Comparative Study on the Nutritional Properties of *Citrullus colocynthis, Irvingia gabonensis* and *I. wombolu* Seeds

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ABSTRACT

***Background**: The effects of malnutrition due to food insecurity demand continuous and urgent efforts to salvage the situations. There are needs to compare the nutritional and anti-nutritional status of edible plant materials commonly used to help consumers make a scientific-based informed decision.*

***Objective**: to determine and compare the nutritional and anti-nutritional contents of three seeds - Citrullus colocynthis, Irvingia gabonensis and I. wombolu.*

***Materials and methods:** The seeds sourced from Nsukka Market and were analyzed for mineral, proximate, vitamin and anti-nutrient compositions using standard protocols.*

***Results**: The concentration of sodium, copper, magnesium, zinc and phosphorous were higher in C. colocynthis seed compared to Irvingia species. I. wombolu had the highest calcium, and potassium contents. I. gabonensis had the highest iron content. C. colocynthis had the highest protein content, while the two Irvingia seeds had higher total fats, fatty acids, and calorific values compared to C. colocynthis seed. Vitamin C, in C. colocynthis was the least total vitamin content and the least antinutrient.*

***Conclusion:** This study demonstrates that seeds of Citrullus colocynthis, Irvingia gabonensis and I. wombolu are rich in nutritive factors, in varying proportions, and are low in antinutrient contents. With the results of this comparative study, consumers are therefore encouraged to make evidence-based decision on the choice of the seed to consume in line with their nutritional and health needs.*

Keywords: Nutritional Contents; Antinutrient Factors; *Citrullus Colocynthis; Irvingia Gabonensis; Irvingia Wombolu*

INTRODUCTION

Malnutrition is one of the public health challenges facing most underdeveloped countries in the world. In addition, consumers are faced with several dilemmas in making choices of edible food materials especially in regions where there are varieties of such foods. In Africa and Asia, plant seeds are employed in making delicacies where they act as thickeners and spices among others. Among the seeds prevalently used for making soups are *Citrullus colocynthis, Irvingia gabonensis,* and *I. wombolu* seeds. *C. colocynthis* is a member of Cucurbitaceae that is made up of about 100 genera and 750 species (1). It is commonly called Bitter Apple, Colocynth, Bitter Cucumber and vine of Sodom in English, *Egunsi* in Yoruba, *Elili/Egwusi* in Ibo and *Egbsi/Guna* in Hausa (2). It is commonly cultivated in the desert regions of North Africa, Western Asia, Middle East, West Africa (Nigeria, Ghana, Togo, and Benin) and other African countries (3). It is a non-hardy, herbaceous perennial plant, that can propagate both vegetatively and generatively (4). The fruit is characterized by a thin and hard rind, and soft white pulp filled with compressed smooth ovoid-shaped seeds whose colour range from yellowish-orange to dark brown (5). The plant is traditionally used in the treatment of common ailments such as diabetes, common cold, constipation, leprosy and asthma, amongst others (3). Other pharmacological properties include anti-inflammatory, antibacterial, antioxidant, analgesic, hypoglycemic and hypolipidemic activities (5).

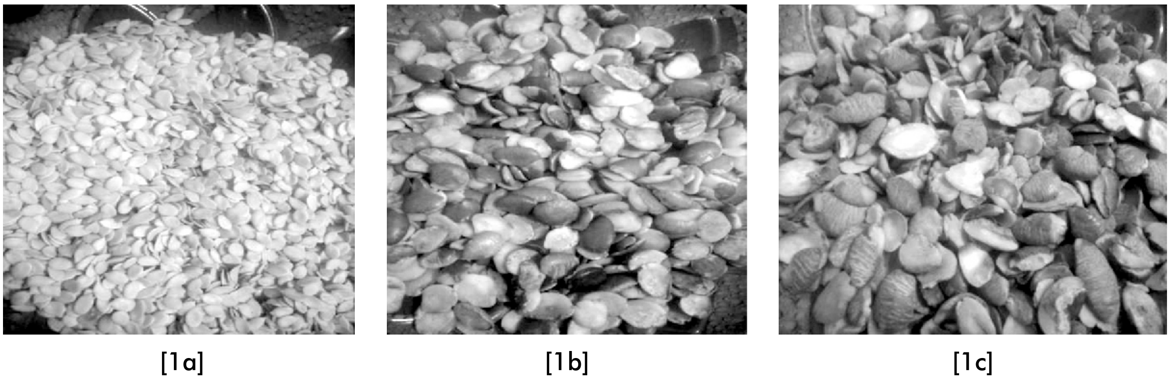
On the other hand, *Irvingia gabonensis* and *I. wombolu* belong to the family Irvingiaceae, an important tropical, non-timber forest products popularly grown for their fruits and seeds. They are widely distributed in West and Central Africa and are commonly called bush mango, wild mango, Dika nut and African wild mango in English (6-7), *Ogbono* in Igbo, *Mbukpabuyo* in Efik and Ibibio, *Aapon* in Yoruba, *Ogwi* in Benin, *Apioro* in Delta and *Goronor* in Hausa languages (8-9).

