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NUTRITIONAL AND ANTINUTRITIONAL EVALUATION OF INDIGENOUS ETHIOPIAN OKRA (*ABELMOSCHUS ESCULENTUS)* SEED ACCESSIONS

Habtamu FG[1*], Haki GD[2], Fekadu B[1], Rakshit SK[3] and ZWAshagrie[4]

Habtamu Fekadu Gemede (PhD)

*Corresponding author email: fekadu_habtamu@yahoo.com or simbokom@gmail.com

[1]Department of Food Technology and Process Engineering, Wollega University, P.O. Box: 395, Nekemte, Ethiopia

[2]Department of Food Science and Technology, Botswana College of Agriculture, Botswana University, Gaborone, Botswana

[3]Department of Chemical Engineering, Canada Research Chair (Tier 1), Lakehead University, Thunder bay, ON, Canada P7B 5E1

[4]Center for Food Science and Nutrition Program, Addis Ababa University, P.O. Box 1176, Addis Ababa, Ethiopia

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ABSTRACT

Okra, of high nutritional potential, is one of the underutilized indigenous vegetables in Ethiopia. A food based-intervention specifically dietary diversification is an affordable and sustainable strategy to meet the demand of adequate food supply and population growth. One way of ensuring dietary diversity is to search and promote underutilized indigenous plant species such as okra. Therefore, the objective of this study was to determine nutritional and anti-nutritional factors content of the seeds of eight okra accessions (OPA#1, OPA#2, OPA#3, OPA#4, OPA#5, OPA#6, OPA#7 and OPA#8) grown at Assosa Agricultural Research Center in Benishangul Gumuz region, Ethiopia. Molar ratios of the seeds were also calculated and compared to the critical values to predict the mineral bioavailability. All the analyses were conducted using official standard procedures and grade standard reagents. The results of this study revealed that the proximate composition (g/100 g) of the seed accessions varied significantly ($P<0.05$) and had respective ranges for moisture content 9.27-12.70, crude protein 22.51-38.09, crude fat 18.64-36.84, crude fibre 1.94-5.96, crude ash 4.53-6.05, utilizable carbohydrate 18.69-37.77 and metabolisable energy 324.88-423.84 kcal/100g. The mineral composition (mg/100g) also varied significantly ($P<0.05$) with range of calcium 66.37 to 103.66, iron 8.33 to 20.29, potassium 90.00 to 187.92, zinc 3.92 to 6.42, phosphorus 16.94 to 1497.23 and sodium 15.06 to 27.81. The seeds of accession of OPA#6 contained high amounts of crude protein and fat, whereas OPA#8 was high in calcium, iron and potassium. The range of phytate, tannin and oxalate content (mg/100g) of the seed of okra accessions ranged from 0.39 to 0.46, 0.71 to 3.78, 0.74 to 0.75, respectively. The calculated molar ratios of phytate:calcium, phytate:iron, phytate:zinc, oxalate:calcium and phytate*calcium/zinc were 0.0025 to 0.0037, 0.0017 to 0.0041, 0.0063 to 0.106, 0.0020 to 0.0051 and 0.0140 to 0.0175, respectively, below the critical value, indicating high bioavailability of calcium, iron and zinc in all accessions. The results of this study revealed that seeds of okra contain appreciable amounts of essential nutrients and are low in anti-nutrient content implying high mineral bioavailability. Hence, increasing the production and consumption of these nutrient rich underutilized okra seeds could help in food fortification, dietary diversification and alleviation of problems associated with malnutrition in the country.

Key words: Okra, Seed, Accession, Proximate composition, Minerals, Anti-nutritional factors

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INTRODUCTION

Okra (*Abelmoschus esculentus*) is a vegetable crop that belongs to the Malvaceae family and which originated in Ethiopia [1]. Okra is now widely spread and grown in tropical, sub-tropical and temperate parts of the world [2]. Considering the little contact between Ethiopia and the rest of the world within historic times, the routes by which okra was taken from Ethiopia to other countries like North Africa, the eastern Mediterranean, Arabia, and India is not documented [3]. Okra is a multipurpose crop due to various uses of the pods, fresh leaves, buds, flowers, stems and seeds. Its seed is a rich source of essential nutrients and could serve as a source of protein and crude fibre [4].

