EFFECTS OF DEHULLING ON THE LEVELS OF MICRONUTRIENTS IN MAIZE, MILLET AND SORGHUM GRAINS

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Joseph Ikwebe*, Mida H. Mayel, Silas V. Tatah, Emmanuel Mamman and Dennis J. Sabo
Department of Biochemistry, Federal University Wukari, PMB 1020, Taraba State, Nigeria
*Corresponding author: i.joseph@fuwukari.edu.ng

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Abstract: Cereals are major staple foods in Nigeria, and are rich sources of nutrients especially when used as whole grains. However, to improve palatability and organoleptic qualities, most grains undergo further processing to yield better products. These processing include dehulling, dehusking, milling, etc. which may alter the nutritional composition of the resultant products to varying degrees. But, the outer parts of the kernels, especially the aleurone layer and the germ, tend to be richer in minerals when compared to the starch endosperm. The present study investigated the effect of dehulling on the levels of micronutrients (Fe, Zn and Mg) of grains (sorghum, millet and maize). The results revealed a clear negative effect of dehulling on the concentrations of Fe, Zn and Mg. In all the grains studied, Fe, Zn and Mg decreased significantly ($P < 0.05$) in the experimental samples when compared to the control samples. In real terms, this represented 40- 44% decrease in the levels of Fe, Zn and Mg in sorghum, 3-24% in maize and 2-7% in millet respectively. Although, dehulling of grains is carried out to also reduce the levels of antinutrients, it inevitably affects negatively the levels of desirable nutrients which are mostly located on the outer parts of the grains.
Keywords: Dehulling, maize, sorghum, millets, iron, zinc, magnesium

Introduction

Nearly two-thirds of the world's food production is made up of cereals, and along with pulses and oilseeds, form a major part of dietary proteins, calories, vitamins and minerals to the world population in general and to the developing world in particular (Betschart, 1982; Salunkhe and Desai, 1986; Badi, 1998). Diet in developing countries is based mainly on cereals and legumes (FAO, 2009; Schönfeldt and Hall, 2012), and 68 to 98% of the cereals produced in these climes are directly used for human consumption (Betschart, 1982; Chavan and Kadam, 1989). Globally, among plant-based foods, cereals are grown in over 73.5% of the world's arable lands (FAO, 2009).
Maize (*Zea mays*) is one of the primary staple cereal crops consumed in many African countries and more than 70 million metric tons of it are produced annually (Macauley, 2015). In many sub-Saharan African (SSA) countries, maize is reputed to be the preferred cereal crop for food, feed and industrial use, displacing traditional cereals such as sorghum and millets (Macauley, 2015). In fact, it is the most important cereal crop in SSA and an important staple food for more than 1.2 billion people in SSA and Latin America. Of the 158 million hectares of maize harvested worldwide, Africa accounts for 29 million hectares, with Nigeria, the largest producer in SSA, harvesting 3% (FAO, 2007). According to IITA, the grains are rich in vitamins A, C and E, carbohydrates, and essential minerals, and contain 9% protein. They are also rich in dietary fiber and calories which are a good source of energy (http://www.iita.org/crops/maize/).
Sorghum and millets are also major food sources for millions of people, especially those who live in hot and dry areas of the world. They are grown mostly on marginal areas under agricultural conditions in which major cereals fail to give substantial yields (Adekunle, 2012). They are the most drought-tolerant cereal grain crops and require little input during growth (Taylor *et al*., 2006). Although millet is a general term for a wide range of cereals, the name millet is used to describe seeds from several taxonomically divergent species of grass (Kamara *et al*., 2009). Millets are classified with maize, sorghum, and Coix in the grass sub-family *Panicoideae* (Yang *et al.*, 2012). Millets are a major source of energy and protein for millions of people in Africa and have been reported to have great nutritious and medicinal functions (Obilana and Manyasa, 2002; Yang *et al.*, 2012). Many varieties of millets are recognised; but the four major types are Pearl millet (*Pennisetumglaucum*), which comprises 40% of the world production, Foxtail millet (*Setariaitalica*) (Yang *et al.*, 2012), Proso millet or white millet (*Panicummiliaceum*), and finger millet (*Eleusinecoracana*). Millets are unique among the cereals because of their richness in calcium, dietary fibre, polyphenols and proteins (Devi *et al.*, 2011). They are generally known to contain significant amounts of essential amino acids, particularly the sulphur-containing amino acids (methionine and cysteine) (Obilana and Manyasa, 2002) as well as vitamins and minerals (Devi *et al.*, 2011; FAO, 2009).
Sorghum (*Sorghum bicolor* (L) Moench), is the fifth most important cereal after rice, wheat, maize, and barley (FAO, 2009), and constitutes the main food grain for over 750 million people who live in the semi-arid tropics of Africa, Asia, and Latin America. The largest group of producers is small-scale subsistence farmers with minimal access to production inputs such as fertilisers, pesticides, improved seeds (hybrids or varieties), good soil and water and improved credit facilities for their purchase (Kabak *et al.*, 2006). Sorghum is one of cereals that constitute a major source of proteins, calories and minerals for millions of people in Africa and Asia.
Rooney and Serna-Saldivar (1999) have reviewed extensively the proximate composition and nutritional aspects of grain sorghum. They found that grain sorghum contains about 10% protein which varies from 4.4 to 21.1% with a mean value of 11.4%. Sorghum grain is however known for its hardness compared to other food grains due to higher content of protein prolamin (Ralph *et al.*, 2000). Although sorghum is of a lower feed quality than maize, it is also high in carbohydrates and fat (3.4%), and contains 50 mg/kg iron (Fe), 15.4 mg/kg zinc (Zn), 16.3 mg/kg magnesium (Mg), 0.05% calcium and small amounts of thiamine and niacin (Rooney and Serna-Saldivar, 1999).
Cereals, especially maize, millets and sorghum are major staple foods in Nigeria, and are rich sources of nutrients especially when used as whole grains. However, to improve palatability and organoleptic qualities, most times, these grains undergo further processing to yield "better products". These processing include dehulling, dehusking, milling, etc.; in Nigeria, this is mostly done traditionally by pounding using stone or wooden mortar and pestle. The first objective of these processing is usually to remove some of the fibrous outer

