

Effect of the Traditional Cooking Methods (Boiling and Roasting) on the Nutritional Profile of Quality Protein Maize

Omenna Emmanuel Chukwuma¹, Olanipekun Oyeyoyin Taiwo¹, Udouso Victory Boniface²

¹Institute of Agricultural Research and Training, Obafemi Awolowo University, Moor Plantation, Ibadan, Oyo State, Nigeria

²Federal College of Agriculture, Ibadan, Oyo State, Nigeria

Email address:

emmanuelomenna@gmail.com (O. E. Chukwuma)

To cite this article:

Omenna Emmanuel Chukwuma, Olanipekun Oyeyoyin Taiwo, Udouso Victory Boniface. Effect of the Traditional Cooking Methods (Boiling and Roasting) on the Nutritional Profile of Quality Protein Maize. *Journal of Food and Nutrition Sciences*.

Vol. 4, No. 2, 2016, pp. 34-40. doi: 10.11648/j.jfns.20160402.12

Received: January 12, 2016; **Accepted:** February 3, 2016; **Published:** May 11, 2016

Abstract: Freshly harvested yellow quality protein maize (QPM) was subjected to boiling and roasting. Proximate, nutrients and anti-nutrients analyses were carried out to investigate the effects of these treatments on the nutritional compositions and anti-nutrients content of quality protein maize. The result showed that the roasted quality protein maize (RQPM) had significantly higher crude proteins, crude fat, crude fiber, ash and carbohydrate value than the boiled quality protein maize (BQPM) and the raw (CQPM). There was an increased in energy value of roasted samples (355.41kcal/100g) whereas boiled samples recorded decreased energy value (73.04 kcal/100g). Roasting had significantly increased the level of Na, K, P, Ca and Mg while boiling slightly decreased the amount of these macro elements compared with the raw (CQPM). There was no significant difference in potassium content of all the samples. Roasted quality protein maize had higher amount of the micro elements (iron, zinc, copper, manganese, and selenium) than BQPM and CQPM. However, boiling had significantly reduced phytate content by 9.62% while roasting had 5.84% phytate reduction when compared with the raw. BQPM had significantly reduced oxalate by 7.03% while RQPM had 3.13% oxalate reduction. Both cooking methods (boiling and roasting) had similar reduction (50%) of tannin. The results demonstrated that boiling was more effective in the reduction of anti-nutritional factors than roasting. Processing had significant impact on the fat soluble vitamins of quality protein maize. RQPM had the highest vitamin A with 88.24% increment whereas BQPM had 8.78% reduction of vitamin A. Similar trend was observed in vitamin E. The effect of processing on the beta -carotene of the quality protein maize was in the increasing order: BQPM < CQPM < RQPM. The superiority of quality protein maize has been demonstrated by its high content of lysine (3.04% for RQPM, 1.73% for BQPM and 2.11% for raw, CQPM) and methionine content ranges from 1.27 to 2.01% for boiled and roasted samples respectively. Roasting enhanced the nutritional values of quality protein maize by increasing the lysine and methionine content. These two essential amino acids are limited in other cereal crops. Boiling appeared to have experienced nutrients loss when compared with others. Therefore, nutritional values of quality protein maize could be harnessed by roasting to meet the nutritional needs of humans and may be used in formulation of various foods.

Keywords: Quality Protein Maize, Boiling, Roasting, Nutritional Composition

1. Introduction

Nutrients losses during food processing and the impact of anti-nutrient factors have become the issue of concern in the recent times. Optimum cooking treatments will not only minimize nutrients loss but also reduce the anti-nutrient factors. Natural toxicants (anti-nutrients) are always present in food materials. The presence of anti-nutrients affects the

absorption and bioavailability of the food nutrients. Food processing therefore destroys (either by heat or other treatments) the concentration of toxins which exert adverse physiological effects when ingested by man and animals. This however affects the nutritional well-being and health of all people. Malnutrition still remains a widespread problem, and is particularly severe in developing countries with low per capital income. Maize is a major cereal crop for both livestock feed and human nutrition, worldwide.

