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Full Length Research Paper

Studies on the chemical compositions and anti nutrients of some lesser known Nigeria fruits

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Fruit samples of *Cola millenii, Strychnos innocua, Bombax glabra, Artocarpus heterophyllus, Parkia biglobosa* and *Gardenia erubescens* were collected from various locations in Oyo and Osun States of Nigeria. The chemical compositions of these fruits were analyzed with a view to evaluating their levels of nutrient and anti-nutrients. The nutrients compositions of the fruits showed that the amount of crude fat ranged between 0.78 and 40.0 g/100 g; crude fibre, 1.23 – 14.57 g/100 g; crude protein, 4.54 - 34.1 g/100 g; ash, 1.79 - 6.10 g/100 g and carbohydrate, 7.88 - 72.67 g/100 g. Concentrations of iron, manganese and zinc were highest in *C. millenii* mesocarp; calcium and magnesium were highest in the yellowish pulp *of P. biglobosa* while potassium content was highest in *B. glabra* seed. *S. innocua* juice contained the highest amount of sodium while *G. erubescens* fruit contained the highest amount of copper. Ascorbic acid was highest in *C. millenii* mesocarp with a value of 953 mg/100 g; *S. innocua* juice contained highest levels of total sugar (168.49 mg/g) and reducing sugar (83.25 mg/g) while *C. millenii* seed contained highest amount of starch (739.38 mg/g). The results of anti-nutrient factors showed that tannin content ranged between 1.0 and 7.5 mg/g catechin equivalent. Phytate, oxalate and trypsin inhibitor ranged from 0.20 - 6.65 mg/g, 0.23 - 1.17 g /100 g, 9.64 - 58.2 TIU/g respectively. The fruit parts with low level of anti nutrient, high elemental composition, protein, lipid, carbohydrates and ascorbic acid could serve as supplementary sources of essential nutrient to man and livestock.

Key words: *Cola millenii*, *Strychnos innocua*, *Bombax glabra*, *Arthocarpus heterophyllus*, nutrients, anti-nutrients.

INTRODUCTION

In most developing countries like Nigeria, food shortage is becoming evident as a result of population growth, competition for fertile land and poverty (Sadik, 1991). In addition to these, restriction on the importation of certain foods has lead to up-surge in prices of available staples, unstable government policies on agriculture, lack of agricultural inputs, poor loan scheme and incentive are responsible for food shortage. The diet of many rural and urban dwellers is deficient in protein and high in carbohydrates, the implication is high incidence of malnutrition and increase dietary disease, a situation in which children and especially pregnant and lactating women are most vulnerable (Sadik, 1991). While every measure is being taken by various levels of government to boost food production by conventional agriculture, a lot interest is currently being focused on the possibilities of exploiting the vast numbers of less familiar plants resources of the wild (Anhwange et al., 2004; Abdullahi and Abdullahi, 2005).

Many of such plants have been identified, but lack of data on their chemical composition has limited the prospect of their utilization (Baumer, 1995). Many reports on some lesser known seeds and fruits indicate that they could be good sources of nutrient for both man and livestock (Elemo et al., 2002; Adekunle and Ogerinde, 2004).

In order to contribute to the growing body of knowledge on this subject, the present study analyzed 6 lesser known fruits from Oyo and Osun States of Nigeria, for their proximate composition, mineral elements, total su-

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gar, reducing sugar, starch content and various anti nutrients like tannin, phytate, oxalate and trypsin inhibitor.

MATERIALS AND METHODS

Collection of fruit samples

Fruit samples were collected from various locations in Oyo and Osun States of Nigeria. *Artocarpus heterophyllus* was collected in front of Agbala compound, beside Olayonu Hospital Ogbomoso, *Cola millenii* behind Department of Botany, Obafemi Awolowo University, Ile – Ife. *Strychnos innocua* was collected around kilometre 10, Igbeti Igboho road, *Bombax glabra,* in front of Animal Production and Health Laboratory, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso. *Parkia biglobosa* was collected from LAUTECH Staff School Compound, Ogbomoso, *Gardenia erubescens* at Budodera farm, Ago kere, Igboho.

Identification of samples

Fruits samples were identified by Mr A. A. Ademoriyo and authenticated by Mr B. O. Daramola of Herbarium, Department of Botany, Obafemi Awolowo University, Ile – Ife, Nigeria. Voucher specimens were deposited in the herbarium: *A. heterophyllus* Moraceae (13535), *B. glabra* Bombacaceae (15357), *C. millenii* K. Schum Sterculiaceae (15333), *G. erubescens* Rubiaceae (14609), *P. biglobosa* Mimosaceae (3356) and *S. innocua* Loganiaceae (13780).