Roasted okra seed is used as a coffee additive [5]. Okra seed flour can also be used to fortify cereal flour to increase protein, ash, oil and fibre contents [6]. Its seed is known to be rich in high quality protein especially with regards to its content of essential amino acids relative to other plant protein sources [7] and hence, it plays a vital role in the human diet. Its seed oil is also rich in unsaturated fatty acids such as linoleic acid, which is an essential fatty acid for human nutrition [8]. Therefore, promoting the consumption of okra could provide cheap sources of nutrients that can improve the nutritional status and reduce the prevalence of malnutrition especially among resource-constrained households and can also be used as a means of dietary diversification [9].

However, okra seed is considered as an underutilized crop and there are no published studies available on nutritional compositions of seeds of okra grown in Ethiopia. In addition, one of the major drawbacks limiting the nutritional qualities of food is the presence of anti-nutritional factors [10]. In this regard, seeds of okra do not only have beneficial nutrients but might also contain traces of anti-nutritional factors, which have adverse effects on bioavailability of some minerals like calcium, iron and zinc. There is also scarcity of information regarding anti-nutritional contents of the seeds of the indigenous Ethiopian okra vegetable. Therefore, the aim of this study was to evaluate nutritional composition and anti-nutritional factors of seeds of eight okra accessions grown in Benishangul Gumuz Region, western Ethiopia.

MATERIALS AND METHODS

Sample collection and preparation

Initially, Assosa Agricultural Research Center collected okra accessions in the 2012 and 2013 harvesting seasons from different areas of the Benishangul Gumuz Region and grew on their plot farm under the same agro ecological conditions during the 2014 main cropping season. The seeds of eight okra accessions labeled (OPA#1, OPA#2, OPA#3, OPA#4, OPA#5, OPA#6, OPA#7 and OPA#8) were harvested from the plot farm of Assosa Agricultural Research Center in Benishangul Gumuz Region, Ethiopia during the 2014 main okra harvesting season. The seeds were manually removed from the pods, sorted and sun dried. The dried seeds of the accessions were milled separately into fine powder using an electric grinder until they could pass through a 0.425 mm sieve size, and finally packed into airtight polyethylene plastic bags and stored in the desiccator until required for analysis.

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Determination of proximate composition

Moisture content, total ash, crude protein, crude fibre, and crude fat of the okra seed accessions were determined according to AOAC [11] using sub components 925.09, 923.03, 979.09, 962.09, and 920.39, respectively. Utilizable carbohydrate content was calculated by difference [12]. The metabolisable energy content was determined by calculation from fat, carbohydrate and protein contents using conversion factors, 4kcal/g for protein, 9 kcal/g for fat and 4 kcal/g for carbohydrates.

Determination of mineral content

Minerals content analysis was done according to AOAC [11]. Sodium (Na) and potassium (K) concentrations were determined by using the standard flame emission photometer and phosphorus (P) was determined colorimetrically by the vanadomolybdate procedure. Calcium (Ca), iron (Fe), and zinc (Zn) concentrations were measured using atomic absorption spectrophotometer.

Determination of anti-nutritional factors

Phytate was determined according to the method described by Vantraub and Lapteva [13]. Oxalate was analyzed using the method originally used by Ukpabi and Ejidoh [14]. Tannin content was determined according to the method described by Maxson and Rooney [15]. The molar ratio between anti-nutrient and mineral was obtained after dividing the mole of anti-nutrient by the mole of minerals [16].

Statistical analysis

The Completely Randomised Design (CRD) was used with two parallel measurements. All the statistical analyses were performed using SPSS version 20.0 for windows. Data were evaluated by use of one way analysis of variance (ANOVA). Means of results were separated by the Duncan's multiple range test and reported as mean ± standard error (SE). A p-value of 0.05 or less was considered as statistically significant.

