International Journal of Sciences

Research Article Volume 10 – July 2021 (07)

Nutrient, Antinutrient and Sugar Contents in Desert Date (*Balanites aegyptiaca* (L.) Del) Seed and Pulp

Matthew Olaleke Aremu[1,2], Crysanthus Andrew[1], Odiba John Oko[1], Raphael Odoh[1], Idzi Amos Ambo[2], Baba Nwuniji Hikon[1]

[1]Department of Chemical Sciences, Federal University Wukari, PMB 1020, Taraba State, Nigeria
[2]Department of Chemistry, Federal University of Lafia, PMB 146, Nasarawa State, Nigeria

Abstract: This study focuses on the nutrient, antinutrient and sugar contents of (desert date) *Balanites aegyptiaca* seed and pulp collected from north–east Nigeria. Proximate, mineral, amino acid, antinutrient and sugar compositions were determined using standard analytical techniques. The calculated parameters were metabolized energy, mineral safety index (MSI), mineral ratios of some minerals, isoelectric point (pI), predicted protein efficiency ratio (P–PER) and leucine to isoleucine ratio. The results showed that seed was very rich in crude protein and crude fat with values of 30.80 and 45.53 g/100 g dry weight basis, respectively whereas, the pulp had values of 8.36 and 5.10 g/100 g dw for the same parameters. The following were observed as the most concentrated minerals: P (312.72 and 138.62 mg/100 g dw), Na (58.49 and 47.65 mg/100 g dw) and Ca (48.57 and 40.26 mg/100 g dw) for seed and pulp, respectively. Other minerals analyzed in the samples had values less than 15.0 mg/100 g. No mineral had deleterious value in the MSI. Amino acid analysis of seed and pulp showed concentrations of TAA (63.21 and 42.62 g/100 g cude protein), TEAA (26.19 and 21.88 g/100 g cp) and TNEAA ((26.19 and 21.88 g/100 g cp). Leucine (7.30 g/100 g cp) and Arg (3.69 g/100 g cp) were the most concentrated essential amino acids in seed and pulp. The phytate, tannin and oxalate concentrations were higher in seed compared with that of the pulp. All the sugars were of low levels. Generally, *Balanites aegyptiaca* seed and pulp contained nutritive minerals and sufficient proportions of EAAs however, dietary formula based on samples of the seed and pulp will require EAAs supplementation except in Leu, TSAA and Phe + Tyr of the seed. Likewise, the high contents of some of the antinutrients may pose a nutritional problem in their consumption.

Keywords: *Balanites aegyptiaca*, Seed, Pulp, Proximate, Minerals, Amino Acids, Antinutrients, Sugars

Introduction

Since ancient time, human beings have depended much on plants for survival either as a source of food or for medicinal purpose. For instance, many fruit produced by plants are widely eaten by humans and animals and constitutes a vital source of nutrients including, minerals, protein and carbohydrate which are needed for growth and development. Furthermore, some plants parts have been utilized as sources of medicine to cure some ailments by the local people in many parts of the world. Hence, it is necessary that the chemical composition of edible plant parts around the environment to be determined in order to explore its potential benefit for the use of man.

Desert date (*Balanites aegyptiaca)* (Figs 1 & 2) belongs to the family of plant called Zygophylaceae and kingdom of Plantae with about 25 known species widely distributed across the continents [1]. The English name of *B. aegyptiaca* is thorn tree/desert date and is known by other different native names. For instance, in the northern part of Nigeria it is called Aduwa (in Hausa), Tanni (Fulani) [1] while the Mummuye people (Rang ethnic group) in Zing LGA of Taraba state call it "Gonze". According to [2], *B. aegyptiaca* is a multipurpose tree with all the parts having valuable importance. However, the National Research Council [3] have identified that the fruits of the plant is the most valued part. The fleshy pulp of the fruits has been reported as edible either fresh or dried [4]. The fruits and leaves are used as fodder for animals and widely used as traditional medicines [5]. The fruit of the plant contains both micro and macro elements thus, could provide human with the necessary supplements of balanced diet required [5]. In addition, the fruits have been claimed to be a cure for liver diseases [2]. The proximate analyses of the seed, coat and pulp of *B. aegyptiaca* were carried out by some researchers [6]. The authors found that the crude protein and lipid in

This article is published under the terms of the Creative Commons Attribution License 4.0
Author(s) retain the copyright of this article. Publication rights with Alkhaer Publications.
Published at: http://www.ijsciences.com/pub/issue/2021-07/
DOI: 10.18483/ijSci.2484; Online ISSN: 2305-3925; Print ISSN: 2410-4477

Matthew Olaleke Aremu (Correspondence)
+

the pulp and coat were relatively low compared to that in the seed.

Fig 1: The unripe fruits of desert date (*Balanites aegyptiaca*)

Fig 2: The ripe fruits of desert date (*Balanites aegyptiaca*)

However, the pulp, seed and coat contain large amount of carbohydrate. The studies further revealed that the pulp and seeds can be an alternative source of vitamin C. The elemental composition of the pulp, seed and coat contained the presence of essential minerals like Na, K, Ca, Mg and P, though, their amount were below the recommended limit for mineral elements intake for humans. In their work, [7] carried out on the biochemical composition and nutritional value of *B. aegyptiaca* fruit pulp. They found that the pulp is good source of sugar, vitamin C and with high content of potassium (2220 mg/100 g of dry matter). In same studies, the author analyzed the amino acids content of the seed and sixteen amino acids profile was revealed. Similarly, [4] reported the nutritional value of the seed of *B. aegyptiaca*. The results of the mineral composition show that potassium (1.09 mg/100 g of dry matter) is the predominant mineral element in the seed of the plant while other mineral elements were in slightly lower amounts. The nutrient content of the fruits of *B. aegyptiaca* was also determined by [8] and it was reported that the fruits was rich in both essential and non-essential nutrients which were present in different concentrations. In 2008, the National Research Council [3] of US, listed *B. aegyptiaca* among 24 lost 'crops" of Africa that its potential has not been fully explored.

However, this work focuses on finding the nutrient, antinutrient and sugar contents of these seed and pulp as sources of food. The knowledge obtained from the study will aid policy-makers in the agriculture sector and food industry to making informed decisions aimed at broadening the nation's food security basket.

Materials and Methods

Samples collection

The samples were collected from Zing local government Area of Taraba State, Nigeria. Identification of the samples was done in the Biology laboratory of Federal University Wukari.

Sample preparation and treatment

The dried fruits of desert date (*Balanites aegyptiaca)* were washed with distilled water to remove foreign materials and then drained through filter paper. The fruit was prepared by sundried, separated into seed and pulp, ground into powder using pestle and mortar, sieved and stored in well labeled air tight plastic container and taken for analysis.