Preparation of samples

A. heterophyllus fruits were removed from the ripe pod, diced into pieces, dried at 50^{o}C, pulverized with the aid of a ball grinder, stored in airtight plastic containers inside the refrigerator. *B. glabra* seeds were removed from the opened pod, shelled, dried at 50^{o}C and kept in airtight container. *C. millenii* seeds were removed from the pod and shelled. Both the seeds and mesocarp were dried separately at 50^{o}C, ground to powder with ball grinder, labelled as *C. millenii* seed and *C. millenii* mesocarp and stored in airtight containers in the refrigerator.

G. erubescens coat was peeled from the fruit, cut into pieces, dried at 50^{o}C, pulverized, stored in airtight container and kept in refrigerator. *P. biglobosa* pod was carefully opened, the yellowish pulp was scraped from the seed, dried at 50^{o}C and stored in airtight container labelled Parkia pulp and kept in refrigerator. The ripe hard shell of *S. innocua* was crushed. The fruit juice was squeezed inside plastic containers, labelled as S. *innocua* juice and kept in freezer. The seeds were oven dried, ground to powder with ball grinder stored in airtight container labelleled as S. *innocua* seed and kept in refrigerator.

Analytical procedure

Proximate analysis was determined by AOAC (1984) method. Carbo-hydrate was determined by difference while nitrogen was converted to protein by multiplying it by a factor of 6.25.

Mineral

Samples were digested as described earlier (Falade et al., 2003). Each sample (0.5 g) was weighed in triplicate into Kjeldahl flasks and 10 ml of conc. HNO_3 was added and allowed to stand over-night. The samples were then heated carefully until the production of brown nitrogen (IV) oxide fume has ceased. The flasks were cooled and (2-4 ml) of 70% perchloric acid was added. Heating was continued until the solutions turned colourless. The solutions were transferred into 50 ml standard flasks and diluted to mark with distilled water. The mineral content was then analyzed by Atomic absorption spectrophotometer (ALPHA 4 model, Fisons Chem-Tech, Analytical, UK).

Determination of carbohydrate components

Soluble sugar was extracted three times from 2 g samples with 80% ethanol using Soxhlet extractor and refluxed for 2 h as described by Bain-bridge et al. (1996). Reducing sugar was determined from the ethanolic extract by the ferricyanide method (AOAC, 1984). Two (2.0) ml extract and was added to 8.0 ml of the ferricyanide reagent and the absorbance read at 380 nm using glucose as the standard. The total sugar content of the samples was determined by hydrolyzing 25 ml of the sugar extracted above in 100 ml beaker using 5 ml concen-trated hydrochloric acid as described earlier (Bainbridge et al., 1996). Total sugar was then determined on 2 ml of the hydrolysate using ferricyanide method (AOAC, 1984). The starch content of the samples was determined on 200 mg residue of the ethanolic extract obtained above by refluxing the residue with 0.7 M HCl for 2.5 h (AOAC, 1984). The acid hydrolysate was neutralised, made up to volume in 500 ml standard flask with distilled water and then filtered through a Whatman No. 541 filter paper. The starch in the original sample was then determined as reducing sugar, using the ferricyanide method described above. The reducing sugar was then converted to starch content using the AOAC (1984) equation.

Ascorbic acid

Ascorbic acid was determined colorimetrically as described earlier (Falade et al., 2003), after the formation of the Osazone which was dissolved in 85% H_2S04 to give an orange-red coloured solution which was measured at 540 nm using a (GENESYS 10 UV spectro-photometer, Thermo Electron Corporation, England) and compared to a standard curve prepared from 0 – 100 mg per litre of ascorbic acid.

Anti-nutritional factors

Tannin was determined by the modified Vanillin–HCl method using 1.0 mg/ml of catechin in 1% HCl-MeOH as standard, the coloured substituted product was measured at 500 nm (Price et al., 1978). Phytate was determined by the anion exchange method as des-cribed by Harland and Oberlas (1986) using KH_2PO_4 as standard. Trypsin inhibitor was determined by the method of Kakade et al. (1974) as modified by Adewusi and Osuntogun (1991). A synthetic substrate (BAPNA) was subjected to hydrolysis by trypsin to pro-duce yellow coloured p-nitroanilide. The degree of inhibition by the extract was measured at 410 nm. Oxalate was determined titrimetrically as described earlier (Falade et al., 2004) by being pre-cipitated as calcium oxalate and titrated against standard potassium permanganate. The oxalate was calculated as sodium oxalate equivalent.

RESULTS AND DISCUSSION

The proximate compositions of the fruits samples were reported in Table 1. The moisture content ranged between 4.0 g/100 g for *P. biglobosa* pulp and 90.96 g/100 g for *S. innocua* juice. Some of the fruit parts have relatively high moisture content which is typical of fresh fruits at maturity (Umoh, 1998), while some have low

Table 1. Proximate compositions of the fruit parts (g/100g) dry weight.

