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Comparative Study of the Constituents of the Fruits Pulps and Seeds of Canarium ovatum, Persea americana and Dacryodes edulis

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Abstract

This work was carried out to evaluate and compare the nutritional and phytochemical composition of three pears commonly consumed as food/snacks in Nigeria. The nutritional and phytochemical composition of the pulps and seeds of African pear (*Dacryodes edulis*), avocado pear (*Persea americana*) and Pili nut (*Canarium ovatum*) were determined using standard methods. The amino acid composition of the fruit pulps was also determined using an amino acid analyzer while the fatty acid composition of the oils extracted from the seeds and pulps was determined using GC-MS. The results show that all three species are good sources of food nutrients. Crude fibre (46.33%) and carbohydrate (54.23%) were more abundant in the African pear seed while Pili nut was found to contain the highest level of fat (45.29%). The avocado pear seed had the highest ash (3.50%) and the lowest protein content (1.33%). Tannin was more abundant in the avocado pear seed (0.76mg/100g) and least in the African pear seed (0.24mg/100g); saponin occurred most in avocado pear pulp (0.88mg/100g) and least in avocado pear seed (0.52mg/100g) while phytates were found more in Pili nut (0.58mg/100g). The three species contain good quantities of amino acids with glutamic acid being the most abundant one (10.94 g/100g protein in African pear pulps) while methionine was the least abundant (0.54 g/100g protein in pili pear pulp). Palmitic acid was present in all the pulp samples. Avocado seed oil was high in fatty acids (100%) while the oil of African pear pulp was found to contain only 29.13% fatty acids. The pulps and seeds of these fruits have been shown to have great nutritional and medicinal potentials which can be exploited to reduce waste generated from the fruits and also increase farmers' income.

Keywords: *Phytochemical*; *nutritional*; *fatty acid; amino acid; D. edulis; P. Americana; C. ovatum.*

Introduction

Canarium ovatum, commonly known as Pili (locally called *ube okpoko* in Ibo language of South Eastern Nigeria), *Persea americana,* otherwise known as avocado pear (locally called *ube oyibo*) and *Dacryodes edulis*, known as African pear (locally called *ube*), are usually consumed in different parts of Nigeria as food/snacks. The

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plants are usually planted as fencer or as a wild bush, but their production and commercialization have been on the increase in the last few years. *Canarium ovatum* pulp and kernel are highly nutritious and excellent source of minerals, fats and proteins.[1] It has a long shelf life and the processed kernel is delicious and can be used in the preparation of many food products.[1] *Dacryodes edulis* is a rich source of nutrients such as lipids, proteins and vitamins.[2,3] It is characterized by its high content of fixed and volatile oils and is highly consumed locally and internationally which gives the plant a high economic value.[2] *Persea americana* is a tropical fruit containing a high level of lipids and minerals.[4,5] The plant is reported to be rich in several phytochemicals and is used in traditional medicine for the treatment of various ailments, such as monorrhagia, hypertension, stomach ache, bronchitis, diarrhea, and diabetes.[6]

As these fruits are widely consumed as snacks, this study is aimed at evaluating and comparing the nutritional and anti-nutritional composition of the pulps of *D. edulis, P. americana* and *C. ovatum* and their respective seeds. The results are expected to provide more information on the nutritional and anti-nutritional potentials and also compare the composition of the three plants.

Materials and Methods

Sample Collection and Preparation

The three pears, *Persea americana, Dacryodes edulis* and *Canarium ovatum*, were harvested from Akabukwu farm in Nnewi North LGA, Anambra State, South Eastern Nigeria located at Latitude and Longitude $6^{o}1'$ 0" N and 6^{o} 55' 0" E, respectively. The trees of these fruits are commonly found in Akabukwu community and environments. African pear and Avocado pear were harvested in June, 2014 while Pili nut was harvested in October of the same year. Each pear sample was sorted out and the spoilt pears were separated from the undamaged ones. The undamaged fruits were thoroughly rinsed, first with tap water and then with distilled water, to remove dust and dirt and they were then air-dried. The African and avocado pears were cut open to remove the seeds while the pili nuts were broken using an iron mortar. The seeds and mesocarp (pulps) were separated and cut into pieces for easier drying. All the samples were dried in an oven at 70 °C, cooled and weighed until there was no significant change in weight. The dried samples were then pulverized using a mortar and pestle, sieved and stored in air-tight cellophane bags for analysis. All reagents were of analytical grade and they include, but not limited to, hydrochloric acid (HCl), concentrated sulfuric acid, ammonia solution, n-hexane, sodium sulphate, boric acid, phenolphthalein, methylene red, methylene blue, ethanol, potassium iodide, trichloroacetic acid (TCA), potassium permanganate, dinitrophenyl hydrazine (DNPH), ferric chloride, copper tetraoxosulphate (VI) salt and selenium oxide catalyst. The reagents were purchased from Sigma-Aldrich.