Proximate analysis

The ash, moisture, crude protein (N x 6.25), crude fat, crude fibre and carbohydrate (by difference) were determined in accordance with the standard methods of AOAC [9]. All proximate analyses of the sample flours were carried out in triplicate and reported in %. All chemicals were of Analar grade. All results were on dry weight (dw) basis.

Amino acid analysis

The amino acid analysis was by Ion Exchange Chromatography (IEC) [10] using the Technico Sequential Multisample (TSM) Amino Acid Analyzer (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 $mLmin^{-1}$ at 60^oC with reproducibility consistent within ± 3%. The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. Amino acid values reported were the averages of two determinations. Nor–leucine was the internal standard. Tryptophan was determined after alkali (NaOH) hydrolysis by the colorimetric method.

Determination of isoelectric point (pI), quality of dietary protein and predicted protein efficiency ratio (P–PER)

The predicted isoelectric point was evaluated according to Olaofe and Akintayo [11]:

$$plm = \sum_{i=1}^{n=1} pliXi \quad --------(1)$$

Where:
pIm = the isoelectric point of the mixture of amino acids;

Xi = the mass or mole fraction of the amino acids in the mixture.
pIi = the isoelectric point of the ith amino acids in the mixture;

The quality of dietary protein was measured by finding the ratio of available amino acids in the sample protein compared with the needs expressed as a ratio. Amino acid score (AAS) was then estimated by applying the formula [12]:

$$AAS = \frac{mg\ of\ amino\ acid\ in\ 1g\ of\ test\ protein}{mg\ of\ amino\ acid\ in\ reference\ protein} \times \frac{100}{1} ------ (2)$$

The predicted protein efficiency ratio (P–PER) of the seed sample was calculated from their amino acid composition based on the equation developed by Alsmeyer *et al.* [13] as stated thus;

$$\text{P–PER} = -0.468 + 0.454(\text{Leu}) - 0.105(\text{Tyr}) \text{ - - - - - - - - - - - - - - - - - - - } (3)$$

Anti–nutritient content determination
The contents of alkaloids, saponins, tannins, oxalate, phytate and cyanide were determined on each of the sample flours by methods described by some workers [14].

Sugar content determination
The various sugar content determinations were carried out as described by Lane and Eynon's method [15]. All chemical used were of analytical grade and were obtained from British Drug Houses (BDH, London, UK). All results were on wet basis.

Statistical analysis of the samples
The energy values were calculated by adding up the carbohydrate x 17 kJ, crude protein x 17 kJ and crude fat x 37 kJ for each of the samples. The fatty acid values were obtained by multiplying crude fat value of each sample with a factor of 0.8 (i.e. crude fat x 0.8 = corresponding to fatty acids value [25]. Errors of three determinations were computed as standard deviation (SD) for the proximate composition. Standard deviation and percentage of coefficient of variation for the seed and pulp samples were also determined.

Results and Discussion
The proximate composition of seed and pulp of *Balanites aegyptiaca* is presented in Table 1. The value obtained for the pulp (7.54 % dw) is much higher than that of seed (1.28% dw). This value for the seed is lower than values obtained for *Canavalia ensiformis* (3.8%) [16], pinto beans (2.3%) [17], *Proposis africana* (3.32%) [18], *Irvingia gabonensis* (2.1 [19] and *Phaseolus coccineus* (3.7%) [20]. The low moisture value ensures a long life of the seed without microbial spoilage. But in the case of pulp, the moisture content of 7.54% dw is high. The result implies that the fruit has low storage capacity or can be easily perishable, highlighting the problems of conservation in warm climate condition. However, the high water content in fruits and vegetables can help enhance food digestion and peristaltic movement on consumption [21]. The values obtained for ash content (6.47 and 5.21% dw) for seed and pulp, respectively were higher than values reported for melon seeds (3.3%) [22], castor seeds (3.2%) [23], wild jack bean (3.0%) [18], and *Vigna ublobata* (3.2%) and *Vigna radiate* (3.4%) [24]. Since the two samples recorded fairly high ash content, it may indicate that the fruit could provide essential useful and valuable minerals needed for good body development [25].

The crude protein value obtained for the seed (30.80% dw) was very high compared with that of pulp (8.36% dw) (Table 1). The value for the seed suggests that it can contribute to the daily protein need of 23.6 g for adults, as recommended by the National Research Council (1974) [3], and is therefore considered good source of protein. The result compared well with selected legumes such as red kidney bean (28.5%) [26], *Parkia biglobosa* (31.0%) [22], *Phaseolus vulgaris* (29.10%) [27] and wild jack bean (28.9%) [18]. It has been reported that diet is nutritionally satisfactory if it contains high calorie value and a sufficient amount of protein [28]. Some researchers also stated that any plant–based foods that provide about 12% of their calorie value from protein are considered good sources of protein [28–30]. Thus, seed of *Balanites aegyptiaca* may be regarded as a good source of protein but the pulp is not. Fat provides very good sources of energy, protects internal tissues, contributes to important oil processes and aids in transport of fat soluble vitamins [31]. The crude fat content of seed and pulp of *Balanites aegyptiaca* were 45.53 and 5.10% dw, respectively. This qualifies *Balanites aegyptiaca* seed as an oil–rich food since it is comparable to *Vitellaria parodoxa* kernel (45.62%) [30], and even higher than the value recorded for soybean (22%) [32]. The crude fat of *Balanites aegyptiaca* seed appears good when rated against the 20–50% reported by [33]. According to the authors, crude fat between 20 and 30% are low, those above 30.5% are intermediate and values above 40% are good. Such classification would place the seed of *Balanites aegyptiaca* crude fat collected from the north–east, Nigeria under good lipid content group.

The crude fibre values were 2.42 and 3.91% dw for seed and pulp of *Balanites aegyptiaca*, respectively. The values compared favourably with reported values of some plant–based foods in the literature [34–36].

Fibre helps to maintain the health of the gastrointestinal tract, but in excess may bind trace elements, leading to deficiencies of iron and zinc [37]. It is not surprised that the carbohydrate value of the seed (13.51% dw) was very low compared with that of the pulp (69.89% dw) because of the high contents of crude protein and crude fat since carbohydrate is obtained by difference between 100 and the summation of other parameters (Table 1). The metabolizable energy in the present study showed that both samples had energy concentrations that are more favourable compared with cereals [38]. The calculated fatty acids of the seed (36.42 %) is much higher than that of pulp (4.08), this suggests that the oils of the seed may be both edible and suitable for industrial purposes [39]. The CV% varied from 15.26 g/100 g dw in ash to 116.72 in crude protein (Table 1).