With its high content of carbohydrates, fats, proteins, some of the important vitamins and minerals, maize acquired a well-deserved reputation as a 'poor man's nutraceutical' [29]. Quality protein maize has recently attracted much attention from the international market because of their high content of essential amino acids such as lysine, tryptophan and threonine. Cereal proteins contain on an average about 2% lysine, which is less than one-half of the concentration recommended for human nutrition by the Food and Agriculture Organization of the United Nations. Therefore, healthy diets for humans and other monogastric animals must include alternate sources of lysine and tryptophan. Quality protein maize is rich for local consumption in the tropics where their role in the human diet is more important than their caloric value [33]. However, no research and development works have been conducted on the effective cooking methods that would improve the nutritional values of quality protein maize. It is imperative therefore to assess the impact of traditional processing on its nutritional superiority. This information poses a major problem for both consumers and farmers.

Objectives

The specific objectives of this research work were to investigate the effect of:

- (1) Boiling on the macronutrients and micronutrients (minerals and vitamins) contents of quality protein maize (QPM)
- (2) Roasting on the macronutrients and micronutrients (minerals and vitamins) contents of quality protein maize (QPM)
- (3) Food processing on the anti-nutrient and proximate composition of quality protein maize (QPM)
- (4) To develop adaptable and appropriate cooking methods of maize based on the traditional treatments with minimum nutrients loss.

2. Method

Sample preparation: cooking /boiling and roasting of Quality Protein Maize.

Three bunches/cobs of quality protein were cooked until the same degree of doneness as adjudged by using the sense organs of taste, smell and touch to determine when the corns were properly cooked. Three bunches/cobs of quality protein maize cob were roasted using charcoal fire.

Proximate analysis of the boiled (BQPM), roasted (RQPM) and raw samples which was the Control (CQPM). Samples were analysed chemically according to the official methods of analysis described by the Association of Official Analytical Chemists [1]. All analysis were carried out in triplicate. Weight of sample digested in milligram x Vol. of digest for steam distillation. The crude protein content is determined by multiplying percentage Nitrogen by a constant factor of 6.25 i.e. % CP = % N x 6.25 [1]

Moisture, protein, ash, crude fibre, fat, vitamins and minerals were carried out using standard methods (AOAC, 2005). Carbohydrate was determined by difference. Calorific values of

samples were obtained by multiplying values of crude protein, crude fat and carbohydrate by 4, 9 and 4 respectively [3].

2.1. Oxalate Determination

2g of sample was boiled in 40ml of water for 30 minutes in a reflux condenser. Add 10ml of 20% Na_2CO_3 and boil for another 30 minutes. Filter the liquid extract and wash with hot water until the wash water does not show any alkaline reaction. Concentrate the combined wash water and filtrate to a small volume and cool. With constant stirring, add HCl (1: 1) dropwise until the final acid concentration after neutralization is about 4% at which stage a heavy precipitate appears (which is allowed to flocculate). Carefully filter the extract into a 250ml flask and make up to mark. Keep overnight, then filter supernatant liquid through a dry filter paper in a dry beaker.

Take an aliquot of this filtrate in a 400ml beaker, dilute with water to 200ml and make just ammoniacal, and reacidify with Lactic Acid. In the cold, medium, add 10ml of a 10% calcium chloride solution and stir well to include calcium oxalate precipitate to appear, and allow it settle overnight. Carefully decant the clean supernatant liquid off through Whatman No. 42 filter paper, without disturbing the precipitate. Dissolve the precipitate in HCL (1: 1). Oxalic acid is reprecipitated by adjusting the pH with ammonium hydroxide solution. Boil contents and allow to settle overnight. Determine oxalic acid by titrating against 0.05N KMnO_4 solution.