RESULTS

Proximate composition

Proximate composition of the seeds of eight okra accessions are presented in Table 1. The level of moisture content varied from 9.27 to 12.70 g/100g. The seeds of okra accession OPA#5 had significantly ($P<0.05$) higher(12.70g/100g) moisture content than all other accessions except accession OPA#7 (12.46 g/100g) but OPA#2 was significantly ($P<0.05$) low in moisture content (9.27g/100g).The protein content of the seeds of okra accessions varied from 22.51g/100g in OPA#3 to 38.09 g/100g in OPA#6.The seeds of accession OPA#6 was significantly ($P<0.05$) high (38.09g/100g) in crude protein while OPA#3 was the lowest (22.51 g/100g) in crude protein content. The levels of crude fat varied from 18.64 g/100g (OPA#3) to 36.84 g/100g (OPA#2).

The seeds of OPA#2 were significantly ($P<0.05$) high in crude fat content (36.84 g/100g) followed by OPA#4 (33.85 g/100g), OPA#7 (33.53 g/100g) and OPA#5 (31.43 g/100g) in that order. However, OPA#3 was low in crude fat content (18.64 g/100g). The content of crude fibre varied from 1.94 to 5.96 g/100g in OPA#2 and OPA#3 accessions,

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respectively. The crude fibre content (5.96 g/100g) of okra seed accession OPA#3 was high whereas crude fibre content (1.94 g/100g) of accession OPA#2 was the low. The level of ash content ranged from 3.6 5g/100g (OPA#1) to 6.05 g/100g (OPA#2). The crude ash content of accession OPA#2 was significantly (P<0.05) high (6.05 g/100g) whereas that of accession OPA#1 was the lowest (1.94 g/100g).

The seeds of accession OPA#3 were significantly (P<0.05) high in utilizable carbohydrate content (37.77 g/100g) followed by OPA#1 (23.62 g/100g) and OPA#6 (18.69 g/100g) in that order. However, OPA#7 recorded the lowest utilizable carbohydrate content (18.64 g/100g) but this was not significantly (P>0.05) different from OPA#4 (10.97 g/100g) and OPA#5 (12.78 g/100g). The metabolisable energy content of okra seed accessions varied from 324.8 kcal/100g to 423.84 kcal/100g in OPA#6 and OPA#2 accessions, respectively. The seeds of accession OPA#2 was significantly (P<0.05) high in metabolisable energy content (423.84 kcal/100g) and was followed by OPA#1 (382.91 kcal/100g), OPA#4 (370.01 kcal/100g) andOPA#5 (376.32 kcal/100g) in that order. However, OPA#6 was low in metabolisable energy content (324.8 kcal/100g).

Mineral composition

The mineral composition of the seeds of the eight okra accessions is shown in Table 2. The seeds of accession OPA#8 were significantly (P<0.05) high in calcium content (103.66 mg/100g) followed by OPA#6 (89.89 mg/100g), OPA#5 (85.62 mg/100g) and OPA#3 (84.31 mg/100g) in that order. However, accession OPA#1 was low in calcium content (324.8 kcal/100g). The level of iron content of the seeds was significantly (P<0.05) high in OPA#8 (20.29 mg/100g) and OPA#1 (20.08 mg/100g) while low in OPA#5 (9.14 mg/100g) and OPA#6 (8.33 mg/100g) accessions.

The content of zinc in seeds of okra accessions ranged from 3.92 mg/100g in OPA#5 to 6.42 mg/100g in OPA#6. Zinc content of the seeds of accession OPA#6 was high (6.42 mg/100g) while accession OPA#5 was low (3.92 mg/100g). The phosphorus content of seeds of OPA#8 (1497.23 mg/100g) was significantly (P<0.05) high and was followed by OPA#7 (1304.27mg/100g), OPA#5 (1221.07 mg/100g) and OPA#6 (1048.21 mg/100g) accessions in that order. However, OPA#2 (516.94 mg/100g) was low in phosphorus content. Potassium content of the seeds of OPA#7 was high (187.92 mg/100g) while OPA#6 was low (90.00 mg/100 g). Sodium content of OPA#4 was high (27.98 mg/100g) while OPA#3 was the low (15.06 mg/100g).