Table 1: Proximate composition (g/100 g dw)[a] of the seed and pulp of desert date (*Balanites aegyptiaca*)

Parameter	Seed	Pulp	Mean	SD	CV%
Moisture	1.28±0.04	7.54±0.30	4.41±0.17	4.43±0.18	100.37
Ash	6.47±0.11	5.21±0.11	5.84±0.11	0.89±0.00	15.26
Crude protein	0.80±1.15	8.36±0.21	4.58±0.68	5.35±0.66	116.72
Cude fat	45.53±1.30	5.10±0.35	25.32±0.83	28.59±0.67	112.93
Cude fibre	2.42±0.11	3.91±0.13	3.17±0.12	1.05±0.01	33.29
[b]Carbohydrate	13.51±2.42	69.89±0.83	41.70±1.63	39.87±1.12	95.60
[c]Fatty acids	36.42±1.04	4.08±0.28	20.25±0.66	22.87±0.54	112.93
[d]Energy	2437.88	1518.95	1978.42	649.78	32.84

[a]Values are ± standard deviations (n = 3); [b]Carbohydrate percent calculated as 100 – total of other components; [c]Calculated fatty acids (0.8 x Crude fat); [d]Calculated metabolizable energy (kJ/100g) (Protein x 17 + Fat x 37 + Carbohydrate x 17); dw = dry weight basis

The mineral profiles of *Balanites aegyptiaca* seed and pulp are displayed in Table 2. Of all the minerals determined, phosphorus is the most abundant having values of 312.72 and 138.62 mg/100 g dw for the seed and pulp, respectively. It is followed by Na (58.49 and 47.65 mg/100 g dw) and Ca (48.57 and 40.26 mg/100 g dw). Phosphorus is always found with Ca in the body both contributing to the blood formation and supportive structure of the body [40]. Low Ca/P ratio facilitates decalcination of Ca in the bone leading to low Ca level in the bones while Ca/P ratio above two helps to increase the absorption of Ca in the small intestine [41]. The values (0.16 and 029) of Ca/P ratio in the present study are far lower than two therefore, seed and pulp of *Balanites aegyptiaca* may not be able to participate well in these functions. None of the values of K, Mn, Cu, Zn and Fe recorded up to 10.0 mg/100 g dw in both samples but Mg content was 14.52 mg/100 g dw in seed sample. Magnesium is required for bone formation which maintains the electrical potential in nerves [42]. The adrenal glands play an essential role in regulating sodium retention and excretion. Studies have also shown that Mg will affect adrenal cortical activity and results in increased in Mg retention [42]. The ratio of sodium to potassium in the body is of great concern for the prevention of high blood pressure. Na/K ratio less than one is recommended [43]. The Na/K ratio values were 11.20 and 8.39 for the seed and pulp of *Balanites aegyptiaca*, respectively. This indicates that regular consumption of *Balanites aegyptiaca* may not prevent high blood pressure. Na/Mg values (4.03 and 9.04) are higher than the normal range of 4.00. Copper and Zn are intricately related to the hormones, progesterone and estrogens, respectively and their tissue levels may be indirectly reflective of the status of these hormones within the body [42]. The CV% varied from 5.99 in K to 66.10 in Mg (Table 2).

Table 2: Mineral composition (mg/100 g) of the seed and pulp of desert date (*Balanites aegyptiaca*)

Mineral	Seed	Pulp	Mean	SD	CV%
Na	58.49	47.65	53.07	7.67	14.44
Ca	48.57	40.26	44.42	5.88	13.23
K	5.22	5.68	5.45	0.33	5.99
Mn	1.65	3.62	2.64	1.39	52.87
Mg	14.52	5.27	9.90	6.54	66.10
Cu	0.87	0.26	0.57	0.43	76.34
Zn	2.80	1.69	2.25	0.78	34.96
Fe	0.39	0.69	0.54	0.21	39.28
P	312.72	138.62	225.67	123.11	54.55
Na/P	11.20	8.39	9.80	1.99	20.29
Ca/P	0.16	0.29	0.23	0.09	40.86
Na/Mg	4.03	9.04	6.54	3.54	54.21

Na/K = Sodium to potassium ratio; Ca/P = Calcium to phosphorus ratio; Na/Mg = Sodium to magnesium ratio; SD = Standard deviation; CV = Coefficient of variation

The mineral safety index (MSI) values of Na, Mg, Cu, Zn, Fe and P of *Balanites aegyptiaca* seed and pulp are presented in Table 3. The standard mineral safety index values for the elements are Na (4.8), Ca (10), Mg (15), Cu (33), Zn (33), Fe (6.7) and P (10) [44]. The explanation of the MSI can be understood as follows taking Na as example: the recommended adult intake (RAI) of Na is 500 mg; its minimum toxic dose (MTD) is 2,400 or 4.8 times the recommended daily average (RAA) which is equivalent to MSI of Na [44]. This explanation goes for the other minerals whose MSI were determined. All the minerals have their table value (TV) > calculated value (CV) giving positive differences with corresponding low percentage differences. The TV greater than CV had been observed in Na, Mg, P, Ca, Fe, Zn and Cu in raw fruit coat, seed and pulp of passion fruit (*Passiflora edulis*) [45]. The CV of MSI values gave an indication that none of the minerals was high enough to the deleterious levels when consumed in the seed and pulp of *Balanites aegyptiaca*)

Table 3: Mineral safety index (MSI*) of Na, Ca, Mg, Cu, Zn, Fe and P in desert date (*Balanites aegyptiaca*

Mineral	RAI (mg)	TV of MSI	Calculated value (CV)	
			Seed	Pulp
Na	500	4.8	0.5615	0.4574
Ca	1200	10	0.4048	0.3355
Mg	400	15	0.5445	0.1976
Cu	3	33	9.5700	2.8600
Zn	15	33	6.1600	1.5180
Fe	15	6.7	0.1742	0.3082
P	1200	10	2.6060	1.1552

RAI = Recommended adult intake; **TV** = Table value; * = No MSI standard for K and Mn