Proximate analysis

The proximate composition (moisture, ash, protein, fat, crude fibre and carbohydrate contents) of the samples were determined according to standard methods.[7] All determinations were done in triplicates.

Phytochemical test

The quantitative determination of alkaloids, flavonoids, tannins, saponins, oxalates and phytates was carried out using standard methods as described by various authors[7-12] The alkaloid content was determined gravimetrically after precipitating it out of solution,[8] flavonoids were extracted with methanol and also determined gravimetrically,[9] tannins was determined spectrophotometrically, [7] saponins by extraction followed by precipitation[10] and the phytates and oxalates were determined by titration.[11,12]

Vitamins analysis

Vitamin A analysis was carried out in the dark to avoid photolysis of the carotenoids. The sample was homogenized and saponified with 12% alcoholic potassium hydroxide then extracted with petroleum ether. The petroleum ether layer containing the carotenoids was collected. This process was repeated until the aqueous layer became colourless. A small amount of anhydrous sodium sulphate was added to the petroleum ether extract to remove moisture and the absorbance was read in an ultra-violet spectrophotometer (Genesys 10-S, USA) at λ_{max} of 450 nm and 503 nm using petroleum ether as a blank.[13]

Vitamin B1: The sample was homogenized with ethanolic NaOH solution and then filtered into a flask. The filtrate was pipetted into a beaker and colour developed by the addition of $KMnO_4$. The absorbance was read at λ_{max} of 360 nm.[13]

Vitamin C: Standard ascorbate solution and the supernant of the samples were separately taken with 4% TCA (Trichloroacetic acid). DNPH (Dinitrophenlhydrazine) reagent was added followed by 10% thiourea solution. The mixture was incubated at 37 ^{o}C for 3 hrs resulting in the formation of osazone crystals which were then dissolved in 85% sulphuric acid; DNPH reagent and thiourea were added, cooled in ice and the absorbance was read at λ_{max} of 540 nm.[13]

Vitamin E: The sample extract, the standard and water were pipetted separately into 3 stoppered centrifuge tubes. Ethanol and xylene were added, mixed and centrifuged. The xylene layer was transferred into another stoppered tube to which 1.0 ml of dipyridyl reagent was added. 1.5 ml of the resulting mixture was pipetted into a cuvette and the extinction was read at 460 nm. Ferric chloride solution (0.33 ml) was added to all tubes and mixed. The red colour developed was read exactly after 15 mins at λ_{max} of 520 nm in a spectrophotometer.[13]

Mineral analysis

Mineral analysis was performed by the triple acid digestion method.[7] A sample was weighed into a conical flask and a mixture of nitric acid (HNO_3), sulphuric acid (H_2SO_4) and perchloric acid ($HClO_4$) (9:2:1 v/v) was added. The mixture was digested by heating it for about 10 min to a clear solution. The solution was cooled and transferred into a 50 ml standard volumetric flask and made up to mark with deionized water. The digest was analyzed for the mineral elements using flame photometry (FP 640 Flame Photometer) and Atomic Absorption Spectrophotometry (AAS) (Buck Scientific 210/211 VGP) using an air-acetylene flame atomization method. Sodium, potassium, calcium and magnesium were determined by digital flame photometer while manganese, iron, copper, zinc, cobalt as well as lead were determined by AAS.[7]

Amino acid analysis

The amino acid profile was determined using methods described by Benitez.[14] The sample was dried to constant weight, defatted with n-hexane by Sohxlet extraction at 60 ºC. It was hydrolyzed and evaporated in a rotary evaporator and loaded into the Technicon Sequential Multi-Sample Amino Acid Analyzer.

