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Chemical analysis, pasting properties and amino acids composition of *Neocarya macrophylla* and *Balanites aegyptiaca* under-utilized seeds from Nigeria

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Abstract: The proximate, minerals, pasting properties and amino acid composition of *Neocarya macrophylla* and *Balanites aegyptiaca* under-utilized seeds (NMS and BAS) were investigated using standard methods. The seed flours **(**NMSF and BASF) were found to be rich in protein (25.43±0.22%; 30.54±0.15%) and lipids (45.96±0.10%; 46.95±0.64%). Higher values of protein (56.04±0.01%; 51.31±0.13%) were also obtained in the seed cakes (NMSC and BASC). The seed samples were good sources of K, Mg, Ca and Fe with high concentration while Mn, Cu, and Zn were observed in minor quantities. Among the identified micro-elements, K is the major element in all samples with 5179.90±0.02ppm, 5767.62±0.11ppm, 5160.09±0.05ppm and 5647.32±0.02ppm respectively recorded for NMSF, BASF, NMSC and BASC. The seed cakes showed good pasting properties. The peak time (5.44±0.03min; 6.30±0.38 min) and pasting temperature (79.66±0.49ºC; 88.00±0.00ºC) were respectively obtained for NMSC and BASC. The major amino acids in NMSC and BASC were glutamic acid (11.36 g/100 g and 12.42 g/100), aspartic acid (7.63 g/100 g and 8.21 g/100) and leucine (7.21 g/100g and 7.62 g/100g). The percentage ratio of essential to non-essential amino acids was 44.83 and 44.82. Among the essential amino acids, isoleucine lysine and leucine were found comparable to FAO/WHO requirements. The predicted protein efficiency ratio (P-PER*) were 2.42 and 2.59 respectively. These seeds are therefore recommended as good source of nutrients and quality food for human consumption.

1. Introduction

The global increasing demand for cheap and affordable dietary proteins among the low income group in developing countries due to inadequate and expensive animal proteins necessitated the current search and utilization of vegetable proteins. An urgent alternative to improve nutritional status and meet the dietary requirement of protein and minerals is to supplement diet with plant proteins (Khalid *et al.*, 2016). A 'complete protein' may be defined as a balanced combination of essential amino acids required for healthy living and consuming wide variety of plant foods help deliver all the required essential amino acids. Determination of amino acid profile is essential to ascertain the nutritional value with respect to the ratio of essential amino acids to non-essential amino acids and to evaluate the quality of raw materials apart from their carbohydrate and mineral constituents (Galla *et al.,* 2012). Studies on the chemical, amino acid and fatty acid composition of common and uncommon sources such as groundnut, *Sterculia urens* and *Lupinus termis* have been reported (Khalid *et al*., 2016; Galla *et al.,* 2012; Atasie *et al.,* 2009) among others. Projections based on the current trends indicate a gap between human population and protein supply. Hence, the need to examine unconventional legumes and oil seeds as alternative protein sources for the future (Fagbemi, 2007). This development has stimulated research on the utilization of *N. macrophylla* and *B. aegyptiaca* indigenous underutilized oil seeds as alternate protein source.

Neocarya macrophylla (formerly *Parinari macrophylla* Sabine) belongs to *Chrysobalanaceae* family. It is grown in arid and semi-arid regions mainly in the Western part of Africa. It is a small tree that is 6-10 m high with densely pubescent and russet brown stems and alternate or ovate leaves 10-25 cm long (Yusuf *et al*., 2016). It is rich in protein, but lesser-known, therefore underexploited. The earlier reported proximate analysis of defatted seed flour shows 56.04% of protein, 4.51% of crude fat, 6.93% of crude ash, and 13.19% of carbohydrate with an energy value of 317.48 Kcal/100 g (Ifedi *et al.,* 2017). Available reports on the nutritional and anti-nutritional profile show that *N. macrophylla* seeds are of high food value with about 40-60 % oil and 21-25% protein contents. They provide energy, dietary fibre, protein, minerals and fatty acids required for human health (Amza *et al.,* 2010; Kadda *et al,* 2022). The seeds are good source of certain amino acids such as lysine, valine and phenylalanine and others which are important for balancing their deficiency in cereal-based diets (Audu *et al.,* 2005). Some preliminary phytochemical screening and physico-chemical studies of the seed oil, (Warra *et al.,* 2013). have been previously undertaken. Pharmacologically, the decoction of the bark and leaves are used as mouth wash, internal troubles and for inflamed eye. It is employed in traditional medicine to manage pain conditions and other ailment such as diarrhea, asthma, dysentery, skin infections, cancer, pulmonary troubles, ear and eye infections, tooth decay, snake bite, pain, inflammation and skin infections (Amza *et al.,* 2010). *N. macrophylla* seed cake showed no toxicological effect on the haematological and biochemical properties of wistar rats (Ifedi *et al.,* 2017).