The results of amino acid composition of *Balanites aegyptiaca* seed and pulp are shown in Table 4. Asp and Leu were the most concentrated in seed sample with the respective value (g/100 g crude protein) of 7.91 and 7.30, while Glu and Asp were the most concentrated in pulp sample with values of 4.25 and 3.81 g/100 g cp, respectively. Leu (7.30 g/100 g cp) and Arg (3.69 g/100 g cp) were the most concentrated essential amino acids in seed and pulp samples. The least was Try (0.84 g/100 g cp) in seed and Met (0.56 g/100 g cp) in pulp. Arg is an essential amino acid which is necessary for children growth [46] and also has direct antioxidant activity [47]. The Lys content in the seed sample (3.34 g/100 g cp) was found to be higher than that of *L. cylindrical* kernel (2.9 g/100 g cp) [34] but lower than the value of 4.03 g/100 g cp reported for *Bucchholzia coriacea* [48], while the Met content (1.39 g/100 g cp) for the seed sample is higher than the report of Olubunmi [49] for *A. cruenthus* (0.93 g/100 g cp), *C. olitorius* (0.75 g/100 g cp), *C. chayamansa* (0.80 g/100 g cp) and *B. alba* (0.67 g/100 g cp). The concentrations of Ile (3.50 g/100 g cp) and Val. (3.51 g/100 g cp) for only seed were found to meet the FAO/WHO/UNU [50] requirements for these two EAA (2.80 and 3.50 g/100 g cp, respectively) for pre–school children aged 2–5 years. Ile is an essential amino acid for both young and old. Leu, Ile and Val (branch–chain amino acids) work together to repair muscles, regulate blood sugar and provide body with energy. Other EAAs with appreciable contents obtained in the analyzed samples include His (6.20 and 1.02 g/100 g cp), Try (0.84 and 0.58 g/100 g cp) and Phe (4.08 and 2.31 g/100 g cp) for seed and pulp of *Balanites aegyptiaca*, respectively. Phe is needed in treating brain disorder, control of symptoms of depression, chronic pain and normal functioning of the central nervous system, while Try is important in the manufacture of neurotransmitter serotonin, which regulates mood and sleep pattern, treatment of jet lag, depression and binge eating [51]. The calculated isoelectric point (pI) is of significance in protein purification. The pI value (3.76) of *Balanites aegyptiaca* seed is higher than that of pulp (2.62), and this is the point at which the protein should accumulate during purification. The predicted protein efficiency ratio (P–PER) is one of the quality parameters used for protein evaluation [52]. P–PER value in this report for seed sample (2.49) is higher than the reported values of *Adansonia digitata* pulp (1.10) [53] and *Lathynia sativus* L. (1.03) [54]. The Leu/Ile ratios in the samples (2.06 and 1.65) were relatively not high. Some studies suggested that the Leu/Ile balance is more important than dietary excess alone [55, 56].

Table 4: Amino acid composition (g/100 g crude protein) of the seed and pulp of desert date (*Balanites aegyptiaca*)

Amino acid	Seed	Pulp
Lysine (Lys)[a]	3.34	2.86
Histidine (His)[a]	6.20	1.02
Arginine (Arg)[a]	1.38	3.69
Aspartic acid (Asp)	7.91	3.81
Threonine (Thr)[a]	2.00	1.44
Serine (Ser)	4.00	2.32
Glutamic acid (Glu)	1.36	4.25
Proline (Pro)	3.45	2.94
Glycine (Gly)	3.80	3.16
Alanine (Ala)	2.28	3.07
Cystine (Cys)	3.39	0.61

Tryptophan (Try)[a]	0.84	0.58
Valine (Val)[a]	3.51	2.98
Methionine (Met)[a]	1.39	0.56
Isoleucine (Ile)[a]	3.54	2.00
Leucine (Leu)[a]	7.30	3.30
Tyrosine (Tyr)	3.44	1.72
Phenylalanine (Phe)[a]	4.08	2.31
Isoelectric point (pI)	3.76	2.62
P–PER	2.49	0.85
Leu/Ile	2.06	1.65

Evaluation report on amino acids based on nutritional classification of the two studied samples is shown in Table 5 because the nutritive value of a protein depends primarily on its capacity to satisfy the needs for nitrogen and essential amino acids. Total amino acids (TAA), total essential amino acids (TEAA) with His and total sulphur amino acids (TSAA) were (63.21 and 42.62 g/100 g cp), (37.02 and 20.77 g/100 g cp) and 4.78 and 1.17 g/100 g cp) for *Balanites aegyptiaca* seed and pulp samples, respectively. The result revealed that seed was of good quality compared with the pulp. The essential aromatic amino acids (EArAA) were 4.08 and 2.31 g/100 g cp for seed and pulp. These values fall within the ideal range suggested for infant protein (6.8 – 11.8 g/100 g) [50]. The aromatic amino acids are precursors of epinephrine and thyroxin [57]. The % of TNAA was 68.06 (seed) and 63.33 (pulp) meaning that the bulk of the amino acids in both samples are neutral. It is also observed that the % TEAA for both samples in this report are well above the 39% considered adequate for ideal protein food [50].

Table 5: Concentration of essential, non-essential, acidic, neutral, sulphur, aromatic, etc. (g/100 g crude protein) of desert date (*Balanites aegyptiaca*)

Amino acid description	Seed	Pulp
Total amino acid (TAA)	63.21	42.62
Total essential amino acid (TEAA)		
With histidine	37.02	20.74
Without histidine	30.82	19.72
% TEAA		
With histidine	58.57	48.66
Without histidine	48.76	46.27
Total non-essential amino acid (TNEAA)	26.19	21.88
%TNEAA	41.43	51.34
Essential alphatic aromatic acid (EAAA)	16.35	9.72
Essential aromatic amino acid (EArAA)	4.08	2.31
Total neutral amino acid (TNAA)	43.02	26.99
%TNAA	68.06	63.33
Total amino acid (TAAA)	9.27	8.06
%TAAA	14.67	18.91
Total basic amino acid (TBAA)	10.92	7.57
%TBAA	17.28	17.76
Total sulphur amino acid (TSAA)	4.78	1.17
% Cystine in TSAA	70.92	52.14

The EAA scores of the seed and pulp samples based on the provisional amino acid scoring pattern are presented in Table 6. With the exception of Leu, Met + Cys (TSAA) and Phe + Tyr in the seed sample, the contents of EAA are lower than FAO/WHO recommendation [52, 59], while all the EAA contents in the pulp sample are lower than FAO/WHO recommendation. Thus, by implication dietary formula based on samples of seed and pulp of *Balanites aegyptiaca* will require essential amino acids supplementation except in Leu, TSAA and Phe + Tyr of the seed. Generally, the EAAs that most often act in a limiting capacity are Met (and Cys), Lys and Try [50]. In this study, Thr (0.50) and Lys (0.61) are the first and second limiting amino acids (LAA) for the seed while Met + Cys (0.33) and Thr (0.36) are LAA for the pulp.