Calculation:

$$\begin{aligned}
 1\text{ml of } 0.05\text{N } \text{KMnO}_4 &= 0.00225 \text{ anhydrous Oxalic Acid} \\
 &= \% \text{ Oxalic Acid} \\
 &= \frac{\text{Titre value} \times 0.00225}{2} \times \frac{100}{1} \\
 &= \text{T.V} \times 0.1125. \quad [1]
 \end{aligned}
 \tag{1}$$

2.2. Phytate Determination

2g of each sample was weighed into 250ml conical flask. 100mls of 2% Hydrochloric Acid was added to soak each sample in the conical flask for 3 hours. This was filtered through a double layer of hardened filter paper. 50ml of each filtrate was placed in 0.50ml conical flask and 107mls distilled water was added in each case to give proper acidity. 10mls of 0.3% Ammonium Thiocyanate (NH_4SCN) solution was added into each solution as indicated. This was titrated with standard iron (III) chloride solution which contained 0.00195g Iron per ml. The end point was slightly brownish-yellow which persisted for 5 minutes. The % phytic acid was calculated using the formula:

$$\% \text{ Phytic acid} = \frac{\text{Titre value} \times 0.00195 \times 1.19 \times 100 \times 3.55}{\text{Wt. of Sample}} \tag{2}$$

2.3. Tannin Determination

0.20g of sample was measured into a 50ml beaker 20ml of

50% methanol was added and covered with parafilm and placed in a water bath at 77-80°C for 1 hour. It was shaking thoroughly to ensure a uniform mixing. The extract was quantitatively filtered using a double layered Whatman No 41 filter paper into a 100ml volumetric flask, 20ml water added, 2.5ml Folin-Denis reagent and 10ml of 17% Na₂CO₃ were added and mixed properly. The mixture was made up to

mark with water mixed well and allow to stand for 20min. The bluish – green color will develop at the end of range 0-10ppm were treated similarly as 1ml sample above.

The absorbance of the Tannic acid standard solutions as well as samples were read after color development on a spectronic 21D spectrophotometer at the wavelength of 760nm. Tannin was calculated using the formula.

$$\%Tannin = \frac{\text{absorbance of sample} \times \text{average gradient factor} \times \text{Dilution factor}}{\text{Wt of Sample} \times 10,000} \quad (3)$$

2.4. Determination of Vitamin E (Tocopherol)

1g of sample was weighed into a 250ml conical flask filtered with a reflux condenser. 10ml of absolute alcohol and 20ml of IM alcoholic Sulphuric acid were added. The condenser and flask were wrapped in a luminum foil and refluxed for 45 minutes and cooled for 15 minutes. 50ml of distilled water was added to the mixture and transferred to a 250ml separating funnel covered with aluminum foil. The unsaponifiable matters in the mixture were extracted with 5 x 30ml dimethyl ether. The combined extracts were washed free of acid and dry evaporated at a low temperature and the

residues obtained were immediately dissolved in 10ml absolute alcohol. Aliquots of solutions of the sample and standards (0.3-3.0mg vitamin E) were transferred to a 20ml volumetric flask, 5ml Absolute Alcohol added, followed by a careful addition of 1ml conc. HNO₃. The flasks were placed on a water bath at 90°C for exactly 3 minutes from the time the alcohol begins to boil. Cool rapidly under running water and adjust to volume with absolute alcohol. Measure the Absorbance at 470nm against a blank containing 5ml absolute alcohol and 1ml conc. HNO₃ treated in a similar manner.

$$\text{Vitamin E } (\mu\text{g}/100\text{g}) = \frac{\text{Absorbances of sample} \times \text{Gradient factor} \times \text{Dil.Factor}}{\text{Wt of sample}} \quad (4)$$