Anti-nutritional factors composition

The anti-nutritional factors composition of seeds of the eight okra accessions is shown in Table 3. The phytate content of seeds of the eight okra accessions ranged from 0.39 mg/100g in OPA#1 to 0.46 mg/100g in OPA#7. The oxalate content was significantly (P<0.05) high in OPA#1, OPA#2, OPA#4, OPA#6 and OPA#8 (0.75 mg/100g) accessions and low in OPA#3, OPA#5 and OPA#7 (0.74 mg/100g) accessions. Tannin content of seeds of okra accession OPA#7 (3.78 mg/100g) was significantly (P<0.05) high while OPA#4 (0.71 mg/100g) was low. The calculated Phy:Ca, Phy:Fe, Phy:Zn, Ox:Ca, and [Ca] [Phy]/[Zn] molar ratios of the seeds of okra accessions are shown in

Table 4. The value of Phy:Ca, Phy:Fe, Phy:Zn, Ox: Ca, and [Ca] [Phy]/[Zn] molar ratiosranged from 0.0025 to 0.0037, 0.0017 to 0.0041, 0.0063 to 0.106, 0.0020 to 0.0051 and 0.0140 to 0.0175, respectively.

DISCUSSION

The mean moisture content (11.22 g/100g) of the seed accessions is almost comparable to the value reported for two okra seed cultivars; 9.6 to 11.7g/100g [17], but higher than the value reported for raw okra seeds; 7g/100g [18] and this might be due to the variation of agro-ecological conditions, genetic factors, and maturity stage. The mean of crude protein (31.88 g/100g) of the seed accession was higher than those reported for okra seed by Aminigo and Akingbala [18] (21 g/100g); Ndangui *et al*. [19] (24.85 g/100g) [19] and Manal *et al.* [1] (22.30 to 26.81 g/100g) [1]. The mean of crude fat (29.21 g/100g) of the seed accession was higher than those reported for okra seed vegetables by Ndangui *et al*. [19] (23.44 g/100g) and Aminigo and Akingbala [18] (16.00 g/100g). The high crude fat values obtained indicate that okra seed accessions could be used in improving palatability of foods in which they are incorporated. The high crude fat values also signify that these seed accessions can be viable sources of oil.

The mean of crude fibre (4.29 g/100g) content of okra seed accession was lower than those reported for okra seed by Ndangui *et al*. [19] (9.7 g/100g) and Manal *et al*. [1] (13.00 to 17.00 g/100g). Crude fibre protects the body against colon cancer, diabetes and cardiovascular illnesses [20]. It provides bulk to food to relieve constipation [21]. Fibre in the diet is also important as it helps to maintain human health by reducing cholesterol levels in the body [22]. Sathish and Eswar [23] also revealed that okra seed contains high fibre which controls blood sugar levels. The mean ash content of the seed accession was 4.70g/100g, which is close to that reported for okra seed (5.68 g/100g) [19] and lower than the value reported for a variety of okra seed (9.02 g/100g) [1]. The high ash content in the sample indicates the percentage of inorganic minerals present in the food sample.

High mineral content in foods enhances growth and development and also catalyses metabolic processes in the human body. The okra seed contained fairly high ash content, which indicates that the seed would provide essential minerals needed for body development. The mean utilizable carbohydrate content of the seed accession was 18.71 g/100g, which is lower than the value reported for okra seed varieties by Manal *et al*. [1] (29.44- 36.13 g/100g) and Ndangui *et al*. [19] (36.83 g/100g). The possible variations are probably as a result of genetic and environmental factors. Manal *et al*. [1]) and Ndangui *et al*. [19] also reported that okra seed contained high metabolisable energy of 379 to 440 kcal/100 g and 385.13 kcal/100g, respectively. The high metabolisable energy values obtained indicate that okra seed could constitute a major source of energy.