Table 6: Amino acid scores of seed and pulp of desert date (*Balanite aegyptiaca*)

EAA	PAAESP* (g/100g protein)	Seed		Pulp	
		EAAC	AAS	EAAC	AAS
Ile	4.0	3.54	0.89	2.00	0.50
Leu	7.0	7.30	1.04	3.30	0.47
Lys	5.5	3.34	0.61	2.86	0.52
Met + Cys (TSAA)	3.5	4.78	1.37	1.17	0.33
Phe + Tyr	6.0	7.52	1.25	4.03	0.67
Thr	4.0	2.00	0.50	1.44	0.36
Try	1.0	0.84	0.84	0.58	0.58
Val	5.0	3.51	0.70	2.98	0.60
Total	**36.0**	**32.83**	**7.20**	**20.78**	**4.73**

EAA = Essential amino acid; **PAAESP =** Provisional amino acid (egg) scoring pattern; **EAAC =** Essential amino acid composition (see Table 4); **AAS =** Amino acid scores; ***Source:** Belschant *et al.* [58]

The antinutrient contents are displayed in Table 7. Dietary anti–nutritional factors such as alkaloid, oxalate, tannin, saponin, cyanide and phytate have been reported to adversely affect the digestibility of protein, protein quality of foods and bioavailability of amino acids [60]. The oxalate contents in the samples (295.00 and 124.50 mg/100 g) were much higher than 36 mg/100 g DM considered to be lethal to man [61]. Excess consumption of oxalate or oxalic acid can cause corrosive gastroenteritis [62]. Oxalate serves as chelating agents and may chelate many toxic metals such as mercury and lead, but one major concern is its ability to rap heavy metals in the tissues of living organisms thereby making elimination of them very difficult. Oxalate binds to calcium and prevents its absorption in human body [62, 63]. The values of saponin were 3.50 and 8.50 g/100 g for the seed and pulp, respectively. The value for the pulp is higher than the reported values for *Phaseolus coccineus* (4.1%), *Vigna subterranea* (4.6%) and *Phaseolus lunatus* (3.2%) [64]. It has been reported that dietary saponins excert various biological benefits such as anti–inflammatory, anti–diabetic, anti–atheroscelerotic and serve as protective functions like gastro–protective, hepatoprotective and hypolipidemic [65]. Alkaloid values in seed (1.40 g/100 g) and pulp (1.51 g/100 g) were very low compared to the reported values of 8.6% (scarlet runner bean) and 9.6% (lima bean) [64], and 5.0% (black turtle bean) [60]. Consumption of high tropane alkaloids will cause rapid heartbeat, paralysis and in fatal case, lead to death. The tannin content in the seed (70.15 mg/100 g) is much higher than that of pulp (7.03 mg/100 g). The nutritional effects of tannins are mainly related to their interaction with protein due to the formation of complexes [65]. Tannin–protein complexes are insoluble and protein digestibility is decreased. Tannin acid may decrease protein quality by decreasing palatability and digestibility. Other nutritional effects which have been attributed to tannins include interference with the absorption of iron, a possible carcinogenic effect and damage to the intestinal tract [66]. Cyanide is the chemical substance responsible for tissue hypoxia and chronic exposure to it particularly hydrogen cyanide may cause respiratory, neurological, thyroid and cardiovascular defects [67]. The cyanide contact in the pulp (11.29 mg/100 g) is higher than that of seed (4.94 mg/100 g). The observed values are lower than 40.78 mg/100 g of *Dioclea reflexa* seed reported by Bolanle and Adedayo [68]. The phytate content in both samples are too high; 591.79 mg/100 g recorded for the seed and 314.87 mg/100 g for pulp. Phytate is a salt form of phytic acid and acts as a strong chelator, forming protein and mineral phytic acid complexes thereby reducing protein and mineral availability [69]. It chelates metal ions such as Ca, Mg, Zn, Cu and Fe to form insoluble complexes that are not readily absorbed from the gastrointestinal tract [69].

Table 7: Antinutrients composition of desert date (*Balanite aegyptiaca*) seed and pulp (wet weight basis)

Parameter	Seed	Pulp	Mean	SD	CV%
Oxalate (mg/100 g)	295.00±7.07	124.50±7.78	209.75±7.43	120.56±0.50	57.48
Saponin (g/100 g)	3.50±0.71	8.50±0.71	6.00±0.71	3.54±0.00	58.93
Alkaloids (g/100 g)	1.40±0.10	1.51±0.13	1.46±0.12	0.08±0.02	5.35
Tannin (mg/100 g)	70.15±11.02	7.03±1.11	38.59±6.07	44.63±7.01	115.66
Cyanide (mg/100 g)	4.94±0.12	11.29±0.54	8.12±0.33	4.49±0.30	55.33
Phytate (mg/100 g)	591.79±11.79	314.87±1.05	453.33±6.42	195.81±7.59	43.19

SD = Standard deviation; CV = Coefficient of variation

The sugar concentrations of the seed and pulp of *B. aegyptiaca* are presented in Table 8. Certain carbohydrates have specific functions in the human body. Ribose is an energy source that the body makes for food. It is naturally occurring pentose sugar and ribose has been shown to enhance the recovery of myocardial or skeletal muscle ATP and TAN levels following ischemia or highly–intensity exercise. The content of ribose in pulp sample (1.26806e^{-10} g/100 g ww) was higher than that of seed sample (8.53815e^{-11} g/100 g ww). There is some evidence that supplemental ribose might prevent muscle fatigue in people with genetic disorders that prevent sufficient energy production by the body. It might provide extra energy to the heart [70]. The values of xylose, arabinose and rhamnose in both samples were very low and comparable to each other (2.00559e^{-8} and 2.00345e^{-8} g/100 g ww; 1.02834e^{-7} and 1.02834e^{-7} g/100 g ww; 7.88728e^{-9} and 7.62351e^{-9} g/100 g ww for seed and pulp, respectively. Xylose is a monosaccharides of the aldopentose type consisted of five carbon atoms and an aldehyde functional group. The dextrorotary form of xylose, D–xylose, refers usually to the endogenously occurring form of the sugar in living things. Xylose by itself may not necessarily serve many purposes immediately but its metabolism results in a variety of substrates that can serve as important nutritional and biological purposes [71]. Arabinose is originally commercialized as a sweetener and it is an inhibitor of sucrose, the enzyme that breaks down sucrose into glucose and fructose in the small intestine [72]. Rhamnose is commonly bound to other sugars in nature. It is a common glycone component of glycosides from many plants. Rhamnose is also a component of the outer cell membrane of acid–fast bacteria in the mycobacterium genus, which includes the organism that causes tuberculosis [70]. Fructose was more concentrated in the pulp than seed. These values reported for the seed and pulp (0.21 and 3.08 g/100 g ww), respectively were very close to the values reported in literature [45, 73]. Fructose is a monosaccharide which is important in human physiology. However, it has been reported that consumption of foods rich in fructose may result in high triglycerides (hypertriglyceridemia) and obesity (74). It is observed that seed and pulp of *Balanites aegyptiaca* cannot be said to be a source of fructose due to low level of fructose. Maltose, lactose and sucrose were the disaccharides evaluated in both samples (Table 8). The concentration of sucrose was the highest while lactose was the least in both samples. Latose appears to increase calcium retention in children [75], and is the type of dietary carbohydrate that has an effect on the level of serum cholesterol, being lower when complex carbohydrates such as dietary fibre and pectin are consumed in preference to sucrose [76]. The CV% varied from 0.0027 in arabinose to 132.40 in glucose.