	Moisture	Crude fat	Crude fibre	Crude protein	Ash	Carbohydrate
Arthocarpus heterophyllus seed	8.25 ± 0.10^{e}	6.10 ± 0.14^{e}	1.23 ± 0.03^{g}	14.02± 0.50^{b}	3.60 ± 0.06^{e}	68.03 ± 0.27^{b}
Bombax glabra seed	65.98± 0.22^{b}	10.78±0.21^{d}	12.01± 0.11^{c}	34.09± 0.94^{a}	7.86 ± 0.62^{a}	15.92 ± 0.92^{e}
Cola millenii seed	10.00 ± 0.01^{d}	40.0 ± 1.16^{a}	4.03 ± 0.01^{f}	9.19 ± 0.62^{c}	3.00 ± 1.41^{e}	37.81 ± 0.71^{c}
Cola millenii mesocarp	19.0 ± 1.41^{c}	37.0 ± 1.41^{b}	10.0 ± 0.62^{d}	7.44 ± 0.01^{d}	2.00 ± 0.01^{f}	34.56 ± 0.62^{d}
Gardenia erubescens fruit	19.15±0.14^{c}	1.54 ±0.20^{f}	14.57± 1.10^{a}	5.68 ± 0.01^{e}	2.94 ± 0.04^{e}	70.69 ± 0.22^{a}
Parkia biglobosa pulp	4.00 ± 0.22^{f}	18.0 ± 2.60^{c}	12.00± 1.20^{c}	5.25 ± 0.04^{e}	4.00 ± 0.10^{c}	68.75 ± 0.89^{b}
Strychnos innocua juice	90.96 ±0.20^{a}	0.78 ± 0.08^{f}	7.85 ± 0.67^{e}	7.85 ± 0.67^{d}	4.65 ± 0.33^{c}	7.88 ± 0.09^{f}
Strychnos innocua seed flour	8.93 ± 0.97$^{e\ d}$	1.67± 0.01^{f}	13.39±0.86^{b}	15.67±2.42^{b}	1.79±0.15^{f}	71.94±2.25^{a}

Mean ± standard deviation of triplicate determinations
Mean with the same superscripts in the same column are not significantly different at 5% probability level.

moisture content, which are within the acceptable range for a good keeping period. The relatively low moisture content is an indication that these fruits parts will have high shelf life especially when properly packaged against external conditions (Eka, 1987).

The crude fat ranged between 0.78 g/100 g for *S. innocua* juice and 40.0 g/100 g for *C. millenii* seed. Most of the fruit parts investigated have relatively high crude fat composition (6.10 g/100 g to 40.0 g /100 g ether extract). *S. innocua* juice and seed flour contain lower level of oil. Lipids are essential because they provide the body with maximum energy; approximately twice that for an equal amount of protein or carbohydrate and facilitate intestinal absorption and transportation of fat-soluble vitamins A, D, E and K (Dreon et al., 1990). Those with high lipid content are comparable with those of soybean oil, locust bean and cottonseed; 19.10 g/100 g, 20.30 g/100 g and 14.05 g/100 g crude fat, respectively. These are commercially exploited and classified as oil seed (Ayodele et al., 2000). This showed that some of these fruits are rich in oil and could be sources of edible vegetable oil if well annexed, hence could complement conventional vegetable oils, which are very expensive. The fruit parts most especially *A. heterophyllus* seed, *B. glabra* seed, *C. millenii* seed, *C. millenii* mesocarp, *P. biglobosa* pulp could also be sources of oil for soap and paint industries but the physicochemical properties of these oils must be ascertained. Those with low ether extract content are comparable to that of cereals like maize; 4.6 g/100 g and millet 4.0 g/100 g (Obioha, 1992). Although those with low oil content are relegated as a source of oil commercially, they can be recommended as part of weight reducing diets.

The crude protein concentration ranged between 4.54 g/100 g for *G. erubescens* fruit and 34.09 g/100 g for *B. glabra* seeds. Proteins are essential component of the diet needed for survival of animals and humans, their basic function in nutrition is to supply adequate amounts of required amino acids (Pugalenthi et al., 2004). Protein deficiency causes growth retardation, muscle wasting, ederna, abnormal swelling of the belly and collection of fluids in the body (Zarkada et al., 1997). The crude protein content of the *C. millenii* seed was 19% higher than *C. millenii* mesocarp. Unfortunately this is the part of the fruit usually thrown away as waste while the mesocarp is consumed. There was no significant difference in the crude protein content of *S. innocua* juice and seed flour. *B. glabra* seed however had the highest crude protein content.