layers of the grain called the hull or bran. Women and children labour hard and long to decorticate these grains to remove the outer layers of fibre which adversely affect the cooking quality and taste mouth-feel of the final product (Schmidt, 1992). The grain may first be moistened with about 10 percent water or soaked overnight helping the endosperm to break into small particles during pounding and the pericarp separated by winnowing, screening and sieving (FAO, 1995). However, this may alter the nutritional composition of the resultant products to varying degrees (Oghbaei and Prakash, 2016). The outer parts of the kernels, especially the aleurone layer and the germ, tend to be richer in minerals when compared to the starch endosperm. Most vitamins and minerals (44.45%) are found in the germ and bran portions of grains, and these types of pre-processing techniques result in major losses (in descending order) of thiamine, biotin, vitamin B6, folic acid, riboflavin, niacin, and pantothenic acid; there are also substantial losses of calcium, iron, and magnesium (Fardet, 2010; Truswell, 2002). A very concerning observation earlier made by Ramberg and McAnalley(2002) and Redy and Love (1999) showed that when wheat is milled into flour, approximately 70% of vitamins and 25–90% minerals and fibre are lost-more specifically, 25% loss of protein, 90% loss of manganese, 85% loss of zinc and linoleic acid, and 80% loss of magnesium, potassium, copper, and vitamin B6 were observed. The present study investigated the effect of dehulling on the levels of micronutrients (Fe, Zn and Mg) of grains (sorghum, millet and maize).

Materials and Methods

Sampling and sample preparation

Samples of maize, sorghum and millet mostly produced and consumed in Wukari Local Government Area of Taraba state, Nigeria were used in this research. The samples were procured from “Wukari new market.” The grains were cleaned and divided into two groups. One group was dehulled, winnowed and dried under mild sunlight, and then ground into flour using a wooden mortar and pestle. The second group was also given the same treatment as the first but without dehulling, and were used as control samples.

All glassware used were washed with detergent and rinse with deionized water. They were then soaked for 24 h in 10% nitric acid solution and dried in an oven before use. Analytical grade reagents were used and standard solutions of trace elements were freshly prepared on the days of analyses.

Sample digestion

Samples were digested according to the method described by the Association of Official Analytical Chemists (AOAC, 2006). Briefly, 5 g of each sample was weighed into 250 mL conical flask, 10 mL *aqua regia* (nitric acid and HCl in a ratio of 1:3) was added which was then evaporated on a hot plate in a fume cupboard until the black fumes disappeared leaving the white fumes. The resulting sample was then made up to 50 mL using deionized water and then filtered (using Whatman No. 1 filter paper) into clean universal bottle for atomic absorption spectrometric (AAS) analysis.

Heavy metals analyses

The digested samples were aspirated into a Thermo Scientific iCE 3000 Atomic Absorption Spectrometer for heavy metals (Zn, Fe and Mg) analyses. Standard addition technique (SAT) was used to calibrate the instrument. Standards were prepared by serial dilution techniques within the concentration range of each metal determined using Analar grade reagents. The instrument was first calibrated with solutions of metal standards before the analyses. The same process was carried out to determine each of the metals in triplicates using different lamps and appropriate blanks.