Table 8: Sugar concentrations (g/100 g ww) of desert date (*Balanites aegyptiaca*) seed and pulp

Parameter	Seed	Pulp	Mean	SD	CV%
Ribose	8.53815×10^{-11}	1.26806×10^{-10}	1.06×10^{-10}	2.9292×10^{-11}	27.60
Xylose	2.00559×10^{-8}	2.00345×10^{-8}	2.00×10^{-8}	1.5132×10^{-11}	0.076
Arabinose	1.02834×10^{-7}	1.02830×10^{-7}	1.03×10^{-7}	2.8284×10^{-12}	0.0027
Rhamnose	7.88728×10^{-9}	7.62351×10^{-9}	7.76×10^{-9}	1.8651×10^{-10}	2.405
Fructose	0.21	3.08	1.645	2.0294	123.37
Glucose	0.11	3.34	1.725	2.2840	132.40
Dextrose	4.21033×10^{-8}	3.50747×10^{-8}	3.86×10^{-8}	4.9699×10^{-9}	12.88
Maltose	0.0049	0.0123	0.0086	0.0052	60.84
Lactose	5.30513×10^{-8}	1.86088×10^{-8}	3.58×10^{-8}	2.4355×10^{-8}	67.97
Sucrose	2.76	1.85	2.305	0.6435	27.92

SD = Standard deviation; CV = Coefficient of variation; ww = wet weight basis

Acknowledgement

Authors would like to thank and appreciate Tertiary Education Trust Fund (TETFund) for giving financial support through Federal University Wukari, Nigeria. Dr. T. O. Ojobe, a former Chief Technologist of Zoology Department, University of Jos, Nigeria is also appreciated for amino acids analysis carried out in his laboratory.

Conclusion

Comparative evaluation of *Balanites aegyptiaca* seed and pulp was presented in this study, which showed that the seed was very rich in crude protein and crude fat comparable with known protein–rich and fat–rich plant–based foods such as soybean and groundnut. However, the contents of protein and fat were too low in the pulp compared with the seed. The seed had higher contents of Na, Ca, Mg and P compared with the pulp but no mineral had deleterious value in the mineral safety index (MSI). Results also revealed that both samples contained sufficient proportions of EAAs however, dietary formula based on samples of the seed and pulp will require EAAs supplementation except in Leu, TSAA and Phe + Tyr of the seed in order to meet FAO/WHO diet requirement. Some antinutrients such as saponin, alkaloid, oxalate and tannin were present in high quantities in the seed sample and they may pose a nutritional problem in its consumption. The sugar levels in both samples were low.

References

1. Manji, A. J., Sarah E. E., Modibbo, U. U. (2013). Studies on the potentials of Balanites aegyptiaca seed oil as raw material for the production of liquid cleansing agents. Inter. J. Phys. Sci. 8: 1655-1660.
2. Tesfaye A. (2015). Balanites (Balanite aegyptiaca) Del., Multipurpose Tree a Prospective
3. Review, Inter. J. of Modern Chem. & Applied Sci. 2: 189-194.
4. National Research Council (2008). Lost crops of Africa: Volume III: Fruits. Development,
5. Security, and Cooperation Policy & Global Affairs. National Academies Press, Washington, DC, USA. 380 pp.
6. Fregon, S. M. E. & Shakak, M. A. S. (2016). Physicochemical properties of Balanites aegyptiaca (Laloub) seed oil. J. Bio. Sci. 2: 10-19.
7. Elfeel, A. A. & Warrag, E. I. (2011). Uses and conservation status of Balanites aegyptiaca (L.) Del. (Hegleig Tree) in Sudan: Local people perspective. Asian J. Agric. Sciences 3: 386–390.
8. Sadiq, I. S., Dangoggo, S. M., Hassan, L. G., Manga, S. B., Thompson, I., Itodo, A. U. (2012). Nutritional composition of aduwa fruit (Balanites aegytiaca) from semi-arid region, north-western Nigeria. Inter. J. Food and Nutri. Sci. 1:7-9.
9. Sagna, M. B., Diallo, A, Sarr, P. S., Ndiaye, O., Goffner, D., Guisse, A. (2014). Biochemical
10. composition and nutritional value of Balanites aegyptiaca (L.) Del fruit pulps from Northern Ferlo in Senegal. Afri. J. Biotechn. 13: 336-342.
11. Feyssa, D. H., Njoka, T. J., Asfaw, Z. & Nyangito, M. M. (2015). Nutritional contents of Balanites aegyptiaca and its contribution to human diet. African Journal of Food Science, 9: 346-350.
12. AOAC. Association of Official Analytical Chemists (2005). Official Method of Analysis 16th Edn. Washington DC.
13. Paul, A. & Southgate, D. (1978). The Composition of Foods. 4th Edn. Eleservier, North.
14. Olaofe, O. & Akintayo, E. T. (2000). Prediction of isoelectric points of legume and oil seed proteins from amino acid composition. J. Technoscience, 4, 49-53.
15. FAO/WHO (1991). Protein Quality Evaluation Report of Joint FAO/WHO Expert Consultative FAO Food and Nutrient.FAO, Rome, Italy.
16. Alsmeyer, R. H., Cunningham, A. E. & Happich, M. L. (1974). Equation to predict (PER) from amino acid analysis.