The crude protein compares favourably with that of melon seed; 33. 8 g/100 g (Achinewu, 1983) and fall within the range of 21 – 34 g/100 g reported for cowpea (Adewusi and Falade, 1996). The high protein content may enhance growth and maintenance of tissue, and will no doubt complement protein from cereals and other plant foods that are known to be low in protein and can complement melon seed as a source of protein in the diet of Nigerians.

The crude fibre ranged between 1.23 g/100 g for *A. heterophyllus* seed and 14.57 g/100 g for *G. erubescens* fruit. Fibre helps in the maintenance of human health and has been known to reduce cholesterol level in the body. The low levels of fibre in *A. heterophyllus* seed flour and *C. millenii* seed flour may be desirable in their incorporation in weaning diets. Emphasis has been placed on the importance of keeping fibre intakes low in the nutrition of infants and pre-school children (Eromosele and Eromosele, 1993). High fibre levels in weaning diet can lead to irritation of the gut mucosa, reduced digestibility, vitamin and mineral availability. Those with high fibre content are desirable in adult diet. Fibre diets promote the wave-like contraction that move food through the intestine, high fibre food expands the inside walls of the colon, easing the passage of waste, thus making it an effective anti-constipation. It also lowers cholesterol level in the blood, reduce the risk of various cancers, bowel diseases and improve general health and well being. Presence of high crude fibre improves glucose tolerance and is beneficial in treating maturity on set diabetics (Eromosele and Eromosele, 1993) thus the incorporation of these fruits into human diets would increase the level of fiber intake and could be of tremendous benefit to the

Table 2. Concentrations of mineral elements in the fruits parts (mg/kg) by AAS.

	Ca	Mg	K	Na	Mn	Fe	Zn	Cu
Artocarpus heterophyllus seed	2281.15 ± 26.09^{f}	2201.10± 41.37^{g}	3418.55± 18.17^{b}	1009 ± 10.10^{f}	98.58 ± 2.40^{e}	197.95 ± 1.40^{c}	201.00 ± 1.42^{e}	72.85 ± 3.50^{b}
Bombax glabra seed	5620 ± 14.14^{d}	3665 ± 7.07^{e}	4895 ± 7.07^{a}	1540 ± 14.14^{c}	148.70 ± 0.85^{c}	390.15 ± 0.35^{e}	303.15 ± 2.90^{c}	78.98 ± 0.01^{b}
Cola millenii Seed	1681.35 ± 30.76^{h}	3934.01± 87.19^{d}	4776.90± 18.24^{a}	1387.90 ± 0.99d	100.20 ± 0.28^{e}	481.3 ± 1.41^{c}	319.05 ± 0.35^{c}	96.53 ± 0.66$^{a\ b}$
Cola millenii mesocarp	11696.92 ± 28.3^{a}	6916.7 ± 19.38^{b}	3458.95± 21.76^{b}	1834.16± 28.25^{a}	973.48 ± 60.26^{a}	1971.29 ±35.09^{a}	559.74 ± 34.22^{a}	65.71 ± 3.46^{b}
Gardenia erubescens fruit	9775 ± 25.00^{c}	4055 ± 63.63^{c}	4755 ± 7.07^{a}	1165 ± 50^{e}	123.70±0.85$^{e\ c\ d}$	472.60 ± 0.07^{c}	277.80 ± 2.90^{d}	113.7 ± 0.64^{b}
Parkia biglobosa pulp	11650 ± 70.71^{b}	7000 ± 10^{a}	3945 ± 7.07^{b}	1795 ± 8.00^{b}	661.56 ± 23.19^{b}	1814.50± 49.32^{a}	437.52 ± 10.47^{b}	447.48 ± 1.09^{a}
Strychnos innocua juice	5220 ±10.24^{e}	3618 ± 21.10^{e}	1930 ± 12.60^{c}	1810 ± 16.40$^{a\ b}$	136.05 ± 3.67^{e}	158.73 ± 4.50^{c}	119.04 ± 2.71^{f}	45.35 ± 0.05^{b}
Strychnos innocua seed	2094 ± 32.48^{g}	3228.1 ± 32.10^{f}	1809.65± 12.52^{c}	790.15 ± 14.64^{g}	118.50 ± 2.97^{c}	440.9 ± 0.85^{c}	317.95 ± 3.61^{c}	82.52 ± 0.06^{b}

Mean ± standard deviation of triplicate determinations
Mean with the same superscripts in the same column are not significantly different at 5% probability level

diabetic patients.

The ash content ranged between 1.79 g/100 g for *S. innocua* seed flour to 7.86 g/100 g for *B. glabra* seed. The percentage ash of the sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained. The ash content obtained is similar to a range of 1.63 g/100 g to 8.53 g/100 g in commonly consumed fruits (Oluyemi et al., 2006). Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development.