Before 1975, *Irvingia gabonensis* and *I. wombolu* were both classified as one species of *Irvingia*. Okafor (10) distinguished them and described *I. gabonensis* ver. Gabonensis (the species that have a sweet/forcet edible pulp) while *I. gabonensis* ver. Excel (the species that have a bitter edible pulp). *Irvingia gabonensis* ver. Excel was later named *I. wombolu*. *Irvingia* fruits resemble that of cultivated mango hence the name 'bush mango'. The fruit is a drupe, broadly ellipsoid and a little flat. The fruit has one large seed that is covered by a hard seed coat which when broken reveals the white cotyledon that is wrapped in a brown testa. The fruit is green but becomes yellow when ripe, but vary between the two species. *I. wombolu* is darker green than *I. gabonensis* (11-12). *Irvingia gabonensis* and *I. wombolu* are similar which makes it difficult to distinguish. Meanwhile, several characteristics for distinguishing them include; fruit of *I. wombolu* is usually smaller in size, bitter and not edible like fruit mesocarp of *I. gabonensis* (13). The fruits and seeds of *I. gabonensis* and *I. wombolu* are known to be rich in nutritional factors, valued especially for their fat and protein contents (14). The sweet fruit pulp of *I. gabonensis* is used industrially in the production of juice, jelly, wine, and jam (12). The seeds have the ability to form gels at a lower concentration than many oilseed flours; hence, they are used as thickeners in food and pharmaceutical industries (15). The oil/fat from the seeds are extracted and its full potential used industrially in making cooking oil, margarine, perfume, cosmetics, soap and pharmaceuticals (16). They are used as a thickening agent in the preparation of "ogbono" soup, a very common food in the Southern part of Nigeria. *I. wombolu* is preferred to *I. gabonensis* in making soup because of its consistent slimy nature. *Irvingia* kernels can be made into cake called 'dikanut' has been studied and used as a dietary fiber for reducing the hyperglycemic effects and lipid metabolism disruption caused by diabetes mellitus (9). The present study was designed to detect, quantify and compare the compositions of nutritional and anti-nutritional factors in three edible seeds (*Citrullus colocynthis, Irvingia gabonensis* and *I. wombolu*) sourced from Nsukka area.

Materials and methods

Sourcing and processing of the plant materials

Dried seeds of *Citrullus colocynthis* (Fig 1a), *Irvingia gabonensis* (Fig 1b) and *I. wombolu* (Fig 1c) were purchased from local farmers at Nsukka Market of Enugu State, Nigeria. The seeds were authenticated at the Department of Crop Science, University of Nigeria, Nsukka, homogenized and subjected to mineral, proximate, vitamin and antinutrient analyses.



[1a] [1b] [1c]

Figure 1: Images of the seed samples used for the study

Analytical protocols

The determination of the nutritive and anti-nutritive contents of the seed homogenates was done using standard methods. The moisture, ash and carbohydrate, and antinutrient compositions of the homogenized seed samples were determined by AOAC (17) method while crude protein, fiber and fat contents were determined using Pearson (18) method. The mineral composition of the three seeds were determined using atomic absorption spectrometry, flame photometry and spectrophotometry according to the AOAC (19) method as earlier described (20). The vitamin contents of the samples were evaluated by AOAC (21) method while the antinutrient contents were determined using the AOAC (22) methods. Each analysis was carried out in triplicates. The study adopted the method of Maclean *et al*. (23) for the calculation of energy values of the seeds as shown in the relation below:

Energy value (KJ/100g) = (17 x % carbohydrate + 17 x % protein + 37 x % fat)

Where; 17 and 37 are constants of proportionality

Statistical analysis

Data were analyzed using one-way analysis of variance in Statistical Product and Service Solutions (SPSS) for PC, Version 18, SPSS Inc., Chicago). Secondary data were reported as mean ± standard deviation (SD) and presented in Tables. Means with $p < 0.05$ were considered significant.