Minerals are considered to be essential in human nutrition [24]. Minerals are vital for the overall mental and physical wellbeing and are important constituents of bones, teeth, tissues, muscles, blood and nerve cells [25]. They help in the maintenance of acid-base balance, response of nerves to physiological stimulation and blood clotting [26]. The mean calcium content (81.77 g/100g) of the seed accession was higher than those reported for okra seed by Ndangui *et al*. [19] (78.65 mg/100g), but lower than those

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reported for okra seed (245 mg/100g) [27]. Calcium is a constituent of bones and helps in muscle contraction, blood clotting and nerve transmission [25]. When the calcium supply to the body becomes insufficient, the body extracts the needed calcium from the bones. If the body continues to draw more calcium than it replaces over a period of years, the bones will become weak and break easily.

Okra seed is a good source of iron which is an important component of haemoglobin in the red blood cells and myoglobin in the muscle [28]. It helps in the formation of blood and in the transfer of oxygen and carbon dioxide from one tissue to another [29]. Zinc plays a role in the proper functioning of some sense organs as in taste and smell. The mean concentration (1007.16 mg/100g) of phosphorus in okra seeds was lower than the value reported by Ndangui *et al*. [19] (1450 mg/100g).

Potassium content of seed accessions was higher than the value reported for okra seed (109.76 mg/100g) [19]. Potassium is a significant body mineral, important to both cellular and electrical functions [25]. High concentration of potassium in the body was reported to increase iron utilization [30] and was beneficial to people taking diuretics to control hypertension and excessive excretion of potassium through the body fluid [31]. Sodium content of seed accession was lower than the value reported for okra seed (54.78 mg/100g) [19]. Sodium helps maintain normal blood pressure and normal function of muscles and nerves [25]. Sodium regulates fluid balance in the body and helps in the proper functioning of muscles and nerves.

Phytate is a very stable and potent chelating food component that is considered to be an anti-nutrient by virtue of its ability to chelate divalent minerals and prevent their absorption [32]. Currently, however, there is evidence that dietary phytate at low levels may have a beneficial role as an antioxidant, anti-carcinogen and likely plays an important role in controlling hypercholesterolemia and atherosclerosis [33]. Oxalates can have a harmful effect on human nutrition and health, especially by reducing calcium absorption and aiding the formation of kidney stones [34]. High-oxalate diets can increase the risk of renal calcium oxalate formation in certain groups of people. The toxicity effects of the tannin may not be significant since the total acceptable tannic acid daily intake for a man is 560 mg/100g [35]. Okra seed contain low phytate and oxalate.

Phytic acids markedly decrease Ca bioavailability and the Phy:Ca molar ratio has been proposed as an indicator of Ca bioavailability with a critical molar ratio [Phy]: [Ca] of $<$ 0.24 indicating good calcium bioavailability [16]. The values in this study were lower in all accessions than the reported critical molar ratio of phytate to calcium, indicating that absorption of calcium is not adversely affected by phytate in all the accessions. The phytate: iron molar ratio greater than 0.15 is indicative of poor iron bioavailability [36]. This result indicated that the phytate:iron molar ratios of all the accessions were less than the critical value, which implies that the absorption of iron in all the accessions is not inhibited by phytate and as a result the bioavailability of iron is good. Phytate: zinc molar ratios >15 is indicative of poor zinc bioavailability [9]. The values of okra seed accessions were lower than the critical molar ratios of Phy:Zn, which indicates good bioavailability of zinc.

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The importance of oxalate contents of an individual plant product in limiting total dietary Ca availability is of significance only when the ratio of Ox:Ca is greater than one [37]. From the result, it was observed that the Ox:Ca values of all okra pod accessions are lower than the reported critical value (1.0).This implies that a low level of oxalate could have no adverse effects on bioavailability of dietary calcium in these accessions. High calcium levels in foods can promote the phytate-induced decrease in zinc bioavailability when the [Ca][phytate]/ [Zn] millimolar ratio exceeds 0.5 mol/kg [38]. The values of okra seed accessions were lower than the critical molar ratios of [Ca][phytate]/ [Zn], which indicates the availability of zinc high in all accessions.