Food Technology, 28: 34 – 38.
17. Olonisakin, A., Aremu, M. O. & Omonigbehin, E. A. (2004). Phytochemical and antimicrobial investigations of extractive from Phyllantus amarus. Biosci. Biotech. Research, Asia, 2(1): 33 – 36.
18. Usoro, E. U., Suyamsothy, E. & Sanni, G. A. (1982). Manual of Chemical Methods of Food Analysis. Bencox International Ltd, Lagos.
19. Vidivel, V. & Janardhanen K. (2001). Nutritional and anti–nutritional attributes of underutilized legume, Cassinfloribundacar, Food Chemistry, 73, 209–215.
20. Audu, S. S. & Aremu, M. O. (2011). Effects of processing on chemical composition of red kidney bean (Phaseolus Vulgaries L.) flour. Pak. J. Nutri., 10(11), 1069 – 1075.
21. Aremu, M. O., Atolaiye, B. O., Pennap, G. R. I., & Ashikaa, B. T. (2007). Proximate and amino acid composition of mequite bean (Prosopis africana) protein concentrate. Indian J. Botanical Res., 3(1), 97–102.
22. Aremu, M. O., Opaluwa, O. D., Bamidele, T. O., Nweze, C. C., Ohale, I. M. & Ochege, M. O. (2014). Comparative evaluation of nutritive value of okro (Abelmoschus esculentus and Mango (Irvingia gabonensis) fruits grown in Nasarawa State, Nigeria, Food Sci. and Quality Mgt., 27, 63–70.
23. Aremu, M. O., Olaofe, O., Basu, S. K., Abdulazeez, G. & Acharya, S. N. (2010). Processed cranberry bean (Phaseolus coccineus) seed flours for African diet. Canadian J. Plant Science, 90, 719 – 728 (DOI: 10.4141/CJPS09149.
24. Al–Wander, H. (1983). Chemical composition of seeds of two okro cultivated. J. Agric. & Food Chem., 31, 1353–1358.
25. Omofuvbe, B. O., Falade, O. S., Osuntogun, B. A. & Adewusi, S. R. A. (2004). Chemical and biochemical changes in African locust bean (Parkia biglobosa) and melon (Citrullus vulgaris) seeds during fermentation to condiments. Pak. J. Nutri., 3(3), 140–145.
26. Onyeike, E. N. & Acheru, G. N. (2002). Chemical composition of selected Nigerian oil seeds and physicochemical properties of the oil extracts, Food Chem., 77, 431–437..
27. Khalil, I. A. & Khan, S. (1995). Protein quality of Asian beans and their wild progenitor, Vigna sublobata (Roxb), Food Chem., 52, 327–330.
28. Audu, S. S., Aremu, M. O. & Lajide, L. (2013). Influence of traditional processing methods on the nutritional composition of black turtle bean (Phaseolus vulgaris L.) grown in Nigeria, Int. Food Res. J., 20(6), 3211–3220.
29. Olaofe, O., Famurewa, J. A. & Ekuagbere, A.O. (2010). Chemical and functional properties of kidney bean seed (Phaseolus vulgaris L.) flour. Int. J. Chem. Sci., 3(1), 51–69.
30. Audu, S. S. & Aremu, M. O. (2011). Effect of processing on chemical composition of red kidney bean (Phaseolus vulagaris L.) flour. Pak. J. Nutri., 10(11): 1069 – 1075. DOI: 10.3923/pjn.2011.1069.1075.
31. Ene-Obong, H. N. (1992). Nutritional evaluation, composition pattern and processing of underutilized traditional foods particular reference to the African yambeans (Sphenostylis stenocarpa). PhD thesis, Department of Home Science and Nutrition, University of Nigeria, Nsukka.
32. Effiong, G. S., Ibia, T. O. & Udofia, U. S. (2009). Nutritive and energy values of some wild fruit spices in South -Eastern Nigeria. Electronic Journal of Environmental, Agricultural and Food Chemistry, 8(10): 917 – 923.
33. Aremu, M. O., Ibrahim, H., Bamidele, T .O., Salau, R. B., Musa, B. Z. & Faleye, F. J. (2018). Nutrient and antinutrient composition of shea (Vitellaria paradoxa C. F. Gaertn) kernel and pulp in the north–east Nigeria, Int. J. Sci., 7, 56–66.
34. Pamela, C. C., Richard, A. H. & Denise, R. F. (2005). Lippincotts illustrated Reviews Biochemistry 3rd ed., Lippincott Williams and Wilkins, Philadelphia, pp. 335 – 388.
35. Elias, L. G., Cristales, F. R., Bressani, R. & Miranda, H. (1976). Chemical composition and nutritive value of some grain legumes nutrient, Abstract Revised (Series B/1977), 47, 603–864.
36. Maranz, S. & Wiesman, Z. (2004). Influence of climate on the tocopherol content of shea butter. J. Agric. Food Chem. 52, 2934–2937.
37. Olaofe, O., Aremu, M. O. & Okiribiti, B.Y. (2008). Chemical evaluation of the nutritive value of smooth luffa (Luffa cylindrica) seed's kernel. Electronic Journal of Environmental and Agricultural Food Chemistry, 7(10), 3444 – 3452.
38. Aremu, M. O., Bamidele, T. O., Nweze, C. C. & Idris, I. M. (2012). Chemical evaluation of pride of barbados (Caesalpinia pulcherrima) seeds grown in Gudi, Nasarawa State, Nigeria. Int. J. Chem. Sci., 5(1): 29 – 34.
39. Oshodi, A. A. & Ekperigin, M. M. (1989). Functional properties of pigeon pea (Cajanus cajan) flour, Food Chem., 34, 187–191.
40. Siddhuraju, P., Vijayakumari, K. & Janardhanan, K. (1996). Chemical composition and protein quality of the little–known legume, velvet bean (Mucuna pruriens L.). J. Agric Food Chem., 44, 2636–2641.
41. Audu, S. S. & Aremu, M . O. (2011). Nutritional composition of raw and processed pinto bean (Phaseolus vulgaris L.) grown in Nigeria, J. Food, Agric. & Environ., 9(3&4), 72–80.
42. Aremu, M. O., Olaofe, O. & Akintayo, E. T. (2006). Compositional evaluation of cowpea (Vigna unguiculata) varieties and scarlet runner bean (Phaseolus coccineus) varieties flour, J. Food, Agric. & Environ., 4(2), 39–43.
43. Ogunlade, I., Olaofe, O. & Fadare, T. (2005). Chemical composition, amino acid and functional properties of Leucaena leucocepha seeds flour. Nigeria J. Appl. Sci., 21, 7–12.
44. Nieman, D. C., Butterworth, D. E. & Nieman, C. N. (1992). Nutrition. Wm. C. Brown Publishers, Dubuque, I. A. 540p.
45. Shills, M. Y. G. & Young, U. R. (1992). Modern nutrition in health and disease. In: Nieman, D.C., Butterworth, D.E. and Nieman, C.N. (eds.). Nutrition. WmC, Brown Publishers, Dubuque, I.A., pp. 276–282.
46. Aremu, M. O., Olaofe, O. & Akintayo, E. T. (2006). Chemical composition and physicochemical characteristics of two varieties of bambara groundnut (Vigna subterrenea) flours. J. Applied Sciences, 6(9): 1900 – 1903.
47. Hathcock, J. N. (1985). Quantitative evaluation of vitamin safety, Pharmacy Times, pp. 104–113.
48. Adeyeye, E. I. & Aremu, M. O. (2017). Chemical composition of the raw fruit coat, seed and pulp of passion fruit (Passiflora edulis), FUW Trends in Sci. & Tech. J., 2(1B), 334–341.
49. Bonger, R. H., Bode-Boger, S. M., Mugge, A., Klenke, S., Brandes, R., Dwenger, A., Frollich, J. C. (1996). Supplementation of hypercholesterolemic rabbits with L-Arg reduces the vascular release of superoxide anions and restores NO production. Atherosclerosis, 117: 273 – 284.
50. Adeyeye, E. I. & Aremu, M. O. (2016). Chemical composition of whole shrimp, flesh and shell of Pandalas borealis) from Lagos atlantic ocean. FUW Trends in Science and Technology Journal, 1(1), 26–32.
51. Aremu, M. O., Passali, D. P., Ibrahim, H. & Akinyeye, R. O. (2018). Chemical composition of wonderful kola (Bucchlozia coriacea) and breadfruit (Artocarpus altilis) seeds grown in South–South, Nigeria. Bangladesh J. Sci. and Ind. Res., 53(1), 125–132. DOI: 10.3329/bjsir.v53i2.36673
52. Olubunmi, A. O., Olaofe, O. & Akinyeye, R. O. (2015). Amino acid composition of ten commonly eaten indigenous leafy vegetables of south-west Nigeria. World Journal of Nutrition and Health, 3(1), 16 – 21.
53. FAO/WHO/UNU (1985). Energy and Protein Requirements; Report of a Joint FAO/WHO/UNU Expert Consultation, WHO Tech Rep Ser no. 724. Geneva: WHO.
54. Arowora, K. A., Ezeonu, C. S., Imo C. & Nkaa C. G. (2017). Protein levels and amino acids composition in some leaf vegetables sold at Wukari in Taraba State, Nigeria. International Journal of Biological Sciences and Applications, 4(2): 19 – 24.
55. FAO/WHO (1991). Protein quality evaluation report of joint FAO/WHO expert consultative FAO, Food and Nutrient.