The total carbohydrate determined by difference ranged between 7.90 g/100 g for *S. innocua* juice to 71.94 g/100 g *S. innocua* seed flour. *A. heterophyllus, P. biglobosa* pulp*, G. erubescens* and *S. innocua* seed flour can be considered as a potential source of carbohydrate when compared to the content of conventional source like cereals, 72 – 90 g/100 g carbohydrate (Adewusi et al., 1995) and could be good supplements to scarce cereal grains as sources of energy in feed formulations. High carbohydrate content of feed is desirable; the deficiency causes depletion of body tissue (Barker, 1996). The carbohydrate content of *B. glabra* and *S. innocua* juice is low (7.9 to 15.92 g/100 g). Samples with low carbohydrate content might be ideal for diabetic and hypertensive patients requiring low sugar diets.

The concentrations of different mineral elements in the fruit samples determined by AAS were reported in Table 2. Calcium ranged between 1681 and 11650 mg/kg. *C. millenii* seed contained the lowest calcium concentration while *P. biglobosa* pulp the highest. The level in *P. biglobosa* pulp is higher than 7220 mg/kg calcium in pulp of grape fruit but similar to 11650 mg/kg calcium in grape fruit peel (Olaofe et al., 1990). Calcium help in regulation of muscle contractions transmit nerve impulses and help in bone formation (Cataldo et al., 1999). The recommended dietary allowance (RDA) for calcium is 800 mg/day (FNB, 1974), which means that about 68 g dry weight of *P. biglobosa* pulp would provide the RDA for calcium. This shows that these fruit parts could be a better source of calcium than some conventional fruits.

Magnesium ranged between 2201.10 and 7000 mg/kg. *A. heterophyllus* seed contained the lowest magnessium concentration while *P. biglobosa* pulp the highest. Magnesium plays a major role in relaxing muscles along the airway to the lung thus allowing asthma patients to breathe easier. It plays fundamental roles in most reac-tions involving phosphate transfer, believed to be essential in the structural stability of nucleic acid and intestinal absorption while deficiency of magnesium in man is responsible for severe diarrhea, migraines, hyper-tension, cardiomyopathy atheriosclerosis and stroke (Appel, 1999). About 0.15 g dry weight of *A. hetero-phyllus* seed and 0.05 g dry weight of *P. biglobosa* pulp would be required to meet the 320 mg/day RDA of magnesium.

Potassium ranged between 1810 and 4895 mg/kg. *S. innocua* seed contained the lowest potassium concentration while *B. glabra* seed the highest level. The concentration in *S. innocua* seed is close to concentration of 1680, 1520 and 2130 mg/kg potassium reported for grape fruit

Table 3. Levels of total sugar, reducing sugar, starch content and ascorbic acid in the fruit parts.

	Total sugar (mg/g)	Reducing sugar mg/g	Starch content mg/g	Ascorbic acid mg/100g
Artocarpus heterophyllus seed	45.31 ± 3.4[e]	20.85 ± 0.53[c]	532.5 ± 25.98[c]	151.76 ± 0.14[e]
Bombax glabra seed	54.13 ± 0.23[c]	10.54 ± 0.56[e]	149.63 ± 6.30[f]	69.92 ± 0.06[g]
Cola millenii seed	54.63 ± 0.01[c]	14.67 ± 0.18[d]	739.38± 12.40[a]	144.26 ± 0.52[f]
Cola millenii mesocarp	47.08 ± 1.22[d e]	4.63 ± 0.26[g]	123.25 ± 0.01[g]	953.33 ± 0.78[a]
Gardenia erubescens fruit	76.47 ± 2.08[b]	53.89 ± 0.64[b]	255.94 ± 16.88[e]	186.27 ± 0.07[g]
Parkia biglobosa pulp	50.67 ± 0.60[d c]	4.27 ± 0.96[g]	151.88 ± 7.95[f]	215.00 ± 0.71[c]
Strychnos innocua juice	168.49 ± 3.67[a]	83.25 ± 0.09[a]	585.01 ± 6.50[b]	274. 73 ± 0.49[b]
Strychnos innocua seed	16.47 ± 0.43[f]	8.24 ± 0.21[f]	461.25 ± 15.90[d]	30.96 ± 0.03[h]

Mean ± standard deviation of quadriplicate determinations
Mean with the same superscripts in the same column are not significantly different at 5% probability level.

juice, orange and pineapple pulp, respectively (Olaofe and Akogun, 1990). For RDA of 2000 mg/day potassium to be met a range of 2.04 g of *B. glabra* seed to 1.1 g of *S. innocua* seed would be required. Sodium ranged between 790 and 1834 mg/kg. *S. innocua* seed contained the lowest sodium while *S. innocua* juice had the highest sodium concentration. The range is similar to 1430 and 1580 mg/kg sodium reported for grape fruit juice and orange juice (Olaofe and Akogun, 1990). For RDA of 1.5 g/day of sodium to be attained 833 g of *S. innocua* juice will have to be consumed.

