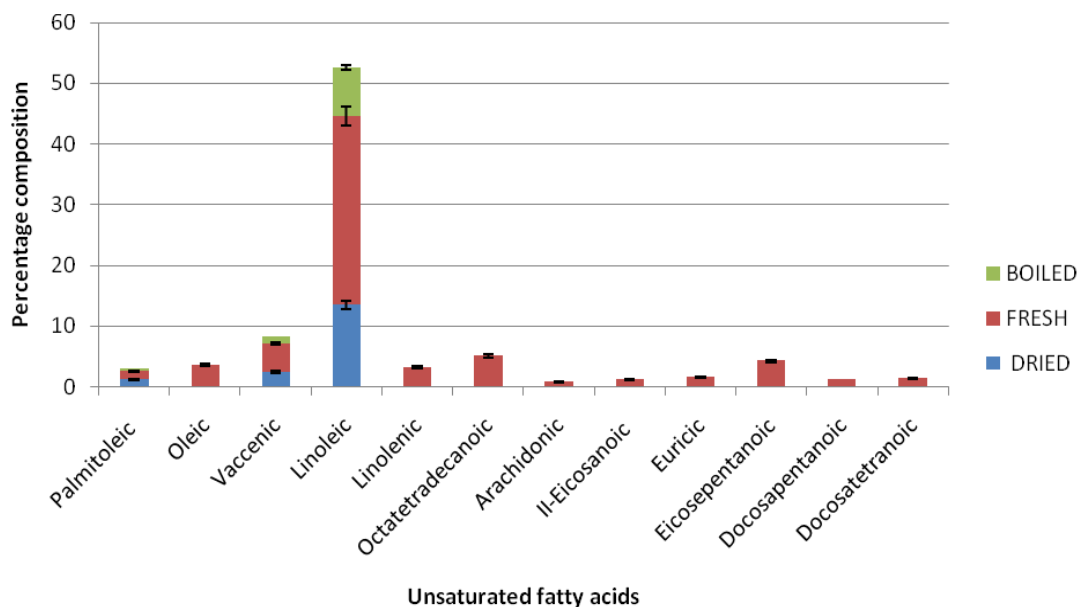


Figure 3. Percentage compositions of saturated fatty acids in fresh, boiled and dried samples from all regions.



**Figure 4.** Percentage composition of unsaturated fatty acids in fresh, boiled and dried samples from all regions.

fatty acids found were linoleic acid, linolenic acid, octadecanoic acid, arachidonic acid, eicosapentanoic acid, erucic acid, docosatetranoic and docosahexanoic acid. They constituted the greatest percentage composition of 46%. This implies that Jackfruit lipid is very beneficial to our health. The total monounsaturated and polyunsaturated fatty acids is 52.92, which shows that Jackfruit mostly consists of polyunsaturated fatty acids and thus healthy as most polyunsaturated fatty acids have been associated with numerous health benefits.

The omega-3/omega-6 ratio was 1:3 which is within the margin of the recommended intake ratio of 1:4. This study was consistent with Kikuta and Erickson (1968) and Mazliak (1965), whose findings indicated, that one of the most dominant saturated fatty acids in Avocado is hexadecanoic acid, which was also found to be the most dominant saturated fatty acid in jackfruit seeds. The monounsaturated fatty acids oleic acid (18:1) and palmitoleic acid (16:1) and the polyunsaturated fatty acids linoleic acid (18:2) and linolenic acid (18:3) were also found to be present, which is consistent with this study as these fatty acids were also found to be present in the fatty acid profile of Jackfruit seeds (Kikuta and Erickson, 1968).

Studies also indicate that the fatty acids profile of different plant oils vary from one plant oil to another. Coconut oil has been found to contain 90% saturated fats with lauric acid constituting a greater percentage and it is therefore likely to cause heart conditions if consumed in high quantities (Vasudevan, 2010). This is contrary to the popular belief that plant oils consist of a greater percentage of unsaturated fatty acids. Peanut on the

other hand, has been found to have a higher percentage of unsaturated fatty acids with oleic acid being the most dominant fatty acid and other dominant fatty acids present were linoleic acid, linolenic acid and palmitic acid (Misuna et al., 2010). The linoleic acid and hexadecanoic acid had the highest percentage, with each having 39 and 30%, respectively. The levels of palmitic acid were lower in Jackfruit unlike in other plant oils.

