

Original Research Article

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

ABSTRACT

Aims: The influence of heat processing on the nutrient composition and energy values of selected cereals (Guinea corn, 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 sieve. The second lot was cooked to tenderness by boiling with deionized water for 15 minutes at 120 °C. 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 (4 °C) 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 metals Na, K 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 sources of energy and protein in the diets of the peoples. 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

27 animal products. The cereals cultivated are sorghum, millet, maize rice, wheat. Together,
28 these five crops occupy an estimated over 16 million hectares of farmland [1]. Nigeria is
29 presently made up of six geo-political zones (north central, northeast, northwest, south-
30 south, southeast and southwest). Sorghum, millet and wheat are mainly cultivated in
31 Northern zones while rice and maize are mainly cultivated in south zones.

32 Sorghum (*Sorghum bicolor*) is well known for its capacity to tolerate conditions of limited
33 moisture and is produced during periods of extended drought. Sorghum can be grown under
34 a wide range of soil and climatic conditions. Its cultivation needs highest fertility for best
35 production. The seed is sown 4-5 m in a hole of not more than 20 cm deep at intervals of 40
36 cm apart. The grain gets matured 90 to 120 days [2]. It is used for alcoholic beverages, pap
37 breads, pan cake etc.

38 Millet (*Pennisetum Americanum*) is a group of small seeded species of cereal crops widely
39 grown around the world for food and fodder [3]. It is drought resistant and capable of growing
40 and maturing quickly under short periods of rainfall. In Nigeria the two main types of millets
41 cultivated are “Gero” and “Maiwa” millets. The “Gero” millets are photo insensitive and early
42 maturing while the “maiwa” are photo sensitive and late maturing [4]. They are used for
43 breakfast, cereals in brewing beer, it is used in making ‘fura’ which drinking together with
44 fermented milk is called ‘nunu’ mostly by the Northerners in Nigeria. Also it is used for
45 making ‘Kunu’ fermented drinks.

46 Maize (*Zea mays spp*) is the third most important cereal crop in the world, next to rice and
47 wheat with regard to cultivation areas and total production. Maize is the second most
48 important cereal crop in Nigeria ranking behind sorghum in the number of people it feeds.
49 The estimated animal production is about 7.9 million tones [1]. Maize is a warm season crop
50 requiring an optimum temperature of 30 °C during flowering and grain ripening. The
51 performance of the crop is greatly influenced by temperature, length of growing season,
52 day length, amount of distribution and efficiency of rainfall. Maize is grown mainly for human
53 consumption. It is utilized in Nigerian household for the preparation of various dishes. Both
54 fresh and dry maize are utilized in a wide range of methods. Fresh maize are either boiled
55 until seeds are soft or roasted over hot charcoal until brown. The boiled or roasted maize is
56 usually eaten from the comb. It is also used as biomass fuel.

57 Rice (*Oryza sativa*) belongs to the gramineae family. It is a tropical crop with the largest
58 product. It is swamp-loving and therefore has modification to resist water logging. It is
59 planted at temperature of about 20-30 °C and rainfall of 75-120 cm in a high fertility but
60 slightly acidic soil. Rice is increasingly being an important cereal food in Nigeria. The
61 estimate animal production is about 4.6 million tones. In Nigeria, people prefer the parboiled
62 rice for different food recipes such as jollof rice, fried rice, rice food or ‘Tuwoshinkapa’ by the
63 Hausa’s in Nigeria. Rice flour is also prepared and taken with soup.

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

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73 2. MATERIALS AND METHOD

74 2.1 Sample Collection

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

78 2.2 Sample Preparation

79 Cereals samples (100 g each) were weighed out for processing prior to analysis. The
80 weighed samples were divided into two lots of raw and cooked sample. Raw sample was
81 sundried and further oven dried for 24 hours and ground into flour which passed through a
82 30-mesh test sieve. Each sample was stored in a clean dry air-tight sample bottle in a
83 refrigerator (4 °C) until required for analysis. The second lot was cooked to tenderness by
84 boiling with deionized water for 15 minutes at 120 °C. Thereafter, the cooking solution was
85 discarded. Samples were drained and oven dried for 24 hrs using oven (Plus II Sanyo,
86 Gallenkamp PLC, England). It is ground using a food grinder (Model MX 491N, National) into
87 flour 20-mesh screen and appropriately stored as indicated above for the first lot prior to
88 analysis.

89 2.3 Analysis of Samples

90 The proximate composition was determined using the recommended methods of the AOAC
91 [5]. Moisture content was determined by heating three 2.0 g portion of each of the samples
92 in an oven (Plus II Sanyo, Gallenkamp PLC, England) maintained at 105 °C until a constant
93 weight was obtained. Ash was obtained by the incineration of 2.0 g samples in a muffle
94 furnace (LMF4 from carbolite, Bamford, Sheffield, England) at 600 °C for 3 hours, while
95 crude protein (%N x 6.25) was obtained by the Kjeldahl method [6] of Nitrogen determination
96 using three 1.0 g portions of each samples. Crude fat was determined by exhaustively
97 extracting 5.0 g sample (three replications) in soxhlet apparatus using petroleum ether with a
98 boiling point range from 40-60 °C as the extractant. Total carbohydrate was calculated by the
99 difference method (summing the values of moisture, Ash, crude protein and crude fat and
100 subtracting the sum from 100).