Balanites aegyptiaca (L.) is a perennial tropical plant that belongs to the family of *Balanitecea*, and commonly known as desert date. It is a small evergreen tree reaching a height of 6-12 m, found to be of tremendous medicinal importance and distributed throughout the dried parts of India. It belongs to the Zygophyllacea family and produces fruits, which are edible. *B. aegyptiaca* is known in Nigeria as adowa (Yoruba), tanni (Fulfulde), cungo (Kanuri), adua or aduwa (Hausa) and widely used in food preparation and herbal medicine, especially in Africa and some developing countries (Wison *et al*., 2009). Available reports on the nutritional and anti-nutritional profile of *B. aegyptiaca* seed powder shows that it contains a relatively high amount of protein and oil contents (Mohamed *et al*., 2002). The earlier reported proximate analysis of defatted seed flour shows protein (49.32%), crude fat (13.92%), crude ash (4.40%) and carbohydrate 23.91% with an energy value of 1760.00 KJ/100 g (Ajayi and Ifedi, 2014). The seed contains high level of anti-nutritional factors; tannins, oxalate and phytic acid (Chotani and Vaghasiya, 2011). The plant was also reported to contain saponins in the ethanol extract that acts as an antioxidant for the prevention of oxidative hepatic damage (Mayba *et al*., 2011). No toxicological effect was recorded on the haematological and biochemical properties of rats' blood when fed with *B. aegyptiaca* seed cake (Ajayi and Ifedi, 2014).

The seeds have potentials as protein supplement in cereal based complementary diets or in the replacement of animal proteins in conventional foods. In addition to all research already carried out by several researchers on their nutritional values, the knowledge of their amino acid composition and amino acid profile is necessary in food product formulations. This research was aimed at evaluating a comprehensive chemical analysis, pasting properties and amino acid composition of *Balanites aegyptiaca* and *Neocarya macrophylla* seeds from Nigeria to further exploit their potential use in food system.

2. Methodology

2.1. Collection *and preparation of Neocarya macrophylla and Balanites aegyptiaca seed flours*

Neocarya macrophylla seeds were obtained from Junju town, Niger Republic while *Balanites aegyptiaca* seeds were bought from Tundun Wada market in Zaria, Kaduna State, Nigeria. They were first identified in the Herbarium Unit of the Botany Department, University of Ibadan and later authenticated at the Forest Research Institute of Nigeria (Ibadan) where Voucher specimen was deposited in the Herbarium.They were dried and milled using a laboratory scale hammer miller prior to extraction. The kernels were pulverized to fine powder and divided into two portions. Oil was extracted from one portion of the seed flour by soxhlet extraction using n-hexane (b.pt 67-68 °C) as the solvent continuously for 8 h to obtain the seed cake. The seed flour and cake were both stored in a properly labeled glass container for further analysis.

2.2 Physical characteristics

The physical parameters such as length and width dimensions of the seeds were determined using a digital veneer caliper (Model 500-196, Mitutoyo Products, America). The weight of the seeds was determined using a weighing balance (Model GF-2000, A & D company Ltd., Japan) of 0.01 accuracy. The determinations were done in triplicate and the mean values were noted (Ajayi *et al.,* 2006).

