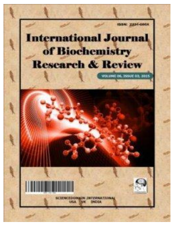

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Influence of Heat Processing on Nutrient Composition and Energy Values of Selected Cereals Consumed in Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author JCI, conceived and designed the study. Authors JCI and SCU wrote the protocol and first draft of the manuscript. Authors JCI, CE and CBL collected the samples, processed it and performed the proximate composition analysis. Authors FO, ACN, and AUO performed the mineral composition analysis. Authors JCI and FO managed the literature searches and interpreted the results. Authors JCI, CE and SCU performed the statistical analysis, proofread, and formatted the final manuscript. All authors read, corrected, and approved the final manuscript.

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ABSTRACT

Aims: The influence of heat processing on the nutrient composition and energy values of selected cereals (Sorghum, Maize, Millet, and Rice) consumed in Nigeria were investigated.
Study Design: Cereals samples (100 g each) were weighed out for processing prior to analysis. The weighed samples were divided into two lots of raw and cooked sample. Raw sample was sun dried, further oven dried for 24 hours and ground into flour which passed through a 30-mesh test

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sieve. The second lot was cooked to tenderness by boiling with deionized water for 15 minutes at 120ºC. Thereafter, the cooking solution was discarded. Samples were drained, oven dried, ground using a food grinder (Model MX 491N, National) into flour 20-mesh screen and stored in a clean dry air-tight sample bottle in a refrigerator (4ºC) until required for analysis.
Place and Duration of Study: Analysis was done at the Department of Biochemistry, Anambra State University, between April 2014 and May 2014.
Methodology: Proximate composition was determined following standard methods. Mineral compositions were determined using Bulk Scientific Atomic Absorption/Emission Spectrophotometer 200A.
Results: Cooking significantly (*P*<0.05) increased the moisture content of the samples with maize retaining the highest moisture content. Dry matter, crude protein, crude fat, ash, total carbohydrate and calorific values decreased significantly after heat processing. Cooking also decreased the level of divalent metals Fe, Zn, and Ca, but increased the monovalent metal Na compared to their levels in raw samples except Cu that decreased significantly.
Conclusion: Heat processing significantly decreased the nutrient compositions of cereals.

Keywords: Heat processing; nutrient compositions; cereals; trace minerals; monovalent metals; divalent metals.

1. INTRODUCTION

Cereals are the most widely cultivated and consumed crops on a global basis. In Nigeria especially in the Northern part of the country, cereals are the major source of energy and protein in the diets of the people. In many other developing countries of the tropics like Nigeria, protein deficiency in the diet is common and is usually found in association with deficiency in calories. Consequently, protein energy malnutrition is endemic, the situation is now complicated by continued inflation, economic recession, insufficient local production of animal protein sources, inefficient system for the distribution of the animal protein sources and above all the exorbitant cost, making it out of reach of the common man. The low income groups who constitute the bulk of the population are particularly at risk in such situation. They usually have no alternative but to depend on cereals which are cheaper than animal products. The cereals cultivated are sorghum, millet, maize rice, wheat. Together, these five crops occupy an estimated over 16 million hectares of farmland [1]. Nigeria is presently made up of six geo-political zones (north central, north-east, north-west, south-south, south-east and south-west). Sorghum, millet and wheat are mainly cultivated in Northern zones while rice and maize are mainly cultivated in southern zones.

Sorghum (*Sorghum bicolor*) is well known for its capacity to tolerate conditions of limited moisture and is produced during periods of extended drought. It is used for alcoholic beverages, pap breads, pan cake etc. Olusanya [2] stated that like other cereals, the protein of sorghum is of poor nutritional quality due to the low presence of methionine, cystine, lysine, tryptophan and histidine. He also stated that sorghum is somewhat high in phosphorus but very low in calcium, sodium, iron, copper, cobalt and chlorine. The proximate composition of the raw sorghum sample as reported by Olusanya [2] is as follows, carbohydrate (68-80%), protein (10-15%), moisture (11-12%), ash (2%), fibre (2%), fat (3%), food energy (394 calories) while the mineral composition of the raw sample are as follows: calcium (50.00 mg/100 g), phosphorus (358.00 mg/100 g), sodium (10.00 mg/100 g), potassium (310 mg/100 g), magnesium (180.00 mg/100 g) and iron (9.00 mg/100 g).