CONCLUSION

This study indicates that there are significant differences in the proximate and mineral composition of the seeds of Ethiopian okra accessions. The seeds of okra accessions are found to be a good source of crude protein, crude fat, calcium, iron and potassium that could contribute useful amounts to the diet. The seed accession OPA#6 has good nutritional profile with high levels of crude protein and crude fat, whereas seed accession OPA#8 is high in calcium, iron and potassium and this is useful to the breeders for further improvement. The anti-nutritional contents of seeds of okra accessions are low, hence increasing the production and consumption of these nutrient rich underutilized indigenous okra seeds will help in food fortification, dietary diversification and alleviation of problems associated with malnutrition in the country.

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Table 1: Proximate composition of the eight okra seed accessions (g/100g dry weight basis)

Accessions	Moisture Content	Crude Protein	Crude Ash	Crude Fibre	Crude Fat	Util. Carbohy.	Metabolisable Energy (Kcal/100g)
OPA#1	$11.67 \pm 0.11^{b,c}$	27.66 ± 0.63^{c}	3.65 ± 0.27^{c}	$4.05 \pm 0.76^{a,b}$	$29.36 \pm 0.46^{d,e}$	23.62 ± 0.05^{b}	382.91 ± 5.29^{b}
OPA#2	9.27 ± 0.70^{e}	29.49 ± 0.34^{c}	6.05 ± 0.61^{a}	1.94 ± 0.72^{c}	36.84 ± 0.38^{a}	16.43 ± 0.63^{c}	423.84 ± 0.78^{a}
OPA#3	10.59 ± 0.01^{d}	22.51 ± 0.98^{d}	$4.53 \pm 0.01b^{c}$	5.96 ± 0.75^{a}	18.64 ± 0.83^{g}	37.77 ± 1.06^{a}	$359.84 \pm 4.39^{c,d}$
OPA#4	$11.09 \pm 0.13^{c,d}$	36.22 ± 0.40^{a}	$4.24 \pm 0.28b^{c}$	3.64 ± 0.20^{c}	33.85 ± 0.72^{b}	10.97 ± 0.02^{d}	$370.01 \pm 6.57^{b,c}$
OPA#5	12.7 ± 0.10^{a}	32.99 ± 0.26^{b}	$5.00 \pm 0.49ab^{c}$	$5.12 \pm 0.49^{a,b}$	$31.43 \pm 0.12^{c,d}$	12.78 ± 0.48^{d}	$376.32 \pm 1.54^{b,c}$
OPA#6	$11.3 \pm 0.30^{c,d}$	38.09 ± 0.31^{a}	3.92 ± 0.55^{c}	$5.23 \pm 0.68^{a,b}$	22.77 ± 0.30^{f}	18.69 ± 2.14^{c}	324.88 ± 6.57^{e}
OPA#7	$12.48 \pm 0.08^{a,b}$	33.83 ± 0.79^{b}	5.32 ± 0.40^{ab}	$3.89 \pm 0.54^{a,b,c}$	$33.53 \pm 1.51^{b,c}$	10.89 ± 0.42^{d}	$367.79 \pm 10.13^{b,c}$
OPA#8	$10.71 \pm 0.11^{c,d}$	34.25 ± 0.66^{b}	$4.91 \pm 0.12^{a,b,c}$	$4.53 \pm 0.31^{a,b}$	27.24 ± 0.11^{e}	18.53 ± 0.83^{c}	344.79 ± 4.41^{d}
Average	11.22	31.88	4.70	4.29	29.21	18.71	368.80

The values not followed by the same superscript letters in the same column are significantly different ($P<0.05$). Data are expressed as mean ± standard error of replicate determinations (n=2)

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Table 2: Mineral Concentration of the eight okra seed accessions (mg/100g dry weight basis)