2.5. Vitamin A Determination

2g of each sample was weighed into a flat bottom reflux flask, 10ml of distilled water was added, shaken carefully to form a paste. 25ml of alcoholic KOH solution was added and a reflux condenser attached. The above mixture was heated in boiling water bath for 1 hour with frequent shaking. The mixture was cooled rapidly and 30ml of water was added. The hydrolysate obtained was transferred into a separatory funnel. The solution was extracted three times with 250ml quantities of chloroform. 2g anhydrous Na₂SO₄ was added to the extract to remove any traces of water. The mixture was then filtered into 100ml volumetric flask and made up to mark with chloroform. Standard solution of β-carotene Vitamin A of range 0 – 50 μg/ml with chloroform by dissolving 0.003g of standard β-carotene in 100ml of chloroform. The above gradients of different standard solutions prepared were determined with reference to their Absorbances from which average gradient was taken to calculate Vitamin A (β-carotene in μg/100g). Absorbances of sample and standards were read on the Spectrophotometer (Metrohm Spectronic 21D Model) at a wavelength of 328nm.

Calculations:

$$x\text{Vitamin A } (\mu\text{g}/100\text{g}) = \frac{\text{Absorbance of sample} \times \text{Dilution Factor}}{\text{Wt.of Sample}} \quad (5)$$

Calcium, potassium and sodium determination: The ash of each sample obtained was digested by adding 5ml of 2M HCl to the ash in the crucible and heat to dryness on a heating mantle. 5ml of 2 MHCL was added again, heat to boil, and filtered through a Whatman No. 1 filter paper into a 100ml volumetric flask. The filtrate was made up to mark with distilled water stoppered and made ready for reading of

concentration of Calcium, Potassium and Sodium on the Jenway Digital Flame Photometer(PFP7 Model) using the filter corresponding to each mineral element [1]. The concentration of each of the element was calculated using the formula:

$$\%Ca \text{ or } \%K \text{ or } \%Na = \frac{\text{Meter Reading (MR)} \times \text{Slope} \times \text{Dilution factor}}{100} \quad (6)$$

NB: MR x slope x dilution factor will give you the concentration in part per million (ppm or mg/kg). You get concentration in % when you divide by 10000.

2.6. Phosphorus Determination (Spectrophotometric Method)

Phosphorus was determined routinely by the vanado-molybdate colorimetric or spectrophotometric method [1].

Determination: The ash of each sample obtained was treated 2M HCl solution as described for calcium determination above. 10ml of the filtrate solution was pipetted into 50ml standard flask and 10ml of vanadate yellow solution was added and the flask was made up to mark with distilled water, stoppered and left for 10 minutes for full yellow development. The concentration of phosphorus was obtained by taking the optical density (OD) or absorbance of the solution on a Spectronic 20 spectrophotometer or colorimeter at a wavelength of 470nm. The percentage phosphorus was calculated from using the formula:

$$\%Phosphorus = \frac{\text{Absorbance} \times \text{Slope} \times \text{Dilution factor}}{10000} \quad (7)$$

2.7. Determination of Se, Cd, Cu, Mn, Fe and Zn

The digest of the ash of each sample above as obtained in calcium and potassium determination was washed into 100ml volumetric flask with deionised or distilled water and made up to mark. This diluent was aspirated into the Buck 200 Atomic Absorption Spectrophotometer (AAS) through the suction tube. Each of the trace mineral elements was read at their respective wavelengths with their respective hollow cathode lamps using appropriate fuel and oxidant combination.

2.8. Statistical Analysis

Data were analysed by the one way analysis of variance (ANOVA). Means were compared by the Duncan's multiple range test (DMRT) and significance was accepted at the 5% level.

3. Results and Discussions

3.1. Effect Processing on the Proximate Composition of QPM

Table 1. Percentage proximate composition of raw and processed quality protein maize.

	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Crude Protein	3.94± 0.05b	2.84± 0.06c	7.00 ± 0.11a
Crude Fat	1.31± 0.02b	1.08± 0.03c	4.65± 0.02a
Moisture	73.86±0.04b	81.53±0.04a	8.77±0.02c
Ash	0.88±0.01b	0.75±0.02c	2.49± 0.03a
Crude Fibre	1.05±0.02b	0.81±0.02c	2.20±0.02a
Carbohydrate	18.96±0.03b	12.99±0.03c	74.89±0.04a
Caloric Value(kcal/100g)	103.39±0.03b	73.04±0.03c	355.41±0.04a

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in a row are not significantly different (p<0.05).