Millet (*Pennisetum americanum*) is a group of small seeded species of cereal crops widely grown around the world for food and fodder [3]. It is drought resistant and capable of growing and maturing quickly under short periods of rainfall. In Nigeria, the two main types of millets cultivated are *"Gero"* and "*Maiwa*" millets. The *"Gero"* millets are photo insensitive and early maturing while the *"maiwa"* are photo sensitive and late maturing [4]. They are used for breakfast, brewing beer, and in making *'fura'* which drinking together with fermented milk is called *'nunu'* mostly by the Northerners in Nigeria. Also it is used for making *'Kunu'* fermented drinks. As stated by Olusanya [2], the percentage carbohydrate content of the raw sample is (80.00%), crude protein (8.00%), ash (0.50%), moisture (11.00%) and calorific value of 334 calories. The major mineral elements in rice are calcium (12.00 mg/100 g), phosphorus (290.00 mg/100 g), sodium (78.00 mg/100 g), potassium (342 mg/100 g), magnesium (119.00 mg/100 g) and iron (2.00 mg/100 g) [2].

Maize (*Zea mays* spp) is the third most important cereal crop in the world, next to rice and wheat with regard to cultivation areas and total production. Maize is the second most important cereal crop in Nigeria ranking behind sorghum in the number of people it feeds. Increased animal production requires increased maize production to the tune of 7.9 million tones [1]. Maize is grown mainly for human consumption. It is utilized in Nigerian household for the preparation of various dishes. Both fresh and dry maize are utilized in a wide range of methods. Fresh maize are either boiled until seeds are soft or roasted over hot charcoal until brown. The boiled or roasted maize is usually eaten from the comb. It is also used as biomas fuel. Raw maize sample contains about 83.80% carbohydrate, 409.65 calorific value with fair amount of protein (9.00%) [2]. The proximate ash content is 3.13%, calcium (6.00 mg/100 g), iron (2.50 mg/100 g), sodium (50.00 mg/100 g), magnesium (160.00 mg/100 g) potassium (400 mg/100 g) [2].

Rice (*Oryza sativa*) belongs to the gramineae family. It is a tropical crop with the largest product. Rice is increasingly been an important cereal food in Nigeria. In Nigeria, people prefer the parboiled rice for different food recipes such as joll of rice, fried rice, rice food or *'Tuwoshinkapa'* by the Hausa's in Nigeria. Rice floor is also prepared and taken with soup. Raw rice sample like other cereals contains high percentage of carbohydrate (80.00%). The crude protein content is 8.00%, ash (0.50%), moisture (11.00%) [2]. The major mineral elements in rice are calcium (12.00 mg/100 g), phosphorus (290.00 mg/100 g), sodium (78.00 mg/100 g), potassium (342 mg/100 g), magnesium (119.00 mg/100 g) and iron (2.00 mg/100 g) [2].

The Nutritional importance of cereals as source of energy and protein has been emphasized. The effect of heat processing on nutrient composition of the cereals analyzed in this study has not been adequately investigated in Nigeria. There is therefore the need for a systematic investigation of the proximate composition, energy value, and levels of some minerals in these raw cereals and the effect of cooking on these nutrients.

2. MATERIALS AND METHODS

2.1 Sample Collection

The samples rice (*Oryza sativa*), maize (*Zea maize* spp) millet (*Pennisetum* spp) and sorghum were bought from Ihiala Local Market in Ihiala Local Government Area of Anmabra State.

2.2 Sample Preparation

Cereals samples (100 g each) were weighed out for processing prior to analysis. The weighed samples were divided into two lots of raw and cooked sample. Raw sample was sundried and further oven dried for 24 hours and ground into flour which passed through a 30-mesh test sieve. Each sample was stored in a clean dry air-tight sample bottle in a refrigerator (4ºC) until required for analysis. The second lot was cooked to tenderness by boiling with deionized water for 15 minutes at 120ºC. Thereafter, the cooking solution was discarded. Samples were drained and oven dried for 24 hrs using oven (Plus II Sanyo, Gallenkamp PLC, England). It is ground using a food grinder (Model MX 491N, National) into flour 20-mesh screen and appropriately stored as indicated above for the first lot prior to analysis.