2.3 The proximate analysis

The proximate analysis of the samples for total ash, moisture, crude fibre and ether extract were carried out using the standard methods of Association of Official Analytical Chemists (AOAC, 2006). The nitrogen content was determined by micro-Kjedahl method as described in (AOAC, 2006) and nitrogen content was converted to protein by multiplying by 6.25. Carbohydrate was calculated by method of difference following the expression 100 – (sum of moisture; total ash; crude fat; crude protein and crude fibre contents).The Energy value (Kj/100g) was equally obtained (Ifedi *et al*., 2017).

2.4 Mineral determination in the seed samples

Minerals such as copper, zinc, iron, magnesium, calcium, sodium, potassium and manganese were all determined. Approximately 1.0 g of NMSC and BASC were dried in an oven at 115 °C for 1-2 hours and ashed in a muffle furnace by gradually increasing the temperature from 100 ^{o}C to 800 ^{o}C and allowed to cool to room temperature after reaching 800 ^{o}C. The ashed samples, allowed to cool in desiccators were digested with a mixture of HNO_3 (0.1 M, 20 mL) and HCl (6 M, 5 mL) at room temperature (25°C) (Parkin *et al*., 2015). The solution was subsequently transferred to a 100 mL standard volumetric flask and diluted with deionized water. The concentrations of elements present were analyzed using an ICP-OES at the Indian Institute of Chemical Technology (CSIR-IICT) Hyderabad-500007, Telangana. The analysis was performed in triplicate and the mean values were noted.

2.5 Pasting properties

The pasting properties of *N. macrophylla* and *B. aegyptiaca* seed cakes were determined using a Rapid Visco Analyser 3C (RVA, model 3C, New port Scientific PTY Ltd, Sydney, Australia). 3 g of NMSC and BASC were separately weighed into a weighing vessel while 25 ml of distilled water was dispensed into a new test canister. The slurries were held at 50^{o}C for 1 min, heated from 50 ^{o}C to 95 ^{o}C with a holding time of 2 min and cooled to 50 ^{o}C for 2 min holding time. The rates of heating and cooling were done at a constant rate of 10 ^{o}C/min.Peak viscosity, peak time, breakdown, final viscosity, set back, and pasting temperature were read from the pasting profile (Ojo *et al*., 2017).

2.6 Amino acids analysis

The profile of amino acid composition in each selected sample was determined by using ion-exchange chromatography with automatic amino acid analyzer (Hitachi L8500, Tokyo, Japan), following the method outlined in (Galla *et al*., 2012). 2 g of each sample flour were defatted through soxhlet extraction methods. The seed cakes sample were re-dried, milled into fine powder, 30 mg was taking from them into a glass ampoules and 5 ml of 6 M HCl and 5 µmolnorleucine were added. The ampoules were evacuated with liquid nitrogen and sealed with burner flame and hydrolyzed in an oven at 110 °C for 24 hours. The ampoules were cooled, broken at the tip and the contents were passed through filter. The filtrates were dried in rotary evaporator at 40 °C under vacuum. The residues were dissolved to 5 µL (for acid and neutral amino acids) or 10 µL (for basic amino acids) with acetate buffer, pH 2.2 and the solutions were dispensed into the cartridge of amino acid analyzer. The quantification was performed by comparing the peak area of each amino acid in the sample to the area of the corresponding standard amino acid of the protein hydrolysate. The predicted protein efficiency ratio (PPER*) was determined using the equations (1.0) below (Ogungbenle *et al*., 2014).

$$\text{PPER} = -0.468 + 0.454\,(\text{Leucine}) - 0.105\,(\text{Tyrosine}) \qquad \text{Equ (1.0)}$$

2.6 Statistical analysis

All experimental results were expressed as mean values and standard deviation of three determinations. Data were analysed using a one-way analyses of variance (ANOVA) in the Statistical Package for Social Science (SPSS) version 20.0 software (version 2010) to test the level of significance (P≤0.05). Duncan New Multiple Range Test was used to separate the means where significant differences existed.