Fatty acid Analysis

The oils were extracted with n-hexane using a Sohxlet extractor at 60 ºC and converted into the corresponding methyl esters by refluxing with 40% methanol and sulphuric acid for 30 min. The fatty acids were determined using GC-MS[7] (7890 Agilent USA GC system) hypherated to a mass spectrometer (5975C) with triple axis detector equipped with an auto injector (10 µl syringe). Helium gas was used as the carrier gas.

Statistical analysis

The results obtained were analyzed using SPSS version 10.0. The means and standard deviations were determined and the statistical significance of differences ($p<0.05$) was determined by analysis of variance (ANOVA).

Results and Discussion

Table 1 shows the results of the proximate composition of the three pears (seed and pulp) on wet basis. The African pear pulp has the highest moisture content (44.18%) while the pili nut seed has the lowest (13.72%). The seed of avocado pear contained the highest ash content (3.50%) and the least protein content (1.33%). Pili nut contained the highest quantity of fat (45.29%) and carbohydrate is more abundant in the African pear seed (49.63%).

The moisture content of fruits is the free water in the fruit. It is one of the most important indices evaluated in foods. The results from Table 1 indicate that all the samples analyzed have relatively high moisture contents, with the pilinut seed having

the least content (13.72%). High moisture content in foods generally supports microbial growth and spoilage; the lower the moisture content, the longer the expected shelf-life.[15] Thus, pili nut will have the longest shelf-life. However, since the intake of fruits and vegetables is encouraged as an additional source of fluid for human body, the high moisture content of African pear pulp is highly beneficial. The ash content of the African pear pulp (2.61%) fell within the range of 2.2–4.7% previously reported.[16] The Lipid content (on wet basis) was higher in the pili nut and the fat may be used for either commercial purposes or domestic use. The crude protein was more abundant in the pulp of pili nut (2.16%) and least in avocado seed (1.33%). The recommended dietary allowance (RDA) for children, adult males, adult females, pregnant women and lactating mothers are, respectively, 28, 63, 50, 60 and 65 g of protein daily.[17] This indicates that the three species of pear are poor sources of dietary protein but can supply other nutrients to the body. It was observed that generally, the fruit pulps are higher in moisture and protein than the corresponding seeds and nuts. Similar observation was made for the fat content except for pili nut, which has a higher fat content than the pulp. Conversely, the fruit pulps are lower in carbohydrate than the seeds and nut. The reported value of the crude fibre for pulp of African pears in literature (12.00%) is lower than the crude fibre obtained from the pulp (38.733%).[18]

Table (1): Proximate composition of pulps and seeds of African pear, avocado pear and pili nut.

Samples	African pear pulp	African pear seed	Avocado pulp	Avocado seed	Pili pulp	Pili nut Seed
Moisture content (%)	44.18 ±0.23^{e}	40.13±0.53^{c}	41.57±0.72^{cd}	34.28 ±0.45^{b}	42.15± 1.84^{d}	13.72 ±0.76^{a}
Ash content (%)	2.61 ±1.16^{ab}	1.99 ± 0.58^{a}	2.55 ± 1.53^{ab}	3.50 ± 0.58^{b}	2.12 ± 0.58^{ab}	2.59 ± 0.00^{a}
Fat content (%)	24.60 ±0.48^{b}	6.48±0.58^{a}	28.88 ±0.84^{c}	6.66 ±0.10^{a}	28.95 ± 0.00^{c}	45.29 ±0.86^{d}
Protein content (%)	2.14 ± 0.10^{e}	1.77 ± 0.02^{b}	1.90 ± 0.02^{d}	1.33 ± 0.01^{a}	2.27 ± 0.00^{e}	2.16 ± 0.20^{c}
Carbohydrate content (%)	26.47 ±0.10^{d}	49.63 ± 0.00^{f}	25.10 ±0.02^{c}	54.23 ± 0.02^{e}	24.51 ± 0.03^{b}	36.24±0.00^{a}
Crude fibre content (%)	39.20 ±0.99^{d}	46.33 ± 0.58^{e}	34.30 ± 0.40^{c}	26.33 ± 1.53^{a}	32.87 ± 2.82^{c}	29.93 ±0.50^{b}

Values are means ± standard deviations of triplicate determinations. Values (a, b...) in the same row sharing the same letters are not significantly different ($p < 0.05$ level).