2.3 Analysis of Samples

The proximate composition was determined using the recommended methods of the AOAC [5]. Moisture content was determined by heating three 2.0 g portion of each of the samples in an oven (Plus II Sanyo, Gallenkamp PLC, England) maintained at 105ºC until a constant weight was obtained. Ash was obtained by the incineration of 2.0 g samples in a muffle furnace (LMF4 from carbolite, Bamford, Sheffield, England) at 600ºC for 3 hours, while crude protein (*%N x 6.25*) was obtained by the Kjeldahl method [6] of Nitrogen determination using three 1.0 g portions of each samples. Crude fat was determined by exhaustively extracting 5.0 g sample (three replications) in soxhlet apparatus using petroleum ether with a boiling point range from 40-60ºC as the extractant. Total carbohydrate was calculated by the difference method (summing the values of moisture, Ash, crude protein and crude fat and subtracting the sum from 100).

The Energy value was obtained by multiplying the mean values for crude protein, crude fat and total carbohydrate by the Atwater factors of 4,9 and 4 respectively, taking the sum of the products and expressing the result in Kilocalories per 100 g sample [7]. The method of AOAC [5] was used for the determination of some minerals. Sodium, Calcium, Iron, Zinc, and Copper were determined by atomic absorption spectrophotometer (AAS) using Bulk Scientific Atomic Absorption/Emission Spectrophotometer 200A.

2.4 Data Analysis

Data were analyzed statistically using independent student T-test and one way analysis of variance (ANOVA) and means were compared by the Duncan's (1995) multiple range test. Significance was accepted at $P<0.05$.

3. RESULTS AND DISCUSSION

The result of proximate composition and energy values of raw cereal samples (Table 1) and heat processed cereal samples (Table 2) showed that the moisture content of raw cereals ranges from (13.31±0.24%) in rice to (21.80±1.40%) in maize differing significantly at $P<0.05$. The result is slightly higher to that reported by Olusanya [2] which has it that the moisture content of sorghum is 11.12% and 11% in both millet and maize. The difference may be due to cultivar differences. But generally, the moisture content of all the cereals investigated was low. The low moisture content of these cereals suggested why cereals could be stored for a long time without spoilage. However, cooking increased the moisture content of the samples. This may be attributed to the absorption of cooking water into the endosperm resulting to swelling and gelatinization of the starch.

The result also revealed that raw millet had significantly ($P<0.05$) higher crude protein (9.60±0.08%), crude fat (1.90±0.17%) and ash (4.03±0.12%) than sorghum, maize and rice. The high crude protein content could serve as alternative source of energy when carbohydrate metabolism is impaired via gluconeogenesis. Generally, there is low crude protein level in all the cereal investigated compared to recommended dietary allowance (RDA) of 13-14 g/day [8] for infants up to 1 year of age. Cereal proteins are limited in essential amino acid (lysine, threonine and tryptophan) [9]. However, cereal diet would require dietary supplementation with animal proteins or complimentary protein-rich legumes especially in diets meant for children and pregnant women [2].

The crude fat content of cereals obtained were low. This implies that cereal foods are not prone to deterioration via lipid peroxidation [10]. Crude fat ranged from (0.13±0.00%) in rice to (1.90±0.17%) in millet. These values will not be able to meet the RDA value of (10-25 g/day) for infants who may use this as complementary food during weaning [8], but not exceed 30 calories so as to avoid obesity and other related diseases [11]. The high ash content of millet (4.03±0.12%) suggested that millet are rich in mineral content compared to other cereals studied. Millet with ash content of more than 3.0% are therefore of nutritional importance as indicated by previous report by Onyeike et al. [12] that when leaves are to be used as food for humans they should contain about 3.0% ash.

Total carbohydrate was high in all the samples studied and ranged from (64.97±1.35%) in millet to (78.47±2.94%) in rice. The calorific value was also high in all samples with the highest value of (341.05 Kcals/100 g) in rice followed by (326.17±0.33 Kcal/100 g) in sorghum, the lowest value of (306.07±0.24 Kcal/100 g) was noted in maize. These values were statistically significant at $P<0.05$. The high level of total carbohydrate content of raw cereals investigated indicates that they contribute significantly to the energy content of food materials. Carbohydrate metabolism is needed in the generation of reducing potentials required to carry out biosynthetic activities.