Manganese ranged between 98.56 and 973.48 mg /kg. *A. heterophyllus* seed contained the lowest manganese concentration while *C. millenii* seed coat the highest. The level of manganese in the seed and seed mesocarp is significantly different ($p < 0.05$). Manganese supports the immune system, regulates blood sugar levels and is involved in the production of energy and cell reproducetion. It works with vitamin K to support blood clotting. Working with the B- complex vitamins, manganese helps to control the effects of stress. Birth defects can possibly result when an expecting mother does not get enough of this important element (Anhawange, 2004).

Iron (Fe) ranged between 158.73 and 1971.29 mg/kg. *A. heterophyllus* seed contained the lowest Fe concentration and *C. millenii* seed mesocarp the highest. The high ascorbic acid concentration of the seed mesocarp might be a strong promoter of the iron, but whether this iron will be available or not is another question. Iron is said to be an important element in the diet of pregnant women, nursing mothers, infants convulsing patients and elderly to prevent anaemia and other related diseases (Oluyemi et al*.,* 2006). The recommended daily allowance of iron for men is 7 mg /day and 12 – 16 mg/day for women during pregnancy (NHMRC, 1991). For RDA of Fe to be provided by *A. heterophyllus* seed an adult men and women would have to ingest 44 and 100 g respectively, while ingestion of 3.5 and 8.0 g (for men and women, respectively) of *C. millenii* seed mesocarp would be required to meet the RDA.

Zinc (Zn) content ranged between 119.04 and 559.74 mg/kg. *S. innocua* juice contained the lowest concentration of Zn while *C. millenii* seed mesocarp the highest. Zinc is said to be an essential trace element for protein and nucleic acid synthesis and normal body development. It plays a central role in growth and development, vital during periods of rapid growth such as infancy, adolescence and during recovery from illness. Zinc defiency has been largely attributable to the high phytic acid content of diets leading to poor growth, impaired immunity, and increased morbidity from common infectious diseases and increased mortality (Melaku, 2005). All the fruits part investigated can supply the 12 mg/day RDA of zinc for men aged 19 – 64 years and woman 19 – 54 years of age (NHMRC, 1991). It would require ingestion of a range of 0.1 g of *S. innocua* juice to 0.02 g of *C. millenii* mesocarp to meet the daily requirement.

Copper (Cu) ranged between 39.48 and 113.70 mg/kg. *P. biglobosa* pulp contained the lowest Cu concentration and *G. erubescens* fruit the highest. Deficiencies of copper have been reported to cause cardiovascular disorders as well as anaemia and disorders of the bone and nervous systems (Mielcarz et al., 1997). According to Reddy and Love (1999), these essential elements are needed for growth, production of bones, teeth, hair, blood, nerves, skin, vitamins, enzymes and hormones. The healthy function of nervous transmission, blood circulation, fluid regulation, cellular integrity, energy production and muscle contraction are influenced by essential elements and too little of any essential element can lead to deficiency disease and too much of any can be toxic (Schauss, 1995).

Chromium, lead, cadmium, cobalt, mercury, aluminium, thorium, and arsenic were not detected in the fruit samples by AAS.

The different carbohydrate constituents were reported in Table 3. The total sugar content ranges between 16.47 and 168.49 mg/g. The lowest total sugar content was recorded in *S. innocua* seed but highest in *S. innocua* juice. The difference in total sugar in the fruit juice is significantly different from other fruit part investigated. The total sugar content in *C. millenii* mesocarp and *A.*

Table 4. Levels of anti nutritional factors in the fruit samples.

	Tannin mg/g	Trypsin inhibitor unit TIU/g	Phytate mg/g	Oxalate g/100g
Artocarpus heterophyllus seed	1.08 ± 0.03^{b}	44.17 ± 1.26^{b}	$0.55 \pm 0.10^{c\,d}$	0.23 ± 0.01^{d}
Bombax glabra seed	1.20 ± 0.01^{b}	17.86 ± 0.57^{c}	$0.54 \pm 0.04^{c\,d}$	0.46 ± 0.01^{c}
Cola millenii Seed	1.27 ± 0.06^{b}	14.86 ± 0.12^{e}	3.90 ± 0.30^{b}	0.56 ± 0.14^{c}
Cola millenii mesocarp	1.33 ± 0.06^{b}	9.64 ± 0.32^{g}	$0.38 \pm 0.02^{c\,d}$	0.25 ± 0.10^{d}
Gardenia erubsecens fruit	7.5 ± 0.71^{a}	16.5 ± 0.54^{d}	0.24 ± 0.02^{d}	1.10 ± 0.10^{a}
Parkia biglobosa pulp	1.08 ± 0.20^{b}	15.55 ± 1.10^{e}	0.20 ± 0.05^{d}	0.93 ± 0.10^{b}
Strychnos innocua juice	1.01 ± 0.01^{b}	10.12 ± 0.22^{f}	0.72 ± 0.02^{c}	1.17 ± 0.10^{a}
Strychnos innocua Seed	1.12 ± 0.05^{b}	58.2 ± 1.60^{a}	6.65 ± 0.60^{a}	0.31 ± 0.01^{d}