Results and discussion

Mineral contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

The mineral contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds respectively yielded 1571.83, 6357.15, 7325.77 mg/Kg calcium, 17.09, 11.83, 13.21 mg/Kg copper, 233.61, 243.33, 194.80 mg/Kg iron, 62.89, 60.93, 75.83 mg/Kg potassium, 36.84, 18.65, 11.99 mg/Kg magnesium, 45.42, 40.21, 41.26 mg/Kg sodium, 22.88, 20.46, 18.39 mg/Kg zinc and 7.80, 25.10 and 28.6 mg/Kg phosphorus. The NA/K values were 0.72, 0.66 and 0.54 for *C. colocynthis, I. gabonensis* and *I. wombolu* seeds, respectively (Table 1). Calcium is most abundant mineral in all the three seeds while phosphorus is the least abundant mineral. This result agrees with the report of Onojah *et al*. (12) and Adam *et al*. (24) that calcium is the most abundant mineral in the seeds of Irvingia with values of 89.3 ± 1.61 mg/100g in *I. wombolu* and 115.1 ± 2.72 mg/100g in *I. gabonensis* but having the least values of 0.04 ± 0.1 mg/100g and 0.02 ± 0.0002 mg/100g for zinc while seeds of *C. colocynthis* had calcium and phosphorus values of 211.0 mg/100g and 16.0 mg/100g respectively. Result of the present study contradicted the report of Ndamitso *et al*. (25) that magnesium is the most abundant mineral in *I. gabonensis* with value of 1700.03 ± 1.02 mg/100g compared to calcium with 15.06 ± 0.13 mg/100g. The least abundant mineral in this report is phosphorus with *C. colocynthis* having the least. This is in contrast to the previous report that iron is the least abundant mineral in agricultural products (12,24). Ndamitso *et al*. (25) reported manganese to be the least abundant mineral in *I. gabonensis* seeds and A. *esculentus* pods with a value of 0.84 and 1.20 mg/kg. *I. wombolu* has more calcium, potassium and phosphorus than *C. colocynthis* and *I. gabonensis*. Calcium, phosphorous and magnesium are essential for bone formation for children since the deficiency of these minerals can lead to abnormal bone development. In addition, phosphorus is also a major constituent of bones, teeth and ATP. Magnesium acts as an activator/cofactor of many enzyme systems and maintains the electrical potential in nerves (26). Hence, the consumption of diets made with *I. wombolu* seeds will help in bone formation more than that made with seeds of *C. colocynthis* and *I. gabonensis*. *C. colocynthis* has more copper, magnesium, sodium and zinc as stated earlier than *I. wombolu* and *I. gabonensis*. Ndamitso *et al*. (25) reported a copper content of 3.02 ± 0.12 mg/kg in seeds of *I. gabonensis* while Taiwo *et al*. (27) reported copper content of 0.33 ± 0.04 mg/100 g in *C. citrullus* seeds. On the other hand, Onojah *et al*. (12) reported very low levels of 0.02 ± 0.003 mg/100g and 0.03 ± 0.004 mg/100g for copper in *I. gabonensis* and *I. wombolu*. Zinc is a cofactor for dehydrogenases, phosphatases, superoxide dismutase, reductase and polymerases (DNA and RNA polymerases) (28). *I. gabonensis* contains more iron than *I. wombolu* and *C. colocynthis*; hence, the consumption of diet rich in *I. gabonensis* seeds will be more ideal for anaemic condition than the other two seeds. Iron plays an important role in the formation of blood and helps in the maintenance and functionality of central nervous system. Magnesium, zinc, copper, and iron serve as cofactors of various enzymes; magnesium is a cofactor in carboxylases, oxidases and kinases. Copper is a cofactor in enzymes such as cytochrome C oxidases and catalases among others (24). Seeds of *C. colocynthis* have more sodium content than *I. gabonensis* and *I. wombolu* seeds while seeds of *I. wombolu* have higher potassium content than seeds of *C. colocynthis* and *I. gabonensis*. Sodium and potassium have homeostatic roles to regulate the internal environment. Diets with Na/K ratio of less than one are recommended for the prevention of high blood pressure. The Na/K ratios of *Citrullus colocynthis, Irvingia gabonensis* and *Irvingia wombolu* seeds from this study were 0.72, 0.66 and 0.54, respectively, which are within the recommended values. Sodium and potassium are important in the maintenance of osmotic balance of the body fluids, regulation of muscles and nerves irritability and control glucose absorption (12). Chromium may be required to maintain glucose balance in organisms. Cadmium and lead are toxic heavy metals of great concern; cadmium is known to inhibit antioxidant enzymes and may lead to oxidative stress. Cadmium is toxic to the liver, kidney, testis, heart, bone, eye and brain while lead and mercury are known carcinogenic agents (28). The absence of these three heavy metals in the seeds shows that the seeds are relatively safe for human consumption.