Table 1. Proximate composition (%) and energy value (Kcal/100 g) of the raw cereal samples

Nutrient composition	Millet	Sorghum	Maize	Rice
Moisture	$19.50±0.20^{b}$	$18.27±0.24^{c}$	$21.80±1.40^{a}$	$13.31±0.24^{d}$
Dry matter	$80.50±0.02^{c}$	$81.70±0.01^{b}$	$77.20±0.12^{d}$	$86.70±0.02^{a}$
Crude protein	$9.60±0.08^{a}$	$7.97±0.21^{c}$	$8.70±0.16^{b}$	$6.50±0.24^{d}$
Crude fat	$1.90±0.17^{a}$	$1.53±0.21^{c}$	$1.63±0.16^{b}$	$0.13±0.00^{d}$
Ash	$4.03±0.12^{a}$	$2.10±0.34^{b}$	$1.47±0.24^{c}$	$1.50±0.16^{c}$
Total carbohydrate	$64.97±1.35^{d}$	$70.13±2.26^{b}$	$66.40±0.20^{c}$	$78.47±2.94^{a}$
Caloritic value (Kcal/100 g)	$315.38±0.29^{c}$	$326.17±0.33^{b}$	$315.07±0.24^{c}$	$341.05±0.26^{a}$

**Values are presented as mean±standard deviation of triplicate determination; values in the same row bearing the same superscript letters are not significantly different at 5% level*

The relatively high energy content of these raw cereals may be attributable to relatively higher nutrient (crude protein, crude fat, and total carbohydrate) content. For instance in (Table 1), the consumption of up to 500 g per day per consumption of raw samples of millet, sorghum, maize, or rice will provide energy value of (1576.90, 1630.85, 1575.35, or 1705.25 Kcal/100 g) respectively. The daily energy requirement of (2500-3000 Kcal/100 g) has been reported for adults [13]. It therefore follows that none of the raw and heat processed cereals investigated would meet the daily energy need of an adult if consumed at 500 g per day. These samples cannot therefore be consumed as a sole source of energy to humans. In other to derive full nutritional benefit of the samples, they should be consumed together with protein and fat-giving foods since low energy may lead to low birth weight and increased infant mortality [14].

Results of the mineral compositions (Fe, Zn, Cu, and Ca) levels of raw samples studied (Table 3) were higher than the values in heat processed samples (Table 4). Values of Fe ranged from (0.22±0.26 mg/100 g) in millet to (22.45±0.29 mg/100 g) in rice; Zn ranged from 0.79±0.31 mg/100g in rice to (3.17±0.26 mg/100 g) followed by millet (0.22±0.34 mg/100 g) and lowest in rice (0.15±0.29 mg/100 g) and Ca ranged from (1.88±0.29 mg/100 g) in rice to (15.23±0.37 mg/g) in sorghum. These differences may be as a result of cultivar differences, climatic and environmental condition of growing the cereals. However, there was increase in monovalent metal Na of heat procesed samples compared to raw samples except in millet. This may be attributable to dissociation of monovalent metals from other macromolecules component to which they are bound [12].

The mineral content of the cereals investigated were observed to be low except Fe in raw maize and rice which met the RDA of 18 mg/day [15]. These short falls could either be attributable to poor mineral content of the cereals or due to nutrient loss during processing [16]. FAO/WHO [17] reported that special emphasis should be placed on micronutrient composition, nutrient availability, and utilization of local diets. Thus adequate dietary iron intake is essential for infants and young children to prevent iron deficiency since growing infants has no iron stores and has to rely on dietary iron [17].

Zinc ion plays both catalytic and structural role in enzyme activity. It is an antioxidant capable of protecting cells from the damaging effects of oxygen radicals released during lymphocyte activation. Zinc deficiency impairs immunity and decreases resistance to infectious disease. The values of Zn in the samples investigated were below RDA of 11 mg Zn/day [18]. Copper levels were below RDA of 1.5-3.0 mg Cu/day [14]. Copper is an essential catalytic cofactor for selective oxidoreductases. It is essential for fundamental processes as energy transduction and iron metabolism. Inadequate supply of Cu decreases enzyme activity and hence affect oxidative phosphorylation in a number staples for most populations of the world at risk of micronutrient deficiencies [17]. Lack of sufficient micronutrient (Fe, Zn, Cu) in the diet affects the health and the development of children and results in potentially life threatening deficiency diseases such as anaemia [17]. Also a positive Ca balance is required throughout growth particularly during the first two years of life and children of this age group are always at risk of Ca deficiency [17]. Adequate calcium intake may be associated with protection against osteoporosis, polycystic ovarian syndrome and hypertension [19].

