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NUTRITIONAL COMPOSITION OF SOME SELECTED, UNPROCESSED AMARANTH GRAIN (*Amaranthus spp*) VARIETIES IN NIGERIA

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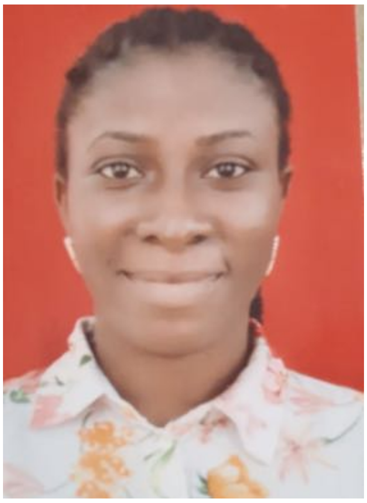

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ABSTRACT

The Amaranth grain is highly nutritious, yet it is hardly utilized in Nigeria. This study seeks to evaluate the nutritional composition of the various Amaranth grains available locally within the country. Five identified varieties were obtained from a research institute in Nigeria and a variety from the market in Ondo State, Nigeria. The six varieties were sorted separately and cleaned manually prior to grinding into flour and then subjected to chemical analysis which included proximate content, minerals, and anti-nutritional composition. An investigation of the constituting proximate, minerals and anti-nutritional compositions of the grain flours was conducted, using standard procedures. Proximate composition was determined using the Association of Official Analytical Chemists (AOAC) methods, carbohydrates were determined by difference, energy content was determined using bomb calorimetry model, mineral analysis were done using atomic absorption spectrophotometer and flame photometer while the anti-nutrients were determined using potassium permanganate titration method and spectrophotometrically. The results were analyzed using ANOVA ($p < 0.05$) which showed significant difference between the moisture content of the market sample and other types (9.50 – 12.13%). Also, the fat and crude fibre contents of Amaranth grain flour ranged from 5.84 to 21.06 % and 0.61 to 2.07 %, respectively. Though the protein contents of the flour samples were not significantly different (14.36 – 16.03%) from each other, the mineral composition (calcium 193.34 – 247.91 mg/100g, magnesium, 65.59 – 73.48 mg/100g, manganese 6.13 – 13.24 mg/100g, sodium 360 – 435 mg/100g) was relatively high. The anti–nutrient composition showed that the varieties were low in phytate and the values ranged from 0.21 –1.74 mg/100g, the oxalate level of the varieties averaged 15.02 mg/100g for the six samples, the tannin level ranged from 9954.6 to 13565 mg/100g. The study showed that Amaranth grain flour is potentially a food commodity item for value addition either by its lone use or in composite flour formulation.

Key words: Amaranth grain flour, Proximate analysis, Protein content, Minerals, Anti–nutrients, Nigeria

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INTRODUCTION

Amaranth is a versatile herbaceous broadleaf plant with an upright growth habit; both its seeds and leaves are cultivatable; however, the produce is underexploited despite its economic and nutritious values [1]. Amaranth grain just like buckwheat and quinoa is referred to as pseudo cereal because it is used like cereal grains, although it is not in the grass family. Amaranth grain belongs to the family *Amaranthaceae* and has been cultivated as grain for 8,000 years. It originated from America and Europe and there are about 60 – 70 species of Amaranth, with three species selected for human and animal consumption over the years. The choice species are *Amaranthus hypochondriacus, Amaranthus cruentus, Amaranthus caudatus* [2]. This is because they produce edible and light-colored seeds. Furthermore, amaranth is one of the common indigenous vegetables produced and consumed in Africa as it serves as a cheap source of vitamins and proteins to both the rural and urban dwellers. In Nigeria, Amaranth is commonly cultivated for its leafy vegetable and the grain receives little or no attention for consumption. This could be because of its low crop productivity and little awareness of the importance of the crop as most people refer to the grain as a minor crop [3]. In Nigeria, it is called '*tete'* in Yoruba, '*alaiyaho'* in Hausa and '*imne'* in Igbo (These are the major tribes in Nigeria).

The grain is useful as flour, popcorn, flakes, and can be fermented, roasted, or extruded, thereby serving both babies and adults [4]. The flour can be combined with wheat to make bread and other confectioneries; it can also be made as porridge just like oat porridge.

Amaranth grain has nutritional benefits that makes it a unique grain among other pseudo cereals. Studies have shown that the Amaranth grain exhibits antioxidant activity because of the polyphenols, anthocyanin, flavonoids, and tocopherols content and these antioxidants have been found to be effective as anti-cancer, anti-aging, anti–inflammatory, anti–viral and anti–bacterial agents in the human body [5]. Amaranth grain is an excellent source of iron and beta carotene, therefore, it can help in reducing iron and vitamin A deficiency [6].