Accessions	Calcium	Iron	Zinc	Potassium	Phosphorous	Sodium
OPA#1	66.37±0.50^{e}	20.08±1.48^{a}	4.18±0.02^{c,d}	166.22±1.99^{a}	797.90±16.58^{e}	27.60±0.57^{a}
OPA#2	75.58±0.92^{d}	15.26±0.86^{b}	4.56±0.02^{c}	97.17±0.86^{c}	516.94±15.19^{g}	19.16±0.59^{b}
OPA#3	84.31±0.89^{c}	14.46±0.32^{b}	6.19±0.08^{a,b}	174.87±3.11^{a}	633.09±18.30^{f}	15.06±0.56^{c}
OPA#4	72.66±1.04^{d}	11.75±0.67^{c}	4.16±0.12^{c,d}	165.27±10.5^{a}	1038.59±24.89^{d}	27.98±1.05^{a}
OPA#5	85.62±3.57^{b,c}	9.14±0.76^{d}	3.92±0.23^{d}	125.49±11.74^{b}	1221.07±4.88^{c}	26.88±0.54^{a}
OPA#6	89.89±0.45^{b}	8.33±0.18^{d}	6.42±0.19^{a}	90.00±1.15^{c}	1048.21±12.83^{d}	17.40±0.62^{b,c}
OPA#7	76.10±1.85^{d}	13.06±0.14^{b,c}	5.79±0.04^{b}	187.92±7.58^{a}	1304.27±5.82^{b}	27.81±0.59^{a}
OPA#8	103.66±1.33^{a}	20.29±0.91^{a}	4.38±0.21^{c,d}	175.01±3.41^{a}	1497.23±25.69^{a}	25.70±1.15^{a}
Average	81.77	14.04	4.95	147.74	1007.16	23.45

The values not followed by the same superscript letters in the same column are significantly different ($P<0.05$). Data are expressed as mean ± standard error of replicate determinations (n=2)

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Table 3: Anti-nutritional factors content of the accessions of the eight okra seed accessions (mg/100g dry weight bases)

Accessions	Phytate	Oxalate	Tannin
OPA#1	0.39±0.01[c]	0.75±0.01[a]	1.79±0.02[c]
OPA#2	0.43±0.00[b,c]	0.75±0.02[a]	3.22±0.21[b]
OPA#3	0.42±0.02[b,c]	0.74±0.01[b]	1.53±0.11[c,d]
OPA#4	0.42±0.01[b,c]	0.75±0.01[a]	0.71±0.03[e]
OPA#5	0.42±0.01[b,c]	0.74±0.03[b]	1.32±0.25[c,d]
OPA#6	0.41±0.02[b,c]	0.75±0.01[a]	1.23±0.19[d]
OPA#7	0.46±0.01 [a]	0.74±0.02[b]	3.78±0.20[a]
OPA#8	0.42±0.01[b,c]	0.75±0.01[a]	1.79±0.01[c]

The values not followed by the same superscript letters in the same column are significantly different (P<0.05). Data are expressed as mean ± standard error of replicate determinations (n=2)

Table 4: Molar ratios of the seeds of okra accessions

Accessions	Phytate: Ca	Phytate: Fe	Phytate: Zn	Oxalate: Ca	Phytate*Ca: Zn (mol/kg)
OPA#1	0.0036±0.004[a]	0.0017±0.001[c]	0.0093±0.0043[a]	0.0051±0.006[a]	0.0154±0.009[cd]
OPA#2	0.0034±0.001[a]	0.0024±0.001[b]	0.0093±0.0005[a]	0.0045±0.007[a]	0.0175±0.002[bc]
OPA#3	0.0030±0.005[b]	0.0024±0.001[b]	0.0067±0.0048[bc]	0.0040±0.006[ab]	0.0140±0.012[d]
OPA#4	0.0035±0.005[a]	0.0030±0.001[b]	0.0099±0.0048[a]	0.0046±0.009[a]	0.0178±0.005[b]
OPA#5	0.0030±0.012[b]	0.0039±0.027[a]	0.0106±0.0116[a]	0.0020±0.066[b]	0.0226±0.011[a]
OPA#6	0.0028±0.004[b]	0.0041±0.000[a]	0.0063±0.0042[c]	0.0038±0.030[ab]	0.0141±0.008[d]
OPA#7	0.0037±0.001[a]	0.0030±0.002[b]	0.0079±0.0010[b]	0.0045±0.016[a]	0.0150±0.007[d]
OPA#8	0.0025±0.007[c]	0.0017±0.001[c]	0.0095±0.0073[a]	0.0033±0.006[ab]	0.0245±0.014[a]

The values not followed by the same superscript letters in the same column are significantly different (P<0.05)

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