Assessment of Metallic Contaminants in Grinded Millet using Domestic Grinding Machine

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ABSTRACT: In this study, the quantity of metallic contaminants extracted from grinded millet was evaluated. The millet was grinded in three different forms; wet, paste, and dry forms for up to 3 minutes using locally fabricated grinding machine with cast grinding discs. Separate grinding discs were used for different millet forms, while the same quantity of millet, 1 kg, was used throughout the experiments. The millet was soaked for 24 hours before grinding in order to obtain wet and paste forms of the millet. Metallic contaminants were carefully extracted from the grinded millet using magnetic bed along with sedimentation and decantation. The extracted materials were then quantified to ascertain the food form that produces the highest amount of metallic contaminants. Also, the wear rate of the grinding disc was also determined with respect to the grinding time. The results show that the wet form has the highest amount of metallic contaminants of about 1.397 g followed by the paste form with 1.075 g. The dry form has the least value corresponding to 0.945 g. The grain sizes of the metallic contaminants were calculated to be 12.095 nm for the wet form, 8.056 nm for paste form while the dry form has the smallest grain size of 3.124 nm. The results revealed that metallic contaminants are always contained in grinded food processed with local grinding discs. Thus, materials with better wear resistance should be selected for production of grinding discs to be used for food processing.

KEYWORDS: Millet, Metallic contaminants, Quantification, Magnetic extraction, Sedimentation and Health hazards.

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I. INTRODUCTION

Food processing is a common practice because most food crops are hardly consumed in raw form. These food crops are usually processed through cleaning, drying, milling, grinding, etc, in order to make them suitable for consumption or for other domestic and commercial purposes (Yahaya *et al,* 2012, Kirk *et al*, 1991). Grinding as a form of food processing involves the mechanical breaking down of food samples into fine powder form before cooking and consumption [Yahaya *et al,* 2012].

The common domestic grinding machine in rural and urban areas uses locally fabricated cast iron grinding discs which are used to reduce the size of food items into smaller quantity for both commercial and domestic purposes. Grinding discs have poor wear resistance because of the materials used for their production (Normayo *et al*, 2010, Edem *et al,* 2012, Anthony *et al,* 2013). These discs are usually fabricated with little or no quality assurance to ascertain some of the critical engineering properties such as hardenability, resistance to wear and corrosion. Based on these, when grinding discs are being in used during grinding of food item, shear force is applied, leading to surface wearing of the discs. This is the main cause of iron filings and metallic inclusions in our grinded food items (Bello *et* al, 2007, Cabrera *et al,* 2003, Llobet *et al,* 2003). Common contaminants in processed (grinded) food item are most likely from the metal components of the mill, the soil, the paints used as coat for machine components, bushings, bearings, grease and grinding discs that originate from ageing and wearing (Normayo *et al,* 2010, Sule *et al,* 2014, Richard *et al,* 2006). Other contaminant from grinded food items may also originate from dirt, sprays, and powdered chemicals use for crops preservation or as insecticides (Jimoh *et al,* 2012, Edem *et al,* 2012, Somer *et al,* 1974).

These contaminants find their ways into our body system whenever we eat these grinded food items. These iron filings and metallic inclusions are heavy metals in grinded food which will have bad effects on human health (Normayo *et al,* 2010, Edem *et al*, 2012, Anthony *et al,* 2013). However, the magnitude of the contact force and the grinding time affects quantity of iron filling and metallic inclusion found in our grinded food item (Edem *et al,* 2012, Llobet *et al,* 2003). Generally, heavy metals disrupt basic metabolic functions in human body in two ways: firstly, they disrupt the functioning of vital organs and glands such as the heart, brain, kidney, bone or liver; and they move nutrients that are essential minerals and prevent them from fulfilling their biological functions (Normayo *et al,* 2010, Bello *et* al, 2007).

Excessive accumulation of iron into the body system is what is referred to as hemochromatosis (Yahaya *et al,* 2012, Kwofi *et al,* 2010, Normayo *et al,* 2010). When these metallic inclusions are ingested, it cannot pass through human organs as it cannot be digested. It gets accumulated and may start damaging functional

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organs. Thus, the normal iron suitable for human consumption is the mineral iron. Therefore, this work is focus on the quantification of the iron filings and other metallic inclusions in our staple grinded grain such as millet to determine the food form that produces the highest amount of metallic contaminants during grinding using domestic grinding machine with grinding disc made from cast material.

II. MATERIALS AND METHODS

A. Material

The materials used in this work include 15 kg of millet (*Pennisetum*), domestic grinding machine, and three pairs of grinding disc from the same manufacturer, magnetic bed, electronic weighing scales, measuring cylinder, bowls and stainless steel stirrer.

B. Method

The research was carried out in three parts consisting of grinding of the millet in different forms, followed by extraction of metallic contaminants and then determination of the quantity of the extracted contaminants. The samples were prepared by cleaning the millet manually to remove stones and particles that could cause damage to the grinding discs. The grinding was carried out in three forms of the millet namely: dry, wet, and paste form using locally fabricated grinding machine shown in Figure 1c.

The machine achieved grinding with the aid of cast grinding disc shown in Figure 2. Separate pair of grinding discs was used for grinding each of the millet in their various forms. The same quantity of millet, 1 kg, was used throughout the experiment and same grinding contact was also maintained with varying grinding time. The millet was soaked for 24 hours to obtain wet and paste form of the grinded millet by using 2 liters of water to grind the wet form. This was achieved by adding the water intermittently at every 10 seconds for a period of 3 minutes.

Half liter of water was also used to grind the paste form of the millet by adding the water intermittently at every 5 seconds for a period of 3 minutes. The weight of the millet and the grinding disc were noted before and after each grinding. This process was repeated for four more batches of 1 kg of the millet in the three forms. Metallic contaminants were carefully extracted from the grinded millet using magnetic bed.

The grinded millet was placed in a big container where a magnet is attached with the stirring rod and stirred continuously for 10 minutes. During this time, the metallic contaminants get attracted to the magnet. Sedimentation and decantation process was further employed in extracting the remaining contaminants in the grinded millet. This was achieved by mixing 10 liters of water with the grinded millet with continuous stirring for up to 3minute. The difference in densities caused the metallic contaminants which are relatively heavier to settle at the bottom of the bowl and the grinded millet was then carefully poured into another container.

This process was repeated severally while the sediments were poured in a separate container before using a magnet to collect the remaining metallic contaminants. This process was repeated until no sediments of contaminants were found. The extracted materials were then weighed separately using electronic weighing scale (Figure 3) to ascertain the food form that produced the highest amount of metallic contaminants into the grinded food item.