In Nigeria, the nutrient–dense amaranth grain remains underutilized though it is widely grown and has potential to contribute to the food security hence, the need to evaluate the nutritional properties of some available cultivars in Nigeria. This will promote the effective and efficient utilization of the grain for replacement of non–wheat flours promoted in the manufacturing of bakery or other flour–based products in Nigeria. Few studies have been carried out to investigate the proximate and mineral compositions of different species of amaranth grains [4, 7].

This study therefore determined the proximate composition, mineral composition and anti–nutritional factors of five (5) known accessions and market sample of amaranth grain flours.

Studies on anti–nutrients composition of unprocessed amaranth grain are limited. Due to the underutilization of this grain in Nigeria, it is important to determine the availability and quality of this underutilized crop.

MATERIALS AND METHODS

The varieties of *Amaranthus spp* used for this research were collected from National Horticultural Research Institute (NIHORT) Ibadan, Oyo State and Ondo Town Central Market, Ondo State in Nigeria. Five identified varieties which are RRC–18C (*Amaranthus* hybrid), NHA/IB (*Amaranthus cruentus*), CEN/IB/97/AMA011 (*Amaranthus dubius*), TE81/760A (*Amaranthus cruentus*), NHA/16B (*Amaranthus cruentus*) were collected from the institute while *Amaranthus spp* was collected from the market in Ondo, Ondo State. The varieties collected from NIHORT were selected based on their yield, seed weight, resistance to drought, physical appearance, and cultivation in different parts of the country, while the market sample represented the specie that is usually available in Nigerian markets.

The Amaranth grains were sorted and manually cleaned to remove dirt and debris. The grains were milled into flour using a blender (Panasonic mixer grinder, MX–AC210S) and further packed in sealed low–density polyethylene bags prior to analysis.

Chemical analysis

Proximate composition of the grain was determined using AOAC method [8] for moisture content (AOAC 930.15), fat content (Soxhlet extraction method – AOAC 930.09), crude protein content (kjeldahl method – AOAC 978.04), ash content (AOAC – 930.05) and crude fibre content (AOAC 978.10). The carbohydrate content was determined by difference. The energy content was determined using the bomb calorimetry model as described by Eleanor *et al.* [9].

Mineral contents were analyzed using the dry ashing method [8] prior to the determination of Zinc (Zn), Iron (Fe), Magnesium (Mg), Manganese (Mn), Calcium

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(Ca) using atomic absorption spectrophotometer, while sodium and potassium were determined using a flame photometer. For the anti–nutrients, oxalate content was determined using potassium permanganate titration method, while phytate content and tannin content were determined spectrophotometrically [10]. Analyses were carried out in triplicates, and data were analyzed using ANOVA and means separation (P < = 0.05).

RESULTS AND DISCUSSION

Proximate composition

The chemical properties of Amaranth grain flours are presented in Table 1. The results showed a significant difference P ≤ 0.05 between the moisture content of the market sample and the sample varieties. The moisture content values ranged from 9.50 to 12.13 %. Sample NHA/IB had the highest moisture content of 12.13 %, while the market sample had the lowest moisture content of 9.50 %. The moisture content of the flour falls within the recommended moisture range (12 – 13 %) for flour stability. Low moisture is important for safe storage of food products against microbial growth, particularly certain species of fungi since they cannot grow at lower moisture environment [11]. Fungi will not grow at lower moisture but at about 14% or slightly above, thus making amaranth grain flour unsuitable for fungal growth. However, the high moisture content in the flour would encourage the growth of molds and can reduce the shelf life of the flour [11].

The fat content ranged from 5.84 to 21.60 %, with sample NHA/16B having the lowest fat content and market sample having the highest value. Sample NHA/IB and market samples were significantly different in fat content from other varieties. Also, a similar study reported that the fat content in Amaranth grain is twice the measure of wheat [1]. It has been found that fat content can vary in a wider range depending on the species, cultivar, agro–technological practices or growing location involved. Another factor that tends to influence the increase of the grain's fat content is the application of a high level of Nitrogen/Phosphorus/Potassium (NPK) fertilizers during production [12].

The colour and the composition of oil from the amaranth grain flour are like corn oil and buckwheat oil. The oil possesses high degree of unsaturation, thus, the fatty acids composition might be altered during processing, although some varieties can still possess good oxidation stability [13].