56. Ibrahim, H., Aremu, M. O., Onwuka, J. C., Atolaiye, B. O. & Muhammad, J. (2016). Amino acid composition of pulp and seed of baobab (Adansonia digitata L.). FUW Trends in Science & Technology Journal, 1(1): 74 – 79.
57. Salunkhe, D. K., Kadam, S. S. & Chavan, J. K. (1985). CRC Postharvest Biotechnology of Food legumes. Boca Raton, FL: CRC Press.
58. Belvady, B. & Gopalem, C. (1969). The role of leucine in the pathogenesis of canine black tongue and pellagra. Lancet, 2: 956 – 957.
59. Ghafoornissa, S. & Narasinga, B. S. (1973). Effect of leucine on enzymes of the tryptophan niacin metabolic pathway in rat liver and kidney. Biochemistry Journal, 134, 425 – 430.
60. Robinson, D. E. (1987). Food Biochemistry and Nutritional Value. Longman Scientific and Technology, Burnmell, Haslow, England, pp. 327 – 328.
61. Belschant, A. A., Lyon, C. K. & Kohler, G. O. (1975). Sunflower, safflower, sesame and castor proteins. In: Food Protein Sources. Pirie (ed.), University Press Cambridge, UK. Pp. 79–104.
62. FAO (1970). List of Foods Used in Agriculture, Nutritional Information Document Series Number 2, Food and Agriculture Organization of the United Nations, Rome, Italy, p. 45.
63. Audu, S. S., Aremu, M. O. & Lajide, L. (2013). Effects of processing on physicochemical and antinutritional properties of black turtle bean (Phaseolus vulgaris L.) seeds flour. Oriental J. Chem., 29(3): 979 – 989.
64. Oke, O. L. (1969). Oxalic acid in plants and nutrition, World Rev. Nutr. Dietetics, 10, 262–302.
65. Adesina, A. J. & Adeyeye, E. I. (2012). The proximate and mineral composition of fatted and defatted marble vine seeds. Proceedings of the 36th Annual Conference of NIFST, 15–19 October, EKO 2012, 225–226.
66. Coe, F.L., Evan, A. and Worcester, E. Kidney stone disease. (2005). J. Clin. Invest, 115(10): 2598 – 2608.
67. Aremu, M. O.,Ibrahim, H. & Ekanem, B. E. (2016). Effect of processing on in–vitro protein digestibility and anti–nutritional properties of three underutilized legumes grown in Nigeria. British Biotechnology Journal, 14(1), 1 – 10.
68. Banno, N., Akihisa, T., Tokuda, H., Yasukawa, K., Higashihara, H., Ukiya, M., Watanabe, K., Kimura, Y. Hasegawa, J. and Nishino, H. (2004). Triterpene acids from the leaves of Perilla frutescenes and their anti-inflammatory and antitumour-promoting effects. Bioscience Biotechnology and Biochemistry, 68, 85 – 90.
69. Ijeomah, A. U., Ugwuona, F. U. & Ibrahim, Y. (2012). Nutrient composition of three commonly consumed indigenous vegetables of north-central Nigeria. Nigerian Journal of Agriculture, Food and Environment, 8(1): 17 – 21.
70. Priya, K. D., Pachiappan, C., Sylvia, J. & Aruna, R. M. (2011). Study of the effects of hydrogen cyanide exposure in cassava workers. Indian J. Occup. Environ. Med., 15(3): 133 – 136.
71. Bolanle, A. O. & Adedayo, A. (2012). Comparative study on chemical compositions, phytochemical screening and physico-chemical properties of the seeds of Dioclea reflexa. Ultra Chem., 8: 251 – 264.
72. Robinson, T. (1985). The organic constituents of higher plants, their chemistry and inter–relationship, 3rd edn. Corcleus Press North Amlerst Mass, 6, 430–435.
73. Oyelaran, O., McShane, L. M., Dodd, L., Gildersleeve, J. C. (2009). Profiling human serum antibodies with a carbohydrate antigen microarray, J. Proteome. Res., 8(9), 4301–4308.
74. ChaHopadhyay, S., Raychaudhuri, U. & Chakraborty, R. (2014). Artificial sweetners – a review, J. Food Sci. Technol., 51(4), 611–621.
75. Krog–Mikkelsen, I., Hels, O., Tetens, I., Holst, J. J., Anderson, J. R. & Bukhave, K. (2011). The effects of L–arabinose on intestinal sucrose activity: dose–response studies in vitro and in humans, The American J. Clinical Nutr., 94(2), 472–478.
76. Adeyeye, E. I., Olaleye, A. A., Aremu, M. O., Atere, J. O. & Idowu, O. T. (2020). Sugar, antinutrient, and food properties levels in raw, fermented and germinated pearl millet grains, FUW Trends in Sci. Technol. J., 5(3), 745–758.
77. Kareem, M. (2021). Fructose sugar: A major driver of obesity, diabetes and hypertension, Premium Times, Nigeria, Published in June 7, 2021.