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

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108 2.4 Data Analysis

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

112 3. RESULTS AND DISCUSSION

113 The result of proximate composition and energy values of raw cereal samples (Tables 1) and
 114 heat processed cereal samples (Table 2) showed that the moisture content of raw cereals
 115 ranges from (13.31±0.24 %) in rice to (21.80±1.40 %) in maize differing significantly at
 116 $P<0.05$. The difference may be due to cultivar differences. But generally, the moisture
 117 content of all the cereals investigated was low. The low moisture content of these cereals
 118 suggested why cereals could be stored for a long time without spoilage. However, cooking
 119 increased the moisture content of the samples. This may be attributable to absorption of
 120 cooking water into the endosperm resulting to swelling and gelatinization of the starch.

121 **Table 1. Proximate Composition (%) and Energy Value (Kcal/100g) of the raw cereal**
 122 **samples**

Nutrient Composition	Millet	Guinea Corn	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/100g)	315.38±0.29 ^c	326.17±0.33 ^b	315.07±0.24 ^c	341.05±0.26 ^a

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

125 **Table 2. Proximate Composition (%) and Energy Value (Kcal/100g) of heat processed**
 126 **cereal samples**

Nutrient Composition	Millet	Guinea Corn	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/100g)	124.61±0.21 ^d	211.07±0.31 ^a	167.12±0.27 ^b	154.00±0.37 ^c

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

130 The result also revealed that raw millet had significantly ($P<0.05$) higher crude protein
 131 (9.60±0.08 %), crude fat (1.90±0.17 %) and ash (4.03±0.12 %) than Guinea corn, maize and
 132 rice. The high crude protein content of millet suggests its richness in essential amino acids.
 133 These amino acids serves as alternative source of energy when carbohydrate metabolism is
 134 impaired via gluconeogenesis. Generally, there is low crude protein level in all the cereal
 135 investigated compared to recommended dietary allowance (RDA) of 13-14 g/day [8] for
 136 infants up to 1 year of age. Cereal proteins are limited in essential amino acid (lysine,
 137 threonine and tryptophan) [9]. However, cereal diet would require dietary supplementation
 138 with animal proteins or complimentary protein-rich legumes especially in diets meant for
 139 children and pregnant women [10].

The crude fat content of cereals obtained were low. This implies that cereal foods are not prone to deterioration via lipid peroxidation [11]. 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 [12]. 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.*, [13] 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 Kcal/100g) in rice followed by (326.17±0.33 Kcal/100 g) in Guinea corn, the lowest value of (306.07±0.24 Kcal/100g) 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.

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, Guinea corn, maize, or rice will provide energy value of (1576.90, 1630.85, 1575.35, or 1705.25 Kcal/100g) respectively. The daily energy requirement of (2500-3000 Kcal/100g) has been reported for adults [14]. 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 [15].

Results of the mineral compositions (Fe, Zn, Cu, and Ca) levels of raw samples studied (Tables 3) were higher than the values in heat processed samples (Tables 4). Values of Fe ranged from (0.22±0.26 mg/100g) in millet to (22.45±0.29 mg/100g) in rice; Zn ranged from 0.79±0.31 mg/100g in rice to (3.17±0.26 mg/100g) followed by millet (0.22±0.34 mg/100g) and lowest in rice (0.15±0.29 mg/100g) and Ca ranged from (1.88±0.29 mg/100g) in rice to (15.23±0.37 mg/g) in Guinea corn. These differences may be as a result of cultivar differences, climatic and environmental condition of growing the cereals. However there was a decrease in monovalent metal (Na and K) of raw samples compared to heat processed samples. This may be attributable to dissociation of monovalent metals from other macromolecules component to which they are bound [13].

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

Mineral Composition	Millet	Guinea Corn	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

Potassium (K)	15.71±0.25 ^b	14.81±0.26 ^c	17.78±0.28 ^a	10.24±0.34 ^d
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181 *Values are presented as mean±standard deviation of triplicate determination; values in the
182 same row bearing the same superscript letters are not significantly different at 5% level.

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

Mineral Composition	Millet	Guinea Corn	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
Potassium (K)	20.32±0.29 ^c	46.55±0.29 ^a	19.93±0.29 ^d	23.93±0.34 ^b

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

186 The mineral content of the cereals investigated were observed to be low except Fe in raw
187 maize and rice which met the RDA of 18 mg/day [16]. These short falls could either be
188 attributable to poor mineral content of the cereals or due to nutrient loss during processing
189 [17]. FAO/WHO [18] reported that special emphasis should be placed on micronutrient
190 composition, nutrient availability, and utilization of local diets. Thus adequate dietary iron
191 intake is essential for infants and young children to prevent iron deficiency since growing
192 infants has no iron stores and has to rely on dietary iron [18].

193 Zinc ion plays both catalytic and structural role in enzyme activity. it is an antioxidant capable
194 of protecting cells from the damaging effects of oxygen radicals released during lymphocyte
195 activation. Zinc deficiency impairs immunity and decreases resistance to infectious disease.
196 The values of Zn in the samples investigated were below RDA of 11 mg Zn/day [19]. Copper
197 levels were below RDA of 1.5-3.0 mg Cu/day [15]. Copper is an essential catalytic cofactor
198 for selective oxidoreductases. It is essential for fundamental processes as energy
199 transduction and iron metabolism. Inadequate supply of Cu decreases enzyme activity and
200 hence affect oxidative phosphorylation in a number staples for most populations of the world
201 at risk of micronutrient deficiencies [18]. Lack of sufficient micronutrient (Fe, Zn, Cu) in the
202 diet affects the health and the development of children and results in potentially life
203 threatening deficiency diseases such as anaemia [18]. Also a positive Ca balance is required
204 throughout growth particularly during the first two years of life and children of this age group
205 are always at risk of Ca deficiency [18]. Adequate calcium intake may be associated with
206 protection against osteoporosis, polycystic ovarian syndrome and hypertension [20].

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

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219 4. CONCLUSION

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

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