The crude fiber content showed significant differences (P ≤ 0.05) among the varieties, ranging from 0.61 to 2.07 %, with sample CEN/IB/97/AMA011 and the

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market sample having the lowest and highest value, respectively. Fibers such as the plant non–digestible carbohydrates and lignin found in food are known to have a lot of health benefits including the reduction of obesity tendencies, cardiovascular diseases, type II diabetes, digestive disorders, and some cancers [14]. The fibre content of the market sample falls within the crude fibre of 2.0 – 2.5% which is recommended by the protein advisory group for weaning formulation [15]. This implies that Amaranth grain flour can be used in the formulation of complementary foods.

The ash content of the market sample was significantly different ($P \leq 0.05$) from the other varieties. The values ranged from 1.40 to 5.18 %. The ash contents were similar when compared with the ash content of wheat flour (1.5 to 2.0%), except for the market sample, which was significantly higher. The difference in the ash content of the market sample and other Amaranth grain flours could be from the altitudinal differences in cultivation and their varietal types.

The carbohydrates content ranged from 47.17 to 65.96 %, with samples NHA/16B and the market sample having the highest and lowest values, respectively. According to United States Department of Agriculture [16], the amount of carbohydrate in Amaranth grain flour is different from that in wheat flour which is 72.57%. This makes Amaranth grain flour suitable as a healthy flour to address the unhealthy change in dietary patterns as it could contribute to lowering the energy density of food intake [17]. Foods high in carbohydrates have been associated with diet and nutrition–related diseases such as obesity, type II diabetes, and cardiovascular diseases [17].

The protein contents of the various flour species ranged from 14.36 to 16.03 %. This is similar to the earlier findings on the protein content of Amaranth grains, 13.57 – 14.60 % [18]. These protein contents of varieties of Amaranth grain flour fell within the range of 13–19 % which qualify them as high protein flours [19]. Compared to other pseudo–cereals like quinoa, buckwheat, the protein content of amaranth grain is higher which makes it more attractive for research [20, 21]. Also, due to this notable protein quality, amaranth grain can be used as composite flour with wheat flour. Wheat flour is of a lower nutritional quality when compared with Amaranth grain flour since its protein is deficient in essential amino acids such as lysine and threonine. Value–added foods can be produced using Amaranth grains, with the intention to minimize the prevalence of protein–energy malnutrition and micronutrient malnutrition. This can be used as composite flour in food items such as bread, biscuits, flour for reconstitution and other bakery products consumed in large quantities. Such production would contribute to the reduction of importation of

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wheat [20]. The amount of lysine in amaranth grain flour is two or three times higher than wheat, rice, and maize. The amount of sulphur amino acids of the flour is greater than legumes, which makes amaranth grain flour an important and inexpensive source of protein [19]. According to Ogbonnaya *et al.* [22], the amount of protein in cassava flour (11.16%) is lower than the amount present in the amaranth grain flour. This indicates that amaranth grain flour could be used as alternative for High Quality Cassava Flour (HQCF). In 2005, the Federal Government of Nigeria developed a policy to include HQCF in bakery and confectionaries products to reduce the cost of wheat importation and to reduce the rate of unemployment in Nigeria [23].

The food energy values ranged between 374.44 kCal/100g and 441.00 kCal/100g, with sample NHA/16B having the lowest energy value (373.44 kcal/100g), and the market sample carrying the highest value. Ali stated that any food plant that provides 12% of the caloric value from protein is considered a good source of protein [24]. Thus, Amaranth grain flour can be classified as a nutritionally satisfactory food and a good source of protein because it contributes more than 12% to the energy values.

The pH of the flour samples was significantly different from each other, ranging from 6.65 to 6.92. This also corresponds to the pH value of wheat flour and cassava flour which is usually between 6.0 and 6.8 [25]. The human body pH is alkaline but the intake of carbohydrates either in their raw state or processed form renders them ultimately acidic. This tendency on increasing body acidity dislocates the pH balance of the body system, thereby causing innumerable health problems. However, since Amaranth grain is slightly acidic, it might not really affect the pH balance of the body unlike the high acid food.