Food processing may affect the functionality and nutritional quality of the food products. Effect of processing methods on the proximate composition of quality processed maize is given in table 1 above.

Protein content of RQPM sample was significantly higher (P<0.05) than CQPM and BQPM. This result indicated that heat treatment (roasting) improved the nutritional value of native protein. The proteins in raw samples were degraded and converted into soluble forms during boiling and this possibly led to low amount of proteins in BQPM. This observation agreed with other scientific findings that processing techniques such as germination and roasting improved the nutritional of food products particularly in terms of protein content [16]; [21]. This trend of decrease is similar to the observation made by Obasi and Wogu [23], who reported decrease in protein content of soaked yellow maize during soaking. The crude protein content of raw QPM was similar with that found in P₁- genotype QPM reported by Sentayehu [30].

Fat content of roasted sample, RQPM was significantly higher than CQPM and BQPM. This result is in agreement with Kavitha and Parimalavalli [16], who stated that roasted maize flour had more fat than the germinated and raw flours. The increased in the fat content of roasted QPM when compared with the raw QPM may be attributed to the increase activity of lipolytic enzymes which produced more free fatty acids. There was 17.56% reduction in boiled sample, BQPM. This result indicates that the fat loss phenomenon was experienced in boiling.

Moisture content of boiled sample, BQPM was the highest (81.53%) followed by CQPM (73.86%) and least in roasted, RQPM (8.77%). This result showed that roasting drastically reduced water activity. However, research had shown that the low moisture content of food samples is a desirable phenomenon since it reduces the microbial activity [17]. RQPM with low moisture content can be stored for a longer period of time without spoilage. It is note while that high moisture content in foods encourages microbial growth hence food spoilage may occur [27].

Roasted sample (RQPM) had the highest Carbohydrate content of 74.89% followed by the raw sample (18.96%) while the boiled sample had least (12.99%). This result was in contrast with the findings by Kavitha *et al.* [16] that raw maize flour (97.60%) contained higher carbohydrate content than the roasted flour (78.02%). Roasted quality protein maize proved to be a good source of energy.

Ash content of processed QPM samples varied significantly between 0.75% for BQPM and 2.49% for RQPM. The ash content of boiled sample was significantly lower than that of raw and roasted samples. The reduction in ash content may be due to the leaching of micro elements into the cooking/boiling water [19]. The roasted sample had significantly higher ash content than control, (raw) quality protein maize.

Similarly, RQPM had the highest fibre content (2.02%) followed by CQPM (1.05%) and least in BQPM (0.81%). This implied the digestibility of maize since the food fibres are known to aid digestion. Dietary fibres facilitate digestion and are reported to prevent colon cancers by Olanipekun *et al.* [27].

3.2. Effect of Processing on the Essential Amino Acids Content of QPM

The nutritional superiority of quality protein maize has been demonstrated by its high content of lysine and methionine. Methionine content ranges from 1.27 to 2.01% for boiled and roasted samples respectively. These two essential amino acids are limited in other cereal crops [30]. Table 2 showed that roasted sample had significantly higher methionine and lysine than boiled and raw samples. Roasting enhanced the nutritional value of quality protein maize by increasing the lysine and methionine content. However, boiling appeared to have experienced nutrients loss when compared with raw and roasted samples.

Table 2. Percentage essential amino acid concentration of processed QPM.

	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Methionine	1.55±0.02b	1.27±0.02c	2.01±0.03a
Lysine	2.11±0.02b	1.73±0.02c	3.04 ±0.02a

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in a row are not significantly different ($p < 0.05$).