Table 2 shows the phytochemical compositions of the three pears and their seeds. The results revealed that tannins were most abundant in avocado seeds and least in African pear seeds. The tannin contents of the seeds are generally higher than those of the pulps except in African pear. Tannins are known to be bitter and form high polyphenol complex with protein making it thereby unavailable in the diet. They may decrease the protein quality by decreasing its digestibility and palatability,[19] but are on

the other hand beneficial to human health in view of its role in preventing tooth decay and protecting from heart diseases and cancer.[20] The tannin contents of these pear samples are relatively low compared with other phytonutrients.

Of all the samples analyzed, the seed of African pear contained the highest quantity of alkaloids followed by the pulp of the pili nut. The lowest alkaloid content was recorded in African pear pulp. On the other hand, the flavonoid content was highest in avocado (both pulp and seed) and lowest in pili nut. Flavonoids are potent water soluble antioxidants and free radical scavengers which prevent oxidative cell damage. They have strong anticancer activity and protect against the different levels of carcinogenesis.[21]

Table (2): Phytochemicals and Antinutrients composition (mg / 100g)

Sample	Tannins	Alkaloids	Flavonoids	Phytates	Oxalates	Saponins
African pear pulp	0.59± 0.21^{c}	3.33± 0.31^{a}	7.10±0.02^{b}	0.29±0.03^{a}	1.69±0.02^{bc}	0.74±0.38^{d}
African pear seed	0.24± 0.04^{a}	15.80±0.00^{e}	7.38±0.00^{c}	0.39±0.05^{d}	1.82±0.04^{c}	0.58±0.02^{c}
Avocado Pulp	0.25 ±0.07^{a}	5.80±0.00^{c}	21.16±0.00^{f}	0.44±0.04^{b}	3.38±0.02^{d}	0.88±0.00^{e}
Avocado Seed	0.76± 0.17^{e}	5.40±0.00^{b}	20.33±0.01^{e}	0.44±0.01^{b}	4.40±0.30^{e}	0.52±0.42^{a}
Pili pulp	0.38± 0.06^{b}	11.60±0.00^{d}	7.44±0.00^{d}	0.39±0.03^{b}	1.57±0.00^{ab}	0.52±0.00^{a}
Pili nut Seed	0.67± 0.03^{d}	5.33±0.05^{b}	5.25±0.04^{a}	0.58±0.02^{c}	1.32±0.02^{a}	0.57±0.22^{b}

Values are means ± standard deviations of triplicate determinations. Values (a, b...) along the same column sharing the same letters are not significantly different ($p<0.05$ level).

Saponins are soap-like in nature and have a general property of being able to form foam in water. They may serve as natural antibiotics; they show microbial activities and are used in the treatment of fungal and yeast infections. Their amphiphilic nature may also cause them to create pores on the surface of intestinal cells, resulting in increased permeability of the intestines and allowing unwanted substances to pass through the gut into the bloodstream.[22] It is therefore important that the saponin content of food should be minimal.[22] The saponin contents recorded for all samples investigated ranged between 0.518g/100g to 0.878g/100g, with the avocado seeds having the least saponin content whereas the pulp showed the highest saponin content.

Phytates and oxalates are antinutrients with established adverse effects on digestibility, nutrient availability and other poisonous effects. Phytates bind to minerals in the gut, thus reducing their availability and absorption.[23] Oxalates may be present in plants as soluble salts; they interfere with the absorption calcium and crystallize in tissues if consumed regularly. All the samples investigated contained less than 0.6 g/100g phytates while the oxalate contents ranged from 1.3 g/100g in pili nut to 4.4 g/100g in avocado seeds. It has been suggested that occasional or infrequent consumption of foods containing these antinutrients may not necessarily pose a

problem and that taking a few days off susceptible foods may be sufficient to allow the body to clear out the toxins/ antinutrients.[24]

Table 3 presents the vitamin contents of the three pears and their seeds. Generally, it can be observed that vitamin A is found to be more abundant when compared with other vitamins, ranging from 96.87 mg/g in avocado pear seed to 612 mg/g in African pear pulp. The least abundant vitamin was vitamin B1 ranging from 9.29 µg/100g in African pear pulp to 20.25 µg/100g in African pear seed. Ujowundu *et al*. [25] reported 25.76 mg/100g vitamin C for the African pear seed which is higher than the value obtained from this work (12.28 mg/100g).