Mineral content

Minerals are inorganic components of diets which perform biochemical and physiological functions in living cells. The mineral content of Amaranth grain flour varieties is shown in Table 2. The iron content of the varieties of Amaranth grain ranged from 17.92 to 56.43 mg/100g. The iron content of the Amaranth grain flour samples (17.92 to 56.43 mg/100g) indicate that they are a good source of iron, and the concentration in 100g samples is slightly above the recommended daily intake of 15 mg, but falls within the range of 30 mg to 60 mg elemental iron/day recommended for pregnant women [26]. According to Rodriguez *et al.* [21], iron from Amaranth grain is mostly in an absorbable form, and it helps in increasing haemoglobin content in the body. However, there is a need for further research on the bioavailability of the mineral composition of the amaranth grain as there are limited studies on this area. On the other hand, the market sample had a significantly ($P \leq 0.05$) higher content (56.43 mg/100g). According to Alvarez–Jubete *et al.* [1], the level of iron in amaranth flour is seven times more than that of wheat flour thus making it a good complement to wheat flour.

The calcium content of the Amaranth samples ranged from 193.34 mg/100g to 247.91 mg/100g. Although other pseudo–cereals such as buckwheat and quinoa have high calcium content, amaranth grain has higher calcium content than the other pseudo–cereals [1]. Also, the calcium content was higher than that of wheat, which was 34.8 mg/100 g. This makes Amaranth grain flour a good source of calcium that is essential for growth, maintenance of bones, teeth, and muscle [1].

The zinc contents of Amaranth grain flour varieties ranged between 5.42 mg/100g and 18.10 mg/100g. These values are in close range with previous values obtained for Amaranth grains, (6.27 mg/100g, and 5.2 mg/100g [18]. Consumption of Amaranth grain can stabilize the zinc concentration and reduce complications from diseases [27]. The manganese contents ranged from 8.60 mg/100g to 13.42 mg/100g, and the magnesium content ranged from 65.59 to 73.48 mg/100g. The values for manganese and magnesium content were higher than those obtained by Mburu *et al.* [4] and Tanimola *et al.* [18] for manganese. Mburu *et al.* [4] reported higher magnesium concentration in Amaranth grains. Wheat flour is a poor source of magnesium when compared to Amaranth grain flour, hence Amaranth grain flour is suitable for composite flour blend. Magnesium is a component of chlorophyll, and it is an important content in connection with ischemic heart disease and calcium metabolism in bones [28].

Anti–nutritional composition of amaranth grain flour

Anti–nutritional factors are compounds that reduce the nutrient utilization and/or food intake of plants or plant products consumed by man, which play an important role in determining the use of plants for humans and animals. Figure 1 shows the anti–nutritional content of the grains' varieties. The Amaranth grain varieties contain oxalate ranging from 5.57 mg/100g to 20.34 mg/100g, a measure lower than 91 mg/100g as reported by Njoki *et al.* [29]. Amaranth grain flour contains a moderate quantity of oxalate. A high amount of soluble oxalate in the body prevents the absorption of soluble calcium ions to form insoluble calcium oxalate complex [27].

The phytate concentrations were between 0.21 mg/100g and 1.73 mg/100g with sample NHA/IB and the market sample having the lowest and highest values, respectively. The phytate values is similar to values from other studies as they

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range from 0.29 – 7.92 mg/100g. Phytate can chelate divalent metal ions and prevent their absorption. Phytate has been observed to be a cause of the indigestion of food and flatulence in humans [28]. The values for tannin content ranged from 9954.67 to 13565.67 mg/100g (Figure 2), which was equivalent to 0.0995 to 0.1357 %. Tannins are polyphenols that can form complexes with metal ions and macromolecules such as proteins and polysaccharides. Tannins are said to have an adverse effect on protein digestibility [28].

However, reduction of anti–nutrients (tannin, phytate and oxalate) in amaranth grain flour can be attained to a great extent by heat treatment, especially by wet processing to enhance nutrient bioavailability.