Table 2. Proximate composition (%) and energy value (Kcal/100 g) of heat processed cereal samples

Nutrient composition	Millet	Sorghum	Maize	Rice
Moisture	$67.78±2.05^b$	$51.27±2.49^d$	$75.07±2.89^a$	$60.34±2.94^c$
Dry matter	$28.36±0.02^c$	$48.73±0.01^a$	$23.36±0.30^d$	$38.06±0.22^b$
Crude protein	$4.36±0.29^b$	$4.40±0.16^b$	$4.53±0.26^a$	$2.60±0.24^c$
Crude fat	$0.53±0.29^b$	$0.43±0.25^c$	$0.60±0.29^a$	BDL
Ash	$1.73±0.26^a$	$0.50±0.24^c$	$0.30±0.37^a$	$1.16±0.31^b$
Total carbohydrate	$25.60±0.24^c$	$43.40±0.29^a$	$19.50±0.29^d$	$35.90±0.24^b$
Caloritic value (Kcal/100 g)	$124.61±0.21^d$	$211.07±0.31^a$	$167.12±0.27^b$	$154.00±0.37^c$

**Values are presented as mean±standard deviation of triplicate determination; values in the same row bearing the same superscript letters are not significantly different at 5% level. (BDL = Below detectable level)*

Table 3. Mineral composition (mg/100 g) of raw cereal samples

Mineral composition	Millet	Sorghum	Maize	Rice
Iron (Fe)	0.22±0.26[d]	4.23±0.29[c]	20.68±0.33[b]	22.45±0.29[a]
Zinc (Zn)	3.17±0.26[a]	1.80±0.21[c]	2.71±0.26[b]	0.76±0.31[d]
Copper (Cu)	0.22±0.34[b]	0.21±0.24[b]	0.36±0.25[a]	0.15±0.29[c]
Calcium (Ca)	3.43±0.29[c]	15.23±0.37[a]	3.67±0.21[b]	1.88±0.29[d]
Sodium (Na)	13.43±0.34[b]	8.81±0.29[c]	14.59±0.29[a]	8.04±0.24[d]

**Values are presented as mean±standard deviation of triplicate determination; values in the same row bearing the same superscript letters are not significantly different at 5% level*

Table 4. Mineral composition (mg/100 g) of heat processed cereal samples

Mineral composition	Millet	Sorghum	Maize	Rice
Iron (Fe)	0.23±0.29[ab]	0.24±0.36[a]	0.22±0.29[b]	0.24±0.43[a]
Zinc (Zn)	0.37±0.28[c]	0.56±0.29[b]	1.50±0.25[a]	0.20±0.33[d]
Copper (Cu)	0.22±0.34[a]	0.15±0.33[b]	0.08±0.29[c]	0.09±0.36[c]
Calcium (Ca)	2.70±0.29[a]	1.87±0.21[b]	0.09±0.25[d]	1.81±0.34[c]
Sodium (Na)	10.51±0.22[c]	25.75±0.29[a]	15.08±0.21[b]	9.76±0.25[d]

**Values are presented as mean±standard deviation of triplicate determination; values in the same row bearing the same superscript letters are not significantly different at 5% level*

Cooking (form of heat processing) generally increased the moisture content but decreased crude protein, crude fat, ash, total carbohydrate and calorific value in all the samples analyzed. The decrease may be due to loss of soluble beneficial nutrients to cooking water that is usually discarded. The heat treatment may also have denatured the proteins rendering them more susceptible to proteolytic degradation. This decrease were not considerable for food materials that must be heat treated in order to destroy natural antinutritional factors and derive their full nutritional potentials. Cooking increases the levels of monovalent metals Na and K but decrease those of the divalent element, iron, zinc, copper and calcium in the samples investigated.

4. CONCLUSION

Since heat processing significantly decreased the nutritive values of cereals and the fact that cereal grains will continue to be the basic diets of infants and adults in developing countries, effort should be geared towards adapting processing methods that will minimize nutrient loss as well supplement cereal diet with a very high protein source to be suitable as weaning foods.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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