Table (3): Vitamin contents.

Samples	Vit A (mg/g) at 450 nm	Vit B1 (µg/100g) at 360 nm	Vit C mg/100g) at 420 nm	Vit E (µg/100g) at 520 nm
African pear pulp	612.00	9.29	43.56	54.17
African pear seed	188.00	20.25	12.28	51.90
Avocado pulp	240.00	8.60	51.63	50.88
Avocado seed	96.87	5.87	6.98	33.64
Pili pulp	532.00	17.30	38.45	52.34
Pili nut seed	285.09	13.26	15.32	38.76

Percentage of standard error < 5%

Vitamin A (carotenoid) is commonly known for good eyesight. It is also useful for regulating genes, maintaining healthy skin, supporting the immune system and producing red blood cells. Vitamin A deficiency primarily causes impaired vision and increases susceptibility to infectious diseases. Vitamin B_1 is an important vitamin required by the human body and is essential for the breakdown of fat and protein and also keeps the mucous membranes healthy. A deficiency of vitamin B1 leads to a decrease in the neurotransmitter and causes irregular heartbeat. Severe deficiency can cause congestive heart failure.[27] Vitamin C is an anti-scurvy vitamin. It hastens the healing of wounds and enhances the absorption of iron thus it has a role in reducing iron deficiency and anemia.[26] The health benefits of vitamin E come from its antioxidant properties and include protection against toxins such as air pollutants, premenstrual syndrome, eye disorders such as cataracts, neurological diseases such as Alzheimer's disease, and diabetes. Another important benefit of vitamin E is that it reduces cholesterol and the risk of developing cancer.

Table 4 shows the mineral compositions of the three species of pear and their seeds. Potassium is the most abundant of all the minerals investigated, with values ranging between 7.25-16.25 mg/g sample. Calcium and magnesium are next in abundance with values ranging from 0.17 mg/g calcium in avocado pulp to 6.93 mg/g magnesium in pili nut. Sodium and iron are also relatively prominent while other minerals are present only in minute quantities.

Table (4): Mineral composition of pulps and seeds of three species of pears (mg/g).

Sample	Ca	Mg	K	Na	Mn	Fe	Cu	Zn	Co	Pb
African pear pulp	3.71	1.55	7.53	0.17	0.04	0.15	0.01	0.02	0.00	0.00
African pear seed	0.43	0.99	7.25	0.18	0.03	0.15	0.01	0.02	0.00	0.00
Avocado pulp	0.17	1.43	16.25	0.17	0.01	0.15	0.01	0.03	0.00	0.00
Avocado seed	0.43	1.19	14.50	0.20	0.01	0.55	0.01	0.05	0.00	0.00
Pili pulp	2.35	1.94	13.19	0.19	0.06	0.13	0.00	0.01	0.00	0.00
Pili nut seed	0.45	6.93	9.53	0.14	0.06	0.33	0.03	0.08	0.00	0.00

Calcium plays an important role in building and maintaining strong bones and teeth, large parts of human blood and cellular fluids. It is also necessary for normal functioning of cardiac muscles, blood coagulation, clotting and regulation of cell permeability. Calcium deficiency causes rickets, back pain, osteoporosis, indigestion, irritability, pre-menstrual tension and cramping of the uterus.[28] Magnesium plays a major role in relaxing muscles along the airway to the lungs allowing asthma patients to breathe easier. It plays fundamental roles in most reactions involving phosphate transfer and is believed to be essential in the structural stability of nucleic acid and intestinal absorption while its deficiency is responsible for severe diarrhea and migraines. The body requires potassium in large quantities for the maintenance of the acid-base balance, body water balance and nerve function; its absence may result in muscular weakness and paralysis. The recommended daily allowance for an adult in good health is 2,500 mg.[29] The body requires also sodium in large quantities in order to maintain the acid-base balance, osmotic balance between cells and interstitial fluid and nerve function.[29] Its absence causes muscle cramps, mental apathy and reduced appetite. The recommended daily allowance of sodium is 115-750 mg/kg for infants, 324-975 mg/kg for children and 1100-3300 mg/kg for adults.[29] Manganese is a micro element essential for human nutrition. The recommended daily allowance (RDA) value for Manganese is 2–5 mg/100g for a male adult.[30] Manganese is believed to support the immune system, regulate blood sugar levels and is involved in the production of energy and cell reproduction.[31] The recommended dietary allowance for iron in adult and children is 10 mg/day while female adult is 15 mg/day. Iron is required for blood haemoglobin formation which also involves energy metabolism. It is a trace element needed by the body. The deficiency of iron in the body results in anemia.[32]