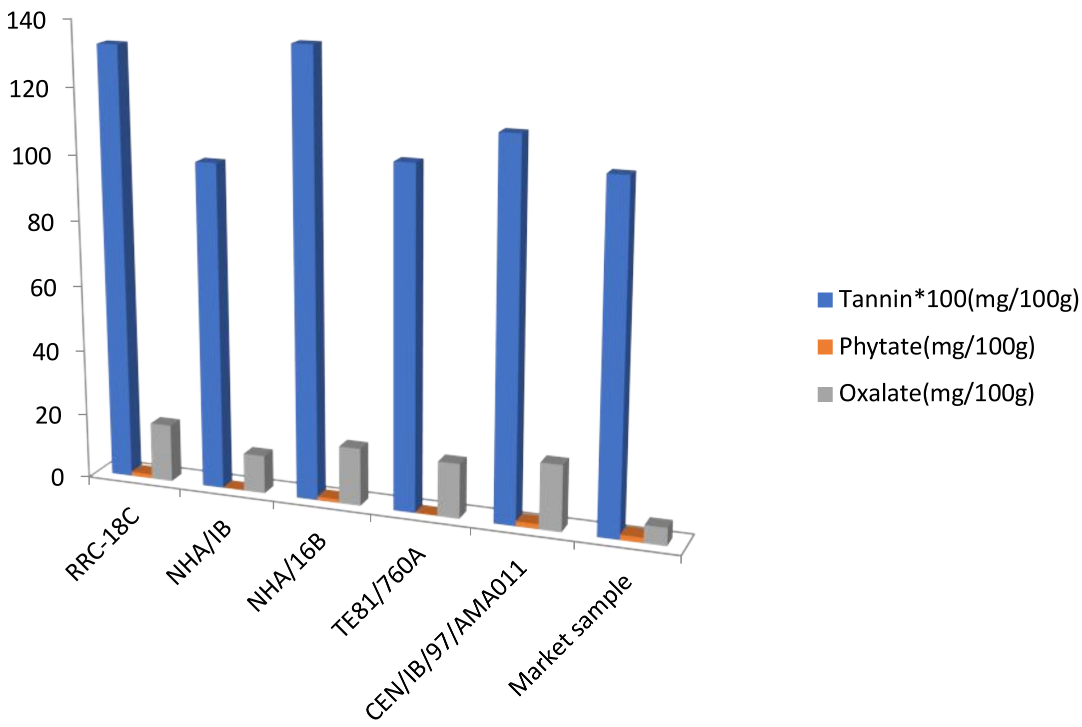

Figure 1: Anti–nutritional content of different Amaranth grain flours

CONCLUSION

This study presents Amaranth grain flour as a highly nutritious grain which is high in protein and mineral content. Therefore, Amaranth grain flour can either be used as a whole food or in composite flour formulation. It can also be used to boost the nutritional status of vulnerable people in the society. Also, varietal differences have little effect on the nutrient density and any of the varieties can be utilized. Further

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research to evaluate its protein digestibility and the antioxidant capacity is recommended.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Table 1: Chemical Composition of Varieties of Amaranth Grain Flour

Parameters	RRC–18C	NHA/IB	NHA/16B	TE81/760A	CEN/IB/97/ AMA011	Market sample
Moisture content (%)	11.781.16[a]	12.13±0.80[a]	11.14±0.91[ab]	10.70±1.00[ab]	11.70±1.63[a]	9.50±0.94[b]
Protein (%)	16.03±0.08[a]	14.36±0.08[c]	14.51±0.16[c]	15.40±0.06[b]	15.11±0.66[b]	14.48±0.12[c]
Fat (%)	7.54±0.43[c]	9.94±1.80[b]	5.84±0.16[d]	6.73±0.24[cd]	6.79±0.21[cd]	21.60±0.60[a]
Fiber (%)	1.55±0.12[b]	1.43±0.09[b]	1.15±0.12[c]	0.88±0.08[d]	0.61±0.05[e]	2.07±0.04[a]
Ash (%)	2.15±0.31[bc]	2.43±0.08[b]	1.40±0.95[c]	2.06±0.09[bc]	2.01±0.03[bc]	5.18±0.07[a]
pH	6.76±0.01[c]	6.92±0.01[a]	6.65±0.01[e]	6.73±0.01[d]	6.81±0.01[b]	6.75±0.01[c]
Carbohydrate (%)	60.95	59.71	65.96	64.23	63.78	47.17
Food energy (kcal/100g)	375.78	385.74	374.44	379.09	376.67	441.00

Note: RRC–18C (*Amaranthus hybrid*), NHA/IB (*Amaranthus cruentus*), CEN/IB/97/AMA011 (*Amaranthus dubius*), TE81/760A (*Amaranthus cruentus*), NHA/16B (*Amaranthus cruentus*), Market sample (*Amaranthus spp*)
*Values are means ± Standard deviation (SD) of 3 replications. Means within a row with the same superscript are not significantly different at 5% level of significance

Table 2: Mineral contents of varieties of amaranth grain flour (mg/100g)

Parameter	RRC–18C	NHA/IB	NHA/16B	TE81/760A	CEN/IB/97/AMA011	Market sample
Zinc	15.36	12.94	18.10	13.53	5.42	14.33
Calcium	208.36	209.61	213.76	202.49	247.91	193.34
Iron	21.77	17.92	23.12	20.15	27.56	56.43
Magnesium	65.62	67.38	66.02	65.59	67.08	73.48
Manganese	8.60	6.13	11.8	8.92	13.24	11.45
Potassium	2920	3280	2980	3200	2980	4900
Sodium	360	390	395	400	415	435

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