3.3. Effect of Processing on the Vitamins Content of QPM

Processing had a significant impact on the fat soluble vitamins of quality protein maize as shown in table 3. RQPM has the highest vitamin A with 88.24% increment whereas BQPM had 8.78% reduction of vitamin A, This could be due to oxidation. Food processing affect fat soluble vitamins which are susceptible to oxidation. Roasting had improved the bioavailability of vitamin A, which acts the precursor of visual pigment 11-cis-retinal. Vitamin A is essential in maintaining healthy vision and play. Therefore, intakes of quality protein maize is highly recommended to ameliorate the cases of night blindness and blindness. It is worthy to note that roasting had significantly increased the beta carotene content of quality protein. The effect of processing on the beta –carotene of the quality protein maize is in the increasing order: BQPM < CQPM < RQPM. This finding supported that observation of Wang and Russell [31] that food processing and heating increased the level of 9-Cis β –carotene. However, β -carotene has been shown to act as an immune modulator, quench singlet oxygen, and reduce peroxy radicals at a low partial oxygen pressure [31]. Numerous animal and laboratory studies have substantiated β -carotene's ability to inhibit tumor cell growth and the progression of carcinogenesis [5]. Regular intake of roasted quality protein maize reduces the risk of lung and prostate cancers and therefore, this is recommended for smokers.

Table 3. Vitamin contents of raw and processed QPM (in $\mu\text{g}/100\text{g}$).

	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Vitamin A	183.52±0.03b	167.41±0.03c	345.45±0.15a
Vitamin E	71.25±0.02b	58.93±0.04c	86.73±0.02a
β -carotene	48.19±0.02b	45.05±0.02c	51.37±0.02a

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in a row are not significantly different ($p < 0.05$).

Vitamin E was significantly higher in roasted sample, RQPM than CQPM and BQPM. It is noteworthy that quality protein maize is rich in antioxidants which are essential to prevent cancers and stress related diseases. The roasted sample had higher β -carotene than the raw and boiled samples. Heating improves the bioavailability of β -carotene by breaking down the carotenoid complexes [31]. Heat treatment resulted in improved nutritional retention and less vitamin loss as it were in boiling. This trend is in contrast with the results by Olanipekun *et al.* [27] which stated that boiling had significantly improved the nutritional value of kidney flour.

3.4. Effect of Processing on the Mineral Elements Content of QPM

Quality protein maize is rich in micro- elements which play a vital role in the maintenance of human health. The iron content of processed QPM range from 4.95 to 7.10 mg/kg for boiled and roasted samples respectively. Roasting had significantly improved the iron content, while boiling reduced the amount of iron. Roasted quality maize is good source of iron which is an important component of blood and enzymes involved in electron transfer. Its deficiency results in fatigue, headache and sore tongue in addition to anaemia [28]. The results showed that RQPM had the highest amount of (5.90mg/kg) zinc followed by CQPM (4.95mg/kg) and least in boiled sample, BQPM (3.80mg/kg). The roasted whole grain of quality protein maize is a good source of zinc which plays essential role in normal taste sensation, protein and nucleic acid synthesis, carbohydrate metabolism, successful pregnancy, delivery and normal development [28] and. The bioavailability of Cu, Mn, and Se may due to the reduced amount of anti-nutritional factors which chelate with these minerals to form insoluble compounds.

There was no significant difference in calcium content of boiled and raw samples while the roasted sample had significantly higher in calcium ($p < 0.05$) than others. Hence, supplementary infant feeding with quality protein maize is needed for bone and teeth formation while. Cereals and legumes are rich in minerals but the bioavailability of these minerals is usually low due to the presence of anti-nutritional factors such as phytate and polyphenols [8]; [20]. An adequate mineral absorption is important for infants, children, older people and people in clinical situation [5]. The result of this work supported literature that different food processes such as soaking, germination and fermentation had significantly reduced of phytate content in cereals and vegetables. Phytic acid reduces the bioavailability of minerals [26]. Phytic acid as powerful chelating agent reduces the bioavailability of divalent cations by the formation of insoluble complexes [2]. This chelates divalent cations such as calcium, magnesium, zinc and iron, thereby also reducing their bioavailability [13]. The removal of undesirable components by processing is essential to improve the nutritional quality of cereals.