Proximate composition of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

The three seeds analyzed contain a reasonable amount of protein, fat, ash, moisture, crude fiber and carbohydrate. The total fat contents of the three seeds are higher than the rest of the proximate content (Table 2). This agreed with the work of Ogunsina *et al*. (11), Onojah *et al*. (12), Adam *et al*. (24) and Onimawo (29) that reported high crude fat content in *I. gabonensis* and *I. wombolu*. Ndamitso *et al*. (25) reported higher carbohydrate in *I. gabonensis* which is not consistent with this work. The fat contents in *I. gabonensis* and *I. wombolu* are higher than that of *C. colocynthis,* making the *Irvingia* seeds potential source of vegetable oil for both domestic and industrial uses. With the high amount of crude fat content (52.48± 1.84%) present in the seeds of *C. colocynthis* as reported by Adam *et al*. (24) and 36.27 ± 0.31 % obtained in the seeds of *C. colocynthis* in this study, the seeds of *C. colocynthis* could also be regarded as an oil seed (30). *C. colocynthis* contains a higher percentage of protein (20.46%) than *I. gabonensis* and *I. wombolu* (6.07 and 6.30%, respectively). This low value of protein in the *Irvingia species* as compared to *C. colocynthis,* and soybean and cowpeas whose protein contents ranges between 23 and 33.0% (30), does not qualify them as protein-rich plant food. Moisture was higher in *C. colocynthis* (11.07%), followed by *I. wombolu* (9.93%) then *I. gabonensis* (4.07%). Non-oil plant materials with low moisture contents have longer shelf life (12), thus *C. colocynthis* will have a faster spoilage rate than *I. gabonensis* and *I. wombolu*. The ash contents in the three seeds are relatively lower compared with that of *C. colocynthis*, and are close to the levels reports by Ndamitso *et al*. (25)

Table 1: Mineral contents of *Citrullus colocynthis, Irvingia gabonensis* and *Irvingia wombolu* seeds

Mineral	*Citrullus colocynthis*	*Irvingia gabonensis*	*Irvingia wombolu*
Calcium (mg/Kg)	1571.83^{a}	6357.15^{b}	7325.77^{c}
Copper (mg/Kg)	17.09^{c}	11.83^{a}	13.21^{b}
Iron (mg/Kg)	233.61^{b}	243.33^{c}	194.80^{a}
Potassium (mg/Kg)	62.89^{b}	60.93^{a}	75.83^{c}
Magnesium (mg/Kg)	36.84^{c}	18.65^{b}	11.99^{a}
Sodium (mg/Kg)	45.42^{b}	40.21^{a}	41.26^{a}
Zinc (mg/Kg)	22.88^{c}	20.46^{b}	18.39^{a}
Phosphorus (mg/100g)	7.80^{a}	25.10^{b}	28.6^{c}
Na/K	0.72^{c}	0.66^{b}	0.54^{a}
Cadmium	ND	ND	ND
Lead	ND	ND	ND
Mercury	ND	ND	ND