The copper content of the three plants studied was very low. The avocado and African pear samples have 0.01 mg/g Cu in pulp as well as in seed while no copper was detected in the pulp of the Pili pear. Copper is known as a micro mineral element that facilitates the absorption of iron and thus the formation of red blood cells. Copper is also required in the body for enzyme production and biological electron transfer.[33] The value of copper in the three pear samples and their seeds are below the

recommended dietary allowance of 3mg/day for adults and 2 mg/day for children.[34] Therefore, they are a poor source of copper for human nutrition.

The zinc content of the pulp and seed of the African pear were the same (0.02 mg/g) while the avocado pear pulp and the seed contained 0.03 and 0.05 mg/g, respectively, which is lower compared to the corresponding values for the fruits and seeds (0.64 and 0.09 mg/g, respectively) reported by Arukwe *et al*.[35] Zinc is said to be an essential trace element for protein and nucleic acid synthesis as well as for normal body development; it is vital during periods of rapid growth such as infancy, adolescence and during recovery from illness.[36] Recommended Dietary Allowances (RDAs) for zinc is 11 mg/day for men and 8 mg/day for women. If large doses of zinc (10-15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea and vomiting may occur.

Table 4 revealed that lead and cobalt were absent in the three samples. Lead is a poisonous metal that can damage the nervous connection especially in young children. It also affects their faculty of reasoning.[37] In adults, it damages brain, kidney and ultimately cause death while in pregnant women it causes miscarriage.[38] The pulps and seeds of these pears are safe for consumption as the presence of injurious heavy metals like Pb and Co is not detected.

Table 5 shows the amino acid profile of the pulps of African pear, pili pear and avocado pear. The results show that African pear pulp had the highest total amino acid (TAA), total essential amino acid (TEAA), total acid amino acid (TAAA), total sulfur amino acid (TSAA), total aromatic amino acid (TArAA) when compared with the pili pear and avocado pear. The quality of protein in food substances is determined by its amino acid content especially the essential amino acids (EAA). The results show that with respect to TAA, TEAA, TAAA, TSAA and TArAA, African pear pulp has the highest content while the least content is found in avocado pear pulp.

Amino acids are the building blocks of proteins; they are important for muscle growth and mental health and do prevent muscle catabolism. The essential amino acids (EAA) are nine different amino acids (stated on table 5) which cannot be produced by the body on its own and are available in plants and supplements. They are found in protein foods like fish, meat, eggs and some plants. Acid amino acids (AAA) have carboxylic acid groups whose pka's are low enough to lose protons, becoming negatively charged in the process. While sulfur amino acids (SAA) and aromatic amino acids (ArAA) are amino acids containing sulfur and aromatic ring on its chain, respectively.

Table (5): Comparison of amino acid profile of African pear, pili pear and avocado pear.

Amino Acid	Concentration (g/100g protein)			
	AFP	PP	AVP	FAO
Arginine (E)	5.10	4.08	7.66	-
Lysine (E)	3.30	2.58	2.09	18
Histidine(EAr)	2.16	1.33	1.65	15
Aspartic Acid (A)	7.20	5.18	6.82	-
Glutamic Acid (A)	10.94	7.39	7.53	-
Cysteine (SE)	1.52	0.41	0.97	4.1
Methionine (SE)	1.29	0.54	0.70	10.4
Phenylalanine (ArE)	5.02	4.05	3.43	21
Tryptophan(ArE)	ND	ND	ND	4
Tyrosine (ArE)	3.31	1.49	1.99	25
Valine (E)	3.22	2.13	4.20	15
Isoleucine (E)	3.00	1.83	2.48	-
Leucine (E)	6.04	7.22	5.69	39
Threonine (E)	2.95	2.30	2.27	15
Serine	3.11	1.94	3.00	-
Proline	3.01	2.32	4.29	-
Glycine	3.48	2.35	4.20	-
Alanine	3.23	5.11	3.07	-
Total Amino acids (TAA)	67.88	52.25	62.04	
Total Essential amino acids (TEAA)	28.13(41.44%)	22.14(42.37%)	22.85(36.83%)	
Total Acid amino acids (TAAA)	18.14(26.72%)	12.57(24.06%)	14.35(23.13%)	
Total Sulphur amino acids (TSAA)	2.81(4.14%)	0.95(1.82%)	1.67(2.69%)	
Total Aromatic amino acids (TArAA)	10.49(15.45%)	6.87(13.15%)	7.07(11.40%)	