Table 4. Percentage (%) concentration of Macro-elements in raw and processed QPM.

	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Na	0.018±0.00c	0.024±0.00b	0.057±0.00a
K	0.280±0.00a	0.297±0.13a	0.330±0.00a
Ca	0.003±0.00b	0.003±0.00b	0.051±0.00a
P	0.117±0.00b	0.112±0.00c	0.297±0.00a
Mg	0.041±0.00b	0.026±0.00c	0.106±0.00a

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in a row are not significantly different ($p < 0.05$).

Table 5. Micro-elements contents (in mg/kg) of raw and processed QPM.

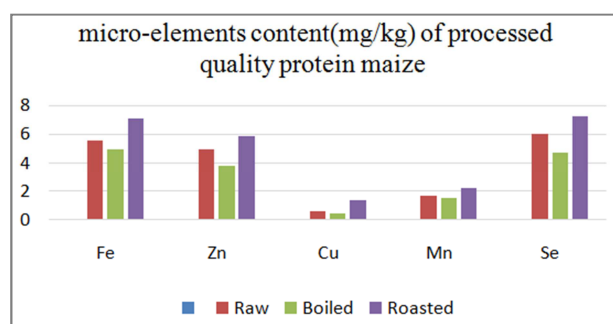
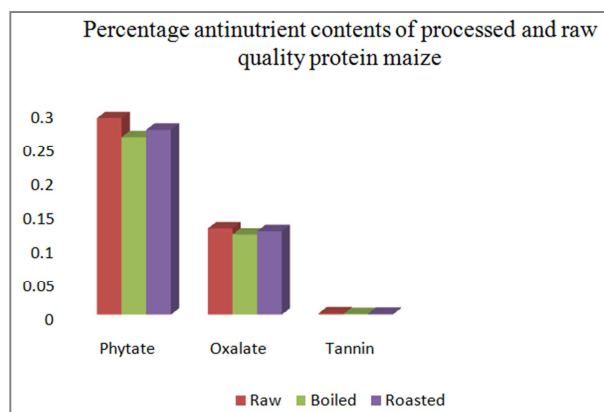
	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Fe	5.55±0.15b	4.95±0.15c	7.10±0.20a
Zn	4.95±0.15b	3.80±0.10c	5.90±0.20a
Cu	0.61±0.03b	0.45±0.02c	1.35±0.15a
Mn	1.68±0.02b	1.56±0.02c	2.20±0.10a
Se	6.00±0.20b	4.75±0.15c	7.25±0.15a

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in rows are not significantly different (p<0.05).

Table 6. Percentage composition of anti-nutrient factors of raw and processed QPM.

	Raw(CQPM)	Boiled(BQPM)	Roasted(RQPM)
Phytate	0.291±0.00a	0.263±0.00b	0.274±0.00b
Oxalate	0.128±0.00a	0.119±0.00c	0.124±0.00ab
Tannin	0.002±0.00a	0.001±0.00b	0.001±0.00b

Mean values of triplicate determination ± standard mean error. Mean values with the same letter in a row is not significantly different (p<0.05).

**Figure 1.** Micro-elements content of processed and raw quality protein maize.**Figure 2.** Anti-nutrients content of processed and raw quality protein maize.

4. Conclusion

This study concluded that quality protein maize is a nutritionally superior cereal with a substantial composition of methionine and lysine. Hence, traditional processing methods such as roasting had significantly improved the protein content and dietary fibres of quality protein maize as well as its vitamins and antioxidants in the form of β -carotene which would be useful in neutralizing free radicals in the body and reduce harmful effect of oxidative stress. Roasting had

significantly increased the concentration of macro and micro elements. Therefore, great nutritional values of quality protein maize could be harnessed by roasting to meet nutritional needs and may be used in formulation of various foods.

Acknowledgment

The authors appreciated the efforts of Mr Afolabi, O. O. in carrying out the laboratory bench works.

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