Mean $\pm$ S.D. of triplicate determinations.
Mean with the same superscripts in the same column are not significantly different at 5%

heterophyllus seed is closer to 50 mg/g total sugar reported in the core of bread fruit from Nigeria while the levels in *C. millenii* seed flour, *B. glabra* and *P. biglobosa* pulp is slightly higher (Adewusi et al., 1995). The reducing sugar ranged between 4.27 and 83.25 mg/g. *P. biglobosa* pulp contained the lowest reducing sugar while *S. innocua* juice the highest reducing sugar. The reducing sugar content in a carbohydrate sources is partly responsible for browning as a result of Maillard reaction between the reducing sugar and the protein content of the sample. Mailard reaction might not pose any problem in those samples with low level of both protein and reducing sugar (Adewusi et al., 1995).

The starch content ranged between 123.25 and 739.38 mg/g. The starch content in *P. biglobosa* pulp and *B. glabra* are not significantly different. *C. milleni* mesocarp contained lowest level of starch while *C. millenii* seed the highest level of starch content among the fruit parts investigated. The starch content of *C. milleni* seed compared favourably with 720 mg/g starch in breadfruit pulp in Brazil (Peter and Wills, 1956), 770 mg/g breadfruit pulp in Nigeria and higher than 563 mg/g and 519 mg/g starch in peel and core of Nigeria breadfruit, respectively (Akpoborie et al., 2003). Also compared to conventional sources of calorie like yam (709 mg/g), cassava (884 g/g) (McArthur and D'Appolonia, 1979) and green banana pulp (780 mg/g) (Erdman, 1986). *C. millenii* seed can be considered as a good source of starch. The high level of starch content could be explored as source of refined starch as binder in pharmaceutical industries.

Ascorbic acid is important water-soluble vitamin already implicated in most of the life processes but principally functions as an antioxidant. It is present abundantly in fruits and vegetables where the common man in the developing countries receives most of their daily intake (Falade et al., 2004). The ascorbic acid content of the fruits parts ranged between 31 mg/100 g for *S. innocua* seed and 953 mg/100 g for *C. millenii* mesocarp. There exists a significant difference between the ascorbic acid of the *C. millenii* mesocarp and that of the *C. millenii* seed as well as *S. innocua* seed and *S. innocua* juice. This is in close agreement with Thomas and Oke's (1980) observation that the peel of mangoes contained 2 to six times as much vitamin C than their pulp. The relatively high amount of ascorbic acid in the *C. millenii* mesocarp compared to other fruits part may be due to its acidity arising from the sour taste, since ascorbic acid occur more in acidic medium than at high pH values (Mapson, 1970). The *C. millenii* mesocarp may then enhance absorption of non-heme iron. The values of the ascorbic acid reported for the fruits except the *S. innocua* seeds were however higher than those recorded in lime *(Citrus aurantifolia*; 46.5 mg/100 g edible portion), pawpaw (*Carica papaya*; 43.2 mg/100 g edible portion), lemon (*Citrus limon*; 35.2 mg /100 g edible portion), pineapple (*Ananas comosus*; 25.2 mg/100 g edible portion), and sweet banana (*Musa paradisiaca*) species and "agbalumo" (*Chrysophyllum albidum*) with 48.0 mg/100 g edible portion (Okegbile et al., 1990). The values reported were however similar to a range of 60.3 to 403.3 mg/100 g ascorbic acid reported for some wild fruits; *Ximenia americana* wild olive and *Sclerocarya birrea* Dineygarma (Eromosele et al., 1991). The recommended daily intake (RDI) for ascorbic acid [30 mg/day for healthy women and 40 mg/day for men (NHMRC, 1991)] can be supplied by 20 g of *P. biglobosa* pulp, *S. innocua* juice and *G. erubescens* fruit usually consumed uncooked. Whereas less than 6 g of these raw fruit parts can supply a daily intake of less than l0 mg of ascorbic acid needed in a human diet to prevent the onset of scurvy (Okegbile et al., 1990).