Jackfruit seeds were found to contain omega-3 fatty acids and the average level of Omega-3 percentages in lipid is 9.94% with the average in 100 g of crushed seeds being 54.18 mg. This falls below the recommended intake of 350 mg (Lee et al., 2009). On the other hand, the fruit has a high level of Omega-6 fatty acids, which are equally important and good for the body and works hand in hand with Omega-3 in controlling heart disease. The fruit also has other unsaturated fatty acids that are healthy for the body apart from the hexadecanoic acids, which are equally in high levels. The World Health Organization stated that intake of hexadecanoic acid puts one at more risk of developing cardiovascular diseases (World Health Organization, 2003), however other studies indicate that hexadecanoic acid has no hypercholesterolaemic effect, if the intake of linoleic acid is 4.5% of the energy (French et al., 2002). From this study the levels of linoleic acid were 30%, which were way above the 4.5% and thus the seed oil may not have any negative cardiovascular effects.

The lipid profile of jackfruit of fresh fruits from all the six regions showed no variation at significance  $p = 0.05$ . A comparison of the means of fatty acid in all the six regions, showed variation in levels of omega-3 polyunsaturated

turated fatty acids at significance  $p = 0.05$ . This could be attributed to factors such as slight difference in weather patterns, which may in turn lead to difference in temperature. Studies show that temperature affects the lipid profile of organisms, with organisms in lower temperature regions having a higher level of polyunsaturated fatty acids especially the omega-3 fatty acid as opposed to regions of higher temperatures (Yaniy et al., 1988). The difference could also be attributed to difference in varieties, which in turn implies difference in genetic makeup may cause variation in composition of polyunsaturated fatty acid. A study done by Green et al. (1984) revealed that difference in fatty composition is also under genetic control. The lipid content was found to show variation in fresh, boiled and dried seeds at  $p = 0.05$ , this could be attributed to the fact that some of the oil may have been lost in the process of boiling, as some of the lipids may have been lost in water (Simopoulos, 2002). There was a significant variation in iodine values in the fresh, dried and boiled seeds at significance of  $p = 0.05$ . This implies that the boiling and drying affects the degree of unsaturation of fatty acids. The double bonds in the unsaturated fatty acids undergo hydrolytic and oxidative reactions in high temperatures leading to a decrease in the iodine number (Ramezanzadeh et al., 2000). The saponification numbers showed no variation in  $p=0.05$  for fresh, dried and boiled samples, which implies that boiling and drying may not have an effect in the chain lengths (Dosumu and Ochu, 1995).

The levels of saturated fatty acids were found to show no variation in fresh, boiled and dried seeds at  $p = 0.05$ , this may be attributed to the fact that saturated fatty acids can withstand high temperatures (Antunes and Sfakiotakis, 2008). This implies that boiling and drying of seeds, does not affect the composition of saturated fatty acids. This is because, the four bonds attached to carbon are all attached to other atoms thus they are not susceptible to oxidative and hydrolytic reactions that cause rancidity (Dosumu and Ochu, 1995). There was however variation in levels of unsaturated fatty acids in fresh, boiled and dried seeds at  $p = 0.05$ . This implies that, drying and boiling of seeds affects the levels of unsaturated fatty acids. The dried and boiled samples of unsaturated fatty acids were in low levels, with most levels of polyunsaturated fatty acids in boiled seeds being below the GC detection limit. This is an indication that most of the polyunsaturated fatty acids are very sensitive to heat and exposure to sunlight and is readily destroyed by both of them (Ramezanzadeh et al., 2000). This means that, the processing and storage conditions that involve high temperatures often lead to enormous loss of the essential fatty acids especially the omega-3 and Omega-6 fatty acids, which have numerous health benefits (Simopoulos, 2002) and both temperature and sunlight has a negative effect on the levels of polyunsaturated fatty acids (Yaniv et al., 1988). This may be attributed to the fact that the unsaturated fatty acids readily

undergo hydrolytic and oxidative reactions, leading to decrease in levels of polyunsaturated fatty acids. The oxidative reactions usually take place at the position of the double bonds (Antunes and Sfakiotakis, 2008). The storage procedures need to ensure protection from Hydrolytic and oxidative deterioration to minimize the ability of the oil to go rancid (Williams et al., 1988).

In most samples the levels of fatty acids in the dried seeds were lower than those in the fresh seeds especially the monounsaturated and polyunsaturated fatty acids. This is consistent with the studies done by Su and Babb (2007), whose evaluation on cooking methods recorded a sharp decrease in levels of omega-3 PUFAs in cooking methods, which involved more exposure to higher temperature (Su and Babb, 2007). The omega-3 PUFA levels are greatly affected by heat and therefore, jackfruit lipid would not be a suitable for cooking oil but instead, it can be added to the margarine or used in spices such as creams or in cake icing as it is high in unsaturated fatty acids and hence provides a healthy diet. The levels of omega-3 were also significantly affected at  $p = 0.05$  in both boiled and dried seeds. This implies that, both drying and boiling the seeds greatly decreases the levels of omega-3 polyunsaturated fatty acids. Future research should focus on coming up with better processing and storage methods that will help in preserving the levels of Omega-3 fatty acids in Jackfruit seeds.

### Conflict of interests

The authors did not declare any conflict of interest.

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