Data represent the result of a single determination. Values with different letters of the alphabets as superscripts in a row are significant at $p < 0.05$. ND = not detected (levels are below detectable limit of the machine used) and Onimawo (29). The three seeds contained reasonable amount of carbohydrate with *C. colocynthis* having the highest carbohydrate content of 20.27 ± 0.99% followed by *I. wombolu* (14.60 ± 1.81%) and *I. gabonensis* (20.06 ± 1.24%) being the least. The fiber contents of the three seeds were relatively low; *C. colocynthis* (3.82%), *I. gabonensis* (5.54%) and *I. wombolu* (5.88%) (Table 2). These results are lower than the crude fiber contents of *I. wombolu* (8.69%) and *I. gabonensis* (10.4%) reported by Onojah *et al*. (12) but higher than the fiber content of *C. colocynthis* (2.3%) reported by Adam *et al*. (24). Dietary fibers are known to improve bowel function and combine with intestinal cholesterol for excretion in the faeces (12). Intake of dietary fiber has been linked with lower cholesterol level and reduced risk to coronary heart disease, hypertension, diabetes and breast cancer (31). The metabolizable energy values (the energy available for growth and supporting metabolic processes) of *I. gabonensis* seeds (537.10 Kcal/100g) were significantly ($p < 0.05$) higher than *C. colocynthis* (486.23 Kcal/100g) and *I. wombolu* (488.79 Kcal/100g) seeds. The energy value of *C. colocynthis* is comparable to the value (592.85 Kcal/100g) reported by Jacob *et al.* (32) on *Citrullus lanatus* seeds. The results are lower than the metabolizable energy values of *I. wombolu* (616.25 Kcal/100g) and *I. gabonensis* (616.25 Kcal/100g) seeds by Onojah et al. (12) but higher than the values reported in *I. gabonensis* seeds (499.29 Kcal/100g) by Ndamitso *et al*. (25). These results showed that the seeds have good nutritional values with *I. gabonensis* seeds having the highest calorific values than other seeds studied. Similarly, *I. gabonensis* seeds have the highest total fat content, followed by *I. wombolu* seeds and then *C. colocynthis* seeds. This result is lower than the total fatty acid content in *I. wombolu* (43.0%) and *I. gabonensis* (47.0%) seeds as reported by Onojah *et al.* (12). Table 2: Proximate contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds .

Vitamin contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

The vitamin content reveals that the three seeds contain vitamins A, B_6, B_{12}, C, D and E in different proportions. Fat-soluble vitamins A, D and E were relatively low in the three seeds (Table 3). *C. colocynthis* has the highest amount of vitamin A (8.53 ± 2.11 µg/g) than *I. gabonensis* (6.26 ± 0.21 µg/g) and *I. wombolu* (6.21 ± 0.49 µg/g) but has a lower amount of vitamins D (4.47 ± 0.42 mg/100g) and E (11.24 ± 0.06 mg/100g). *I. gabonensis* has a higher amount of vitamin E (37.98 ± 0.59 mg/100g), while *I. wombolu* has a higher amount of vitamin D (7.96 ± 0.12 mg/100g). Due to their fat soluble nature, vitamins A, D, E and K have higher tendency of accumulating in the body, leading to hypervitaminosis compared to water-soluble vitamins (33-34). Vitamin C was more in the three seeds. Vitamin C is higher in *C. colocynthis* than in *I. wombolu* and *I. gabonensis*. Vitamins B_6 and B_{12} are higher in *I. gabonensis*, followed by *I. wombolu* then *C. colocynthis*. Vitamin C is an antioxidant while vitamin B_{12} helps in blood clotting. Table 3: Some vitamin contents of *Citrullus colocynthis, Irvingia gabonensis* and *Irvingia wombolu* seeds

Proximate content (%)	*Citrullus colocynthis*	*Irvingia gabonensis*	*Irvingia wombolu*
Protein	20.46 ± 2.48^b	6.07 ± 0.52^a	6.30 ± 0.31^a
Total fats	36.27 ± 0.31^a	48.73 ± 0.12^c	45.67 ± 0.12^b
Total fatty acids	29.02 ± 0.25^a	38.98 ± 0.10^c	36.54 ± 0.10^b
Ash	3.13 ± 0.23^b	2.33 ± 0.12^a	2.53 ± 0.12^1
Moisture	11.07 ± 0.31^c	4.07 ± 0.31^a	9.93 ± 0.31^b
Fiber	3.82 ± 0.15^a	5.54 ± 0.07^b	5.88 ± 0.10^c
Carbohydrates	20.27 ± 0.99^b	20.06 ± 1.24^b	14.60 ± 1.81^a
Metabolizable energy values (KJ/100g)	2,034.4^a	2,247.22^b	2,045.09^a
Metabolizable energy values	486.23^a	537.10^b	488.79^a

Data represent mean ± SD of triplicate determination. Values with different letters of the alphabets as superscripts in a row are significant at $p < 0.05$. Total fatty acid content (%) was calculated as 0.8 x total fats content