Statistical analysis

The data obtained from the various metal determination experiments were subjected to one-way Analysis of Variance (ANOVA) using SPSS version 21 at 95% confidence level.

Results and Discussion

Results of the AAS analysis are presented in Table 1. The concentrations of the metals presented are the mean ± Standard Error (SE) of triplicate analyses and were calculated from Equation 1.

$$\text{Conc. (mg/kg)} = \frac{[Conc.\,of\ sample\,(ppm) - Conc.\,of\ blank\,(ppm)]\ x\ Vol.\,(50\ mL)}{Weight\,of\ sample\,(g)\ x\ 1000......}\ x\,100 \quad \text{Eqn. 1}$$

Table 1: Levels of Fe, Zn and Mg in dehulled and whole grains of sorghum, maize and millet*

Sample	Fe	Zn	Mg
SM	61.93 ± 0.01	42.77 ± 0.00	277.96 ± 0.00
SSM	37.16 ± 0.01	25.76 ± 0.01	155.93 ± 0.00
CM	32.42 ± 0.00	22.76 ± 0.01	154.30 ± 0.01
CCM	31.46 ± 0.00	16.86 ± 0.01	117.49 ± 0.00
MM	40.30 ± 0.01	38.53 ± 0.01	311.06 ± 0.01
MMM	39.30 ± 1.11	35.97 ± 0.00	306.45 ± 0.00

*values represent mean of three readings ± SE; SM– Control un-dehulled sorghum, SSM – dehulled sorghum; CM – Control un-dehulled maize, CCM – dehulled maize; MM – Control un-dehulled millet and MMM –dehulled millet.

The present study investigated the effect of dehulling on the levels of micronutrients (Fe, Zn and Mg) of grains (sorghum, millet and maize).Generally, in refining grain, the bran is separated, resulting in the loss of dietary fibre, vitamins, minerals, lignans, phytoestrogens, phenolic compounds, and phytic acid (Oghbaei and Prakash, 2016). The results in Table 1 revealed a clear negative effect of dehulling on the concentrations of Fe, Zn and Mg. In all the grains studied, Fe, Zn and Mg decreased in the experimental samples when compared to the whole, un-dehulled control samples. The decrease in the levels of these micronutrients was statistically significant ($P < 0.05$) when compared with the control samples. In real terms, this represented 40 – 44% decrease in the levels of Fe, Zn and Mg in sorghum, 3 - 24% in maize and 2-7% in millet, respectively. Although, dehulling of grains is carried out to also reduce the levels of anti-nutrients, it inevitably and negatively affects the levels of desirable nutrients which are mostly located on the outer parts of the grains. For example, when wheat is dehulled and milled, approximately 70% of the vitamins and minerals are reportedly lost (Ramberg and McAnalley, 2002; Redy and Love, 1999). Also, wheat has been reported (Thompson, 1992; Oghbaei and Prakash, 2013) to lose 57 – 73% Fe and 38 - 57% Zn when subjected to dehulling and milling. The findings in the present study also agree with the report of Cubadda *et al*. (2009) when they observed a 32 - 36% decrease in the levels of Zn and Mg in dehulled and milled wheat grains for pasta. Similarly, Doesthale *et al.* (1979) had also previously reported a 51-67% reduction in Fe, 54-64% Zn and 40-64% Mg in 16 varieties of polished rice. This further adds credence to the observations that most minerals and other micronutrients are located on the outer parts of grain kernels. The observations in the present study throw more light on the negative effects of dehulling and other processing practices on the levels of micronutrients in grains.

Although phytin phosphorus have previously been reported to affect the bioavailability of many minerals, including of Fe and Zn in sorghum (Radhakrishnan and Sivaprasad, 1980), and that dehulling can remove 40 to 50 percent of both phytate and total phosphorus (FAO, 1995), this observed significant increase was demonstrated only during pearling of sorghum grains and relates specifically to ionisable iron and soluble zinc (SankaraRao and Deosthale, 1980).

Conclusion

The practice of dehulling cereals to improve palatability and organoleptic qualities, most times, unwittingly leads to severe reduction or total loss of valuable micronutrients. The findings in this investigation indicate that Fe, Zn and Mg are substantially lost when sorghum, maize and millet are decorticated- a practise aimed at producing "better products" but unfortunately does more harm than good.

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Conflict of Interest

The authors report no conflict of interest.

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