ND = Not determined, B= Basic amino acid, A = Acidic amino acid. S = Sulphur containing amino acid, Ar = Aromatic amino acid, E = Essential amino acid, AFP, PP, AVP means African fruit pulp, pili pulp and avocado pulp respectively.

Table 6 shows the fatty acid composition of the three pear pulps and their respective seeds. The oils extracted from all samples are liquid at room temperature except that of the pili pulp which was solidifying at room temperature. This suggests that pili pulp contains only saturated oil and this was confirmed from the results shown in Table 6. The main fatty acids detected were palmitic acid (96.82% in pili pulp) and linolenic acid (67.46% in avocado seed). They also contain oleic acid, stearic acid, margaric acid and pentadecylic acid. The essential fatty acids in the human body help to prevent nutrition-related illnesses and since they are not synthesized by the human body, they are provided in the diet. Dietary fat rich in linoleic acid prevents disorders such as coronary heart diseases and athero- sclerosis.[39]

Table (6): Fatty acid compositions of the three pears pulps and seeds.

Sample	Fatty Acids	Molecular Formula	%	Total % fatty acid	Total % saturated fatty acid	Total % unsaturated acid
African pear pulp	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	10.13	29.13	10.13	19.00
	Oleic acid	$C_{18}H_{34}O_2$ (C_{18}:1)	19.00			
African pear seed	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	44.41	71.19	64.99	6.20
	Linoleic acid	$C_{18}H_{32}O_2$ (C_{18}:2)	3.36			
	Oleic acid	$C_{18}H_{34}O_2$ (C_{18}:1)	2.84			
	Pentadecylic	$C_{15}H_{30}O_2$ (C_{15}:0)	5.84			
	Stearic acid	$C_{18}H_{36}O_2$ (C_{18}:0)	11.05			
	Margaric acid	$C_{17}H_{34}O_2$ (C_{17}:0)	3.69			
Avocado pulp	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	39.23	86.02	51.44	34.58
	Oleic acid	$C_{18}H_{34}O_2$ (C_{18}:1)	34.58			
	Pentadecylic	$C_{15}H_{30}O_2$ (C_{15}:1)	8.20			
	Stearic acid	$C_{18}H_{36}O_2$ (C_{18}:0)	4.01			
Avocado seed	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	32.54	100	32.54	67.46
	Linoleic acid	$C_{18}H_{32}O_2$ (C_{18}:2)	67.46			
Pili pulp	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	96.82	96.82	96.82	-
Pili nut seed	Palmitic acid	$C_{16}H_{32}O_2$ (C_{16}:0)	14.27	50.82	14.27	46.55
	Oleic acid	$C_{18}H_{34}O_2$ (C_{18}:1)	29.89			
	Linoleic acid	$C_{18}H_{32}O_2$ (C_{18}:2)	16.66			

Conclusions

This work has shown that all the samples investigated are very rich in fat and crude fibre but contain very little of other macronutrients apart from carbohydrates. The seed of pili nut is the highest reservoir of fats among all samples investigated. All samples analyzed contain rich amounts of phytochemicals with the avocados (both pulp and seed) containing significantly greater amounts of flavonoids and oxalates than the other species.

Although the samples are not very rich in protein, the little protein they do contain represents a good source of many amino acids especially the essential amino acids. The oils extracted from the seeds and pulps are also shown to contain several fatty acids. Avocado pulp, avocado seed and pili nut seed are particularly rich in unsaturated fatty acids which are believed to be beneficial for heart health.

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