Vitamin content	*Citrullus colocynthis*	*Irvingia gabonensis*	*Irvingia wombolu*
Vitamin A (μg/g)	8.53 ± 2.11^{a}	6.26 ± 0.21^{a}	6.21 ± 0.49^{a}
Vitamin B6 (μg/g)	19.43 ± 0.15^{a}	24.83 ± 0.21^{c}	22.53 ± 0.50^{b}
Vitamin B12 (μg/g)	8.57 ± 0.18^{a}	10.22 ± 0.18^{b}	9.90 ± 0.13^{b}
Vitamin C (mg/100g)	85.85 ± 4.11^{c}	71.46 ± 1.59^{b}	60.45 ± 2.03^{a}
Vitamin D (mg/100g)	4.47 ± 0.42^{a}	6.87 ± 0.06^{b}	7.96 ± 0.12^{c}
Vitamin E (mg/100g)	11.24 ± 0.06^{a}	37.98 ± 0.59^{b}	37.45 ± 1.02^{b}

Data represent mean ± SD of triplicate determination. Values with different letters of the alphabets as superscripts in a row are significant at $p < 0.05$.

Anti-nutrient contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

The results on the antinutrient levels are comparable with the reports of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds; while some are higher than reported in the present study, others are lower. Abdulhamid *et al*. (35) reported the lower phytate (3.09 ± 0.65 mg/100 g), higher oxalate (16.20 ± 2.12 mg/100 g), higher cyanogenic glycoside (13.78 ± 0.13 mg/100 g) and lower tannins (6.19 ± 0.04 mg/100 g) contents in oil-free *C. colocynthis* L. seed cake. Igwenyi (15) assessed the levels of anti-nutrients in *C. colocynthis* seeds and reported higher tannins (49.67 mg/100g), phytates (10.6 mg/100g), cyanogenic glycosides (1.58 mg/100g), hemagglutinin (5.63 mg/100g) and trypsin inhibitor (0.75 mg/100g), and lower oxalates (1.30 mg/100g). Similarly, the levels of the antinutrients in *I. gabonensis* seed were tannins (54.75 mg/100g), phytate (9.30 mg/100g), trypsin inhibitor (9.37 mg/100g), cyanogenic glycosides (1.43 mg/100g), oxalates (1.08 mg/100g) and hemagglutinin (0.95 mg/100g) which were all higher than the amounts reported in this study. Onojah *et al*. (12) reported lower tannin (0.66 ± 0.17 and 0.13 ± 0.02) mg/100g, higher oxalate (0.38 ± 0.06 and 0.30±0.08) mg/100g and lower phytate (0.02 ± 0.00 and 0.01 ± 0.01) mg/100g contents, respectively for *I. gabonensis* and *I. wombolu* seeds when compared with the result of the present study. Similarly, Taiwo *et al.* (27) reported higher oxalate (16.1 ± 0.11 mg/100 g) and lower phytate (3.09 ± 0.07 mg/100 g) contents in *C. citrullus* seeds when compared with the present study. Similarly, Ezeabara and Ezeani (36) recorded higher hydrogen cyanide (4.78 ± 0.03 mg/kg) and lower tannin (1.25 ± 0.00%) contents for *I. gabonensis* seeds, as well as higher hydrogen cyanide (3.21 ± 0.05 mg/kg) and lower tannin (1.17 ± 0.02%) contents for *I. wombolu* seeds. Phytate content, like other nutrients and anti-nutrients in foods usually vary depending on the plant species (37), climate condition and type of soil in the location they are planted, and the season of the year during which they are grown (38). Tannins are shown form complexes with proteins which can chelate calcium, iron and zinc and render them bio-unavailable. They also inhibit the activities of digestive enzymes; this makes tannins to be regarded as antinutrient and hence not desirable especially at high levels in food (39). Trypsin inhibitors prevent the activation of some digestive enzymes which require trypsin for their own activation (40). In addition, the formation of calcium oxalate is implicated in causation of kidney stones (41). Oxalate also reduces bioavailability of calcium and magnesium (20).