3. Results and Discussion

3.1 Physical characteristics

The physical characteristics of *N. macrophylla* and *B. aegyptiaca* seeds with regards to weight, length, width, oil yield and kernel percentage are shown in Table 1. The average weight of twenty seeds was 18.86±1.05 g and 56.90±1.05 g for *N. macrophylla* and *B. aegyptiaca* seeds. The average mean weight of each seed was determined to be 0.94±0.12 g and 2.84±0.24 g. The seed kernel percentage was found to be 98.24% and 38.81%. Mean length and width of each seed measured respectively were 1.60±0.15 cm, 11.24±0.10 cm, 3.19±0.86 cm and 2.38±0.90 cm while oil yields were 45.96±0.10% and 46.95±0.10%.

3.2 Proximate analysis of N. macrophylla and B. aegyptiaca seed flours and cakes

The proximate analysis of *N. macrophylla* and *B. aegyptiaca* seed flours and cakes were presented in Table 2. NMSF and BASFhad low moisture content (8.83±0.04% and 7.78±0.04%). These values increased to 12.32±0.53% and 8.45±0.03% in the seed cakes. The moisture content was higher than 4.01±0.60% and 2.90±0.30% for *Trilepisium madagascariense* and *Antiaris africana* (Adewuyi *et al.*, 2010). The low moisture content of NMSF and BASF may help to prevent microbial growth. It is reported that high moisture content might be associated with rise in microbial activitiesduring storage (Hassan *et al*., 2008) and even affect the storage condition. NMSF and BASFwere found to be rich in fat (45.96±0.10% and 46.95±0.64%), protein (25.43±0.22% and 30.54±0.15%) and ash (3.81±0.03% and 2.95±0.05%). The protein content of 56.04±0.01% and 51.31±0.13% were reported for the seed cake due to extraction (Ifedi *et al*., 2017; Ajayi and Ifedi, 2014). The high crude fat content in both seeds is comparable to the values reported in (Amza *et al*., 2010).

Table 1. Physical properties of *N. macrophylla* and *B. aegyptiaca* seed

Properties	NEMS	BAS
Weight of 20 seeds(g)	18.86±1.05[b]	56.90±1.05[a]
Weight of a seeds(g)	0.94±0.12[b]	2.84±0.24[a]
Seed length (cm)	1.60±0.15[b]	3.19±0.86[a]
Seed width (cm)	11.24±0.10[b]	2.38±0.90[a]
Oil yied	45.96±0.10[a]	46.95±0.64[a]
Kernel Percentage	98.24%	38.81%
State of the oil @ RT	Liquid	Liquid

Values are mean± standard deviation, (n = 3) Values on the same row having the same letter as superscripts are not significantly different ($P < 0.05$). NEMS: *N. macrophylla*seed, BAS: *B. aegyptiaca* seed

Protein content of 36.65±0.60% and 39.40±0.30% were reported for *T. indica* and *A. saman* (Adewuyi *et al*., 2011). The energy values of 2277.33 KJ/100g and 2342.69 KJ/100g were obtained in the seed flours. These energy values reduced to 1343.78 KJ/100g and 1400.08 KJ/100g in NMSC and BASC. The ash content of 3.81±0.03% and 2.95±0.05% obtained in the seed flours slightly increased to 6.53±0.06% and 4.40±0.02% in the seed cakes. The ash content obtained in NMSF and BASF is higher than 2.55±0.12% reported for *Nicker* bean seed flour (Ogungbenle *et al*., 2014) and 3.08% as reported for *Arachis hypogaea* seed flour (Atasie *et al*., 2009). The proximate compositions of these seeds flours and cakes revealed their possibility as potential resources.

Table 2. Proximate and energy compositions of *N. macrophylla* and *B. aegyptiaca* seeds flours and cakes