The levels of the anti-nutritional factors were reported in Table 4. Tannin ranged between 1.0 to 7.5 mg/g in the studied samples. The values were not significantly different except for *G. erubescens* fruit. Tannin in fruits imports an astringent taste that affects palatability, reduce food intake and consequently body growth. Tannins are known to inhibit the activities of digestive enzymes and nutritional effects of tannin are mainly related to their interaction with protein. Tannin protein complexes are insoluble and the protein digestibility is decreased (Carnovale et al., 1991).

The values reported were low to be of any nutritional importance except for *G. erubescens* fruit that recorded the highest value. The value was however low when compared to 13.3, 19.1 and 99.2 g/kg tannin reported for cashewnut, fluted pumpkin and raw breadnut, respectively (Fagbemi et al., 2005). Studies on rats, chicks and livestock revealed that high tannin in diet adversely affects digestibility of proteins and carbohydrates, thereby reducing growth, feeding efficiency, metabolizable energy and biovailability of amino acids (Aletor, 1993). From medicinal point of view, polyphenol to which tannin belongs has been reported to act as antioxidant by preventing oxidative stress that causes diseases such as coronary heart disease, some types of cancer and inflammation (Tapiero et al*.,* 2002). This shows that fruit like *G. erubescens* is likely to have antioxidant activity.

Phytate ranged between 0.20 and 6.65 mg/g. The values reprted fall within the level of phytate in Thailand fruits commonly consumed by diabetic patients; longan, 0.37 mg/g, dragon 0.39 mg/g, durian 0.51 mg/g, guava 0.8 mg/g, mango 0.86 mg/g and pineapple 0.90 mg/g (Suree et al*.,* 2004). The problem with phytic acid in foods is that it can bind some essential minerals nutrients in the digestive tract and can result in mineral deficiencies. There was a significant difference ($P < 0.05$) in the phytate composition of these fruit parts. The level is however low and might not pose any health hazard when compared to a phytate diet of 10 – 60 mg/g if consumed over a long period of time that has been reported to decrease bioavailability of minerals in monogastric animals (Thompson, 1993). Phytic acid also binds to phosphorus and converts it to phytate, while other mineral elements like calcium, zinc manganese, iron and magnesium are converted to the phytic complexes, which are indigestible substance, thereby decreasing the bioavailability of these elements for absorption. Phytic acids also have a negative effect on amino acid digestibility, thereby posing problem to non-ruminant animals due to insufficient amount of intrinsic phytase necessary to hydrolyze the phytic acid complex, but the presence is also beneficiary because it may have a positive nutritional role as an anti oxidant and anti cancer agent (Turner et al., 2002).

Trypsin inhibitor unit ranged between 9.64 for *C. millenii* mesocarp to 58.2 TIU/g for *S. innocua*. *C. millenii* mesocarp, *S. innocua* juice, *G. erubescens* fruit and *P. biglobosa* pulp are usually consumed uncooked. The presence of trypsin inhibitor in uncooked animal feed has long been known to cause diminished growth in rats, chickens and other experimental animals (Liener and Kakade 1980). However this is low when compared to a range of 15000 to 23000 TIU/g and 6700 to 23300 TIU/g reported for *Phaseolus vulgaris* and cowpea, respectively (Elias et al., 1979, Adewusi and Osuntogun, 1991). Typsin inhibitor is heat labile and can be inactivated by heat treatment such as steaming and extrusion cooking (Liener, 1994). The level of trypsin inhibitor in raw *A. heterophyllus* and *C. millenii* seed might be destroyed by boiling, baking or roasting.

Oxalate is a concern because of its negative effect on mineral availability. High oxalate diet can increase the risk of renal calcium absorption and has been implicated as a source of kidney stones (Chai and Liebman, 2004). Oxalate ranged between 0.23 for *A. heterophyllus* seed and 1.17 g/100 g for *S. innocua* juice. The levels of oxalate in the different fruit part is similar to 0.33 g/100 g oxalate in orange pulp, 0.28 g/100 g in okro, 0.99 g/100 g in red pepper and 1.31 g/100 g in tangarine pulp (Munro and Bassir, 1989). The levels of oxalate in the studied fruits might not play important role in their nutritive values. The highest oxalate level of 1.17 g/100 g in *S. innocua* juice would require ingestion of 3.85 kg dry matter to provide the 45 g reported to be toxic to mature sheep (Muhammed et al., 2002). Munro and Bassir (1989) have revealed that the possibility of oxalate poisoning in Nigeria from consumption of local fruits and vegetables is as remote as it is in other parts of the world. Spinach that recorded 19.72 g/100 g oxalate can only be hazardous if there is calcium oxalate interaction in the body.

Conclusion

The data reported show that the various fruits part are rich in nutrients and can serve as potential sources of food nutrient for man and livestock. The low level of anti-nutrients and high level of ascorbic acid may enhance mineral availability in composite meals. Further study is however needed to determine the digestibility and bioavailability of these plant foods.

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