Table 4: Antinutrient contents of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

Antinutrient content (mg/100g)	*Citrullus colocynthis*	*Irvingia gabonensis*	*Irvingia wombolu*
Phytate	4.42 ± 0.06^{c}	4.70 ± 0.01^{b}	4.30 ± 0.02^{a}
Tannin	14.04 ± 0.25^{a}	14.81 ± 0.07^{b}	14.66 ± 0.11^{b}
Cyanogenic glycosides	0.35 ± 0.05^{a}	0.35 ± 0.01^{a}	0.67 ± 0.03^{c}
Trypsin inhibitors	0.02 ± 0.01^{a}	0.02 ± 0.01^{a}	0.03 ± 0.01^{a}
Oxalate	0.04 ± 0.00^{a}	0.86 ± 0.04^{b}	0.95 ± 0.03^{c}
Hemagglutinin	0.13 ± 0.06^{a}	0.33 ± 0.06^{b}	0.40 ± 0.00^{b}

Data represent mean ± SD of triplicate determination. Values with different letters of the alphabets as superscripts in a row are significant at $p < 0.05$.

Table 5: Evaluation of mineral availability based on antinutrient/mineral molar ratio of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

Molar ratio parameters	*Citrullus colocynthis*	*Irvingia gabonensis*	*Irvingia wombolu*	Recommended values
[Phytate]/[Ca]	$2.81x10^{-3c}$	$7.39x10^{-4b}$	$5.87x10^{-4a}$	< 0.24
[Phytate]/[Zn]	0.19^{a}	0.23^{b}	0.23^{b}	≤ 15
[Phytate]/[Fe]	0.02^{a}	0.02^{a}	0.02^{a}	≤ 0.15
[Oxalate]/[Ca]	$2.54x10^{-5a}$	$1.35x10^{-4b}$	$1.49x10^{-4c}$	≤ 1
[Oxalate]/[Zn]	$1.75x10^{-3a}$	$4.20x10^{-2b}$	$5.20x10^{-2c}$	≤ 1
[Phytate]*[Ca]/[Zn]	0.30^{a}	1.46^{b}	1.71^{b}	≤ 0.5

Data represent mean ± SD of triplicate determination. Values with different letters of the alphabets as superscripts in a row are significant at $p < 0.05$.

Evaluation of mineral availability based on antinutrient/mineral molar ratio of *C. colocynthis, I. gabonensis* and *I. wombolu* seeds

The effects of antinutrient contents of the seeds on the bioavailability of their mineral element contents were assessed by estimating the antinutrient/mineral molar ratios. To check the effect of phytate in this seeds on the absorption of calcium, [Phytate]/[Ca] molar ratios of the seeds were calculated to be $2.81x10^{-3}$, $7.39x10^{-4}$ and $5.87x10^{-4}$ for *C. colocynthis, I. gabonensis* and *I. wombolu* seeds, respectivelywhich are lower than the critical molar ratio (0.24). This shows the phytate level does not adversely affect the absorption of calcium in the three seeds (42). Similarly, the effect of phytate contents of the seeds on the bioavailability of zinc, [Phytate]/[Zn] were 0.19, 0.23 and 0.23, respectively for *C. colocynthis, I. gabonensis* and *I. wombolu* seeds. These values were lower than the critical molar ratio of 15 and hence imply that the levels of phytate in the seeds do not interfere with the absorption of zinc. Similar findings were observed when the effects of phytate on iron and oxalate on calcium and zinc were evaluated. However, high Ca^{2+} level in diets promotes phytate-associated reduction in bioavailability of zinc when [Phytate]*[Ca]/ [Zn] molar ratio is > 0.5. The [Phytate]*[Ca]/[Zn] molar ratios recorded in this study were 0.30, 1.46 and 1.71 molar/Kg for *C. colocynthis, I. gabonensis* and *I. wombolu* seeds (Table 5). [Phytate]*[Ca]/[Zn] describes how phytate affects calcium and zinc bioavailability and values (≤ 0.5) is recommended. Since the values recorded for the two Irvingia seeds are higher than the recommended values unlike that of *C. colocynthis*, it implies that zinc from *C. colocynthis* will be more bioavailable and hence, a better source of zinc than the Irvingia seeds (43).

Conclusions

This study demonstrated that the nutritional and anti-nutrient contents of the seeds though richly present vary among seeds of *C. colocynthis, I. gabonensis* and *I. wombolu*. However, *C. colocynthis* generally showed more nutritive value and lower antinutrient effect compared with *I. gabonensis* and *I. wombolu* and is hereby recommended. Further study to compare the amino acid and fatty acid profiles is warranted to fully provide consumers the evidence to base their decisions on which seed to consume at a particular nutritional need.

Conflict of interest: The authors declare none.

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