Properties	NMSF	BASF	NMSC* ifedi *et al.*, 2017	BASC*Ajayi and Ifedi, 2015.
Dry Mater (%)	91.17±0.05	92.22±0.02	87.68±0.03	91.55±0.01
Moisture content	8.83±0.04	7.78±0.04	12.32±0.53	8.45±0.03
Protein content	25.43±0.22	30.54±0.15	56.04±0.01	51.31±0.13
Crude fat	45.96±0.10	46.95±0.64	4.51±0.01	6.90±0.04
Ash content	3.81±0.03	2.95±0.05	6.53±0.06	4.40±0.02
Crude Fibfe	7.82±0.04	6.70±0.03	7.41±0.01	12.90±0.02
Carbohydrate	8.15±0.25	5.08±0.14	13.19±0.49	16.03±0.18
Energy (Kj/100g)	2277.33	2342.69	1343.78	1400.08
PTE due to protein	18.98	22.16	22.16	18.98
PTE due to fat	74.68	74.15	74.15	74.68
PTE due to CHO	6.08	3.69	3.69	6.08

NMSF: *N. macrophylla* seed flour, BASF: *B. aegyptiaca* seed flour, NMSC: *N. macrophylla* seed cake, BASC: *B. aegyptiaca* seed cake; PTE: Proportion of total energy; CHO: Carbohydrate. Values are mean± standard deviation, (n=3).

3.3 Mineral composition

The mineral composition of *N. macrophylla* and *B. aegyptiaca* seed flours and cakes were presented in Table 3. The various metals, Ca, Mg, K, Na, Fe, Mn, Cu, and Zn analysed, are known to play vital roles in both plants and animals. The metals were accumulated in different amount in the seed flours and cakes. K has the highest concentration in both seed flours (5179.90±0.02 ppm and 5767.62±0.11 ppm) as well as in the seed cakes (5160.09±0.05 ppm and 5647.32±0.02 ppm) where as Cu has the lowest concentration among all the metals (7.43±0.02 ppm and 4.73±0.00 ppm in the seed flours and 7.17±0.00 ppm and 4.25±0.00 ppm in the seed cakes). *N. macrophylla* and *B. aegyptiaca* seeds are good sources of K, Mg, Ca and Fe. *T. indica, M. griffonianus* and *A. saman* seed flours were also found to be rich in K, Na, Ca, Mg and Fe (Adewuyi *et al*., 2011). The concentrations of these metals obtained were higher among others in the seed flours than in the seed cakes. K is an essential metal in human nutrition and a major cation inside the animal cell. It is important in maintaining fluid and electrolyte balance in the body system. It is also important in favoring muscle contraction and sending nerve impulses in animals through action potential (Jiang *et al*., 2002). The concentration of Ca was higher in the seed flours. This metal is essential in organisms particularly in cell physiology where movement of calcium ion in and out of the cytoplasm function as a signal for many cellular processes (Remington, 2005). It also plays important role in building stronger and denser bones early in life as well as keeping these bones strong and healthy later in life. The concentration of Fe ranged from 9102.38±0.01 ppm to 33.36±0.11 ppm in the seed flours and 92.90±0.01 ppm to 26.58±0.10 ppm in the seed cakes. These seeds might be good sources of nutrients.

Table 3. Mineral composition (ppm) of *N. macrophylla* and *B. aegyptiaca* seed flours sees cake

Seed flours	NMSF	BASF	NMSC	BASC
Ca	973.36±0.03[b]	1225.12±0.02[a]	647.15±0.05[d]	913.51±0.01[c]
Cu	7.43±0.02[a]	4.73±0.00[c]	7.17±0.00[b]	4.25±0.05[d]
Fe	102.38±0.01[a]	33.36±0.11[c]	92.90±0.01[b]	26.58±0.10[d]
K	5179.90±0.02[c]	5767.62±0.11[a]	5160.09±0.05[c]	5647.32±0.02[b]
Mg	1028.56±0.11[c]	1845.83±0.20[a]	947.49±0.05[d]	1695.61±0.01[b]
Mn	9.36±0.03[c]	12.69±0.01[a]	7.75±0.00[d]	11.35 ±0.01[b]
Na	12.70±0.00[c]	98.19±0.05[a]	12.04±0.05[c]	32.62±0.02[b]
Zn	25.42±0.02[b]	34.83±0.05[a]	25.40±0.05[b]	31.11±0.01[a]
Na/K	0.002±0.00[a]	0.0017±0.00[a]	0.002±0.00[a]	0.005±0.00[a]

Values are mean± standard deviation, (n = 3) Values on the same row having the same letter as superscripts arenot significantly different ($P < 0.05$). NMSF: *N. macrophylla* seed flour, BASF: *B. aegyptiaca* seed flour, NMSC: *N. macrophylla* seed cake, BASC: *B. aegyptiaca* seed cake

3.4 Pasting properties of N. macrophylla and B. aegyptiaca seed cakes

The pasting properties NMSC and BASC are presented in Table 4. The peak viscosity of 1753.00±25.98 RVU and 1007.66±1.14 RVU were respectivelyobtained for NMSC and BASC. Peak viscosity is indicative of the viscous load that might be likely encountered during mixing. Higher peak viscosity is associated with higher swelling index, while low peak viscosity is indicative of highersolubility as a result of starch degradation. It is equally an indication of the suitability of the blends for products requiring high gel strength and elasticity (Ojo *et al*., 2017). Trough viscosity (TV) which is the minimum viscosity value measures the ability of paste to withstand breakdown during cooling obtained respectively for NMSC and BASC were 1366.00±15.5 RVU and 802.33±1.15 RVU. The setback viscosity ranged between 520.66±5.77 to 154.33±1.15 RVU respectively in NMSC and BASC. When starch is heated in the presence of water and subsequently cooled, the disrupted amylose and amylopectin chains can gradually re-associate into a different ordered structure in a process termed retrogradation. The time at which peak viscosity occurred in minutes is termed peak time (Adebowale *et al*., 2005). It is also known as pasting time which is the measure of the cooking time. The peak time of 5.44±0.03 min and 6.30±0.38min were obtained respectively implies that NMSC and BASC. NMSC will cook faster than BASC.

Table 4. Pasting properties of *N. macrophylla* and *B. aegyptiaca* seed cakes

Parameter	NMSC	BASC
Trough viscosity (RVU)	1366.00±15.5	802.33±1.15
Peak viscosity (RVU)	1753.00±25.98	1007.66±1.14
Break down viscosity (RVU)	387.00±10.39	272.33±6.57

Final. Viscosity (RVU)	1883.33±9.81	956.00±0.00
Set back viscosity (RVU)	520.66±5.77	154.33±1.15
Peak time (min)	5.44±0.03	6.30±0.38
Pasting temperature (°c)	79.66±0.49	88.00±0.00

Values are mean± standard deviation, (n = 4) Values on the same row having the same letter as superscripts are not significantly different ($P < 0.05$).
NMSC: *N. macrophylla* seed cake, BASC: *B. aegyptiaca* seed cake

The pasting temperature is a measure of the minimum temperature required to cook a given food sample. The pasting time found was 79.66 ºC in NMSC and 88.00 ºC in BASC. The final viscosity was 1883.33±9.81 RVU and 956.00±0.00 RVU respectively. NMSC and BASC seed cakes showed good pasting properties and might find applications in the confectionary industries.

3.5 Amino acid composition in N. macrophylla and B. aegyptiaca seed proteins

The Amino acid composition of NMSC and BASCare presented as g/100 g protein in Table 5. Glutamic acid (11.36 g/100 g and 12.42 g/100), aspartic acid (7.63 g/100 g and 8.21 g/100) and leucine (7.21 g/100g and 7.62 g/100g) were higher than other amino acids found in the seed cakes. It was in good agreement with literature as glutamic acid was the most abundant amino acid in seed samples (Ogungbenle and Ebadan, 2014; Olaofe *et al.,* 2013). The glutamic acid contents obtained was slightly lower than 14.8 mg/100g in velvet tamarind (*Daliumguineense*) pulp (Ogungbenle and Ebadan, 2014); 14.20 mg/100g in *Sterculia urens* (Galla *et al.,* 2012); 13.8 g/100g in *Moringa oleifera* (Olaofe *et al.,* 2013); 19.00 mg/100g in casein and 21.29 mg/100g in soy protein isolate (Tang *et al.,* 2006). The second most abundant amino acid in this study was aspartic acid with 7.63 g/100g and 8.21 g/100g respectively. Aspartic acid values of 7.56 g/100g, 9.86 g/100g and 9.9 g/100g were reported in (Galla *et al.,* 2012; Ogungbenle and Ebadan, 2014; Khalid *et al*., 2016). Leucine content was 7.21 g/100g and 7.62 g/100g in both seed cakes studied. The leucine value obtained was higher than 4.72 g/100g reported (Galla *et al.,* 2012) and compared favorably with both reported data (Ogungbenle and Ebadan, 2014; Khalid *et al*., 2016). Significant quantities of lysine (4.96 g/100g, 5.25 g/100g); isoleucine (4.03 g/100g, 4.32 g/100g) and valine (3.74 g/100g, 3.81 g/100g) respectively observed in NMSC and BASC were comparable to soy protein isolate (Tang *et al.,* 2006). Methionine content of 1.12 g/100g and 1.26 g/100g were obtained for NMSC and BASC. The proportions of the essential amino acids available in NMSC and protein were comparable to those of the required amino acids as per FAO/WHO (FAO/WHO,1985). Hence these proteins can be termed as possessing a near balanced profile of essential amino acids. The total amino acids accounted for 71.81 g/100 g protein in NMSC, 77.02 g/10gin BASC and the rest of the nitrogen might be from non-protein nitrogen such as alkaloids, ammonia, purines, pyrimidines, vitamins and amino sugars (Galla *et al.,* 2012).

3.6 Amino acid classification in N. macrophylla and B. aegyptiaca seed proteins

Table 6 reveals the amino acid classification in NMSC and BASC proteins in terms of essential, non-essential, acidic, basic, neutral, total sulphur and total aromatic amino acids and their percentages. The total amino acid (TAA) in NMSC and BASC samples was 71.81 g/100 g and 77.02 g/100g. This TAA value is similar to 77.22 g/100 g for *Sterculia urens* (Galla *et al.,* 2012) but lower than 98 g/100g obtained in *Lupine termis* (Khalid *et al.,* 2016), 97.38 g/100g in *Cannabis sativa* seed protein isolate (Tang *et al.,* 2006) and 102 g/100g for *Dalium guineense* (Ogungbenle and Ebadan, 2014). The total non-essential amino acid (TNEAA) of 39.67 g/100g protein and 42.50 g/100 g protein obtained in NMSC and BASC was higher than the total essential amino acid (TEAA) of 32.24 g/100g and 34.52 g/100g obtained without histidine and 34.06 g/100g and 36.69 g/100 g obtained with histidine. The values of TEAA with and without histidine obtained compared favorably with 34.70 g/100g and 32.60 g/100g (Ogungbenle and Ebadan, 2014) as well as 34.24 g/100g and 29.9 g/100g (Khalid *et al.,* 2016). The ratio of essential to non-essential amino acids percentage in the samples studied was 44.83 and 44.82. These values compared very well with 45 reported for *Sterculia urens* (Galla *et al.,* 2012); 46.52 for *Lupinus termis* (Khalid *et al.,* 2016) and 52.83 for *Daliumguineense* (Ogungbenle and Ebadan, 2014).

Table 5. Amino acid composition in *N. macrophylla* and *B. aegyptiaca* seed cakes

AMINO ACID	**NMSC**	**BASC**	**SPI*** Tang *et al.,* (2006)	**FAO/WHO (1973)**	**FAO/WHO (1985)** requirements (g/day for 70 kg adult)
Leucine	7.21	7.62	7.00	7.00	2.73
Lysine	4.96	5.25	5.39	5.00	2.10
Isoleucine	4.03	4.32	4.48	4.00	1.40
Phenylalanine	3.73	3.99	5.30		1.75
Tryptophan	0.87	1.02	ND	1.00	
Valine	3.74	3.83	4.41	5.00	1.82 (includes cysteine)
Methionine	1.12	1.26	0.93		1.05 (includes tyrosine)
Proline	3.66	3.86	5.20		
Arginine	4.82	5.25	7.57		
Tyrosine	2.75	3.10	3.71		
Histidine	1.82	2.17	2.90		
Cystine	0.73	0.91	0.06		
Alanine	3.60	3.83	3.83		
Glutamic acid	11.36	12.42	21.29		
Glycine	3.35	3.09	3.86		
Threonine	3.00	3.22	4.10	4.00	1.05
Serine	3.43	3.67	5.48		
Aspartic acid	7.63	8.21	11.81		
Total amino acids	71.81	77.02	97.32		
PPER	2.42	2.59	2.32		

NMSC: *N. macrophylla* seed cake, BASC: *B. aegyptiaca* seed cakes, SPI: Soy protein isolate.
NA: Not Available. Values are means of duplicate analyses.

The percentage of total neutral amino acid (% TNAA) in the samples is 57.46 and 56.76. The percentage of TNAA (57.46 and 56.76) > % TAAA (18.99 and 20.63) > % TBAA (11.60 and 12.67) > % TSAA (1.85 and 2.17) > % TArAA (4.60 and 5.01). The % TAAA (18.99 and 20.63) obtained were greater than the % TBAA (11.60 and 12.67) and indicated that NMSC and BASC proteins might be acidic in nature. Similar statements were made and reported in (Ogungbenle and Ebadan, 2014).

The overall quality of NMSC and BASCproteins can be assessed by their high essential amino acid content out of the total amino acid. This study revealed that 100 g of NMSC and BASC proteins provide good quantities of leucine (7210 mg and 7620 mg), isoleucine (4030 mg and 4320 mg), threonine (3000 mg and 3220 mg) and lysine (4960 mg and 5250 mg). Following FAO/WHO, the recommended values of essential amino acids (mg/kg body weight per day) for adult humans are isoleucine (20), leucine (39), lysine (30), methionine and cysteine (15), phenylalanine and tyrosine (25), threonine (15), tryptophan (4) and valine (26), (FAO/WHO/UNU, 2007). The predicted protein efficiency ratio (P-PER) is one of the parameters used for protein evaluation. The result of P-PER obtained for the cake samples (2.42 and 2.52) as shown in Table 5 were compared favorably with 2.62 reported for *Dalium guineense* (Ogungbenle and Ebadan, 2014).This investigation provides therefore valuable information on amino acid composition and classification, which suggest that NMSC and BASCcould be good sources for preparation of protein concentrates, isolates and hydrolysate for industrial uses.

Table 6. Summary of amino acid composition of *N. macrophylla* and *B. aegyptiaca* seed flour (mg/g protein)

AMINO ACID CLASSIFICATION	NMSC	BASC
Total amino acids (TAA)	71.91	77.02
Total essential amino acids (TEAA) with histidine	32.24	34.52
TEAA/TAA (%)	44.83	44.82
Total essential amino acids (TEAA) without histidine	34.06	36.69
Total non essential amino acids (TNEAA)	39.67	42.50
TNEAA/TAA (%)	55.16	55.18
Total sulphur amino acids (TSAA)	1.85	2.17
Cystine (%) in TSAA	39.46	41.94
Total aromatic essential amino acids (ArEAA) phe + tyr.	6.48	7.09
Total acidic amino acids (TAAA) % Glu. + Asp.	18.99	20.63
Total basic amino acids (TBAA) % Lys. + Arg. + His	11.60	12.67
Total neutral amino acids (TNAA)	41.32	43.72
Total neutral amino acids (TNAA)%	57.46	56.76
Ratio of TEAA:TNEAA%	81.27	81.35
Predicted protein efficiency ratio (PPER)	2.42	2.59

NEMC: *N. macrophylla* seed cakes, BASC: *B. aegyptiaca* seed cake, Values are means of duplicate analyses.

Conclusion

N. macrophylla and *B. aegyptiaca* seed cakes are valuable sources of nutrients and protein. The seed cakes have higher protein content than the seed flours. The seeds possessed considerable amount of essential amino acids and mineral elements which could be useful for both infants and adults and were comparable with the values recommended by FAO/WHO standards. The NMSC and BASC showed good pasting properties and can be blended with other seed meals in appropriate proportions for optimum amino acid balance. The knowledge derived would be helpful in the preparation of adequate protein isolates or concentrates with tailor-made amino acid composition. They could therefore serve as good source of quality raw materials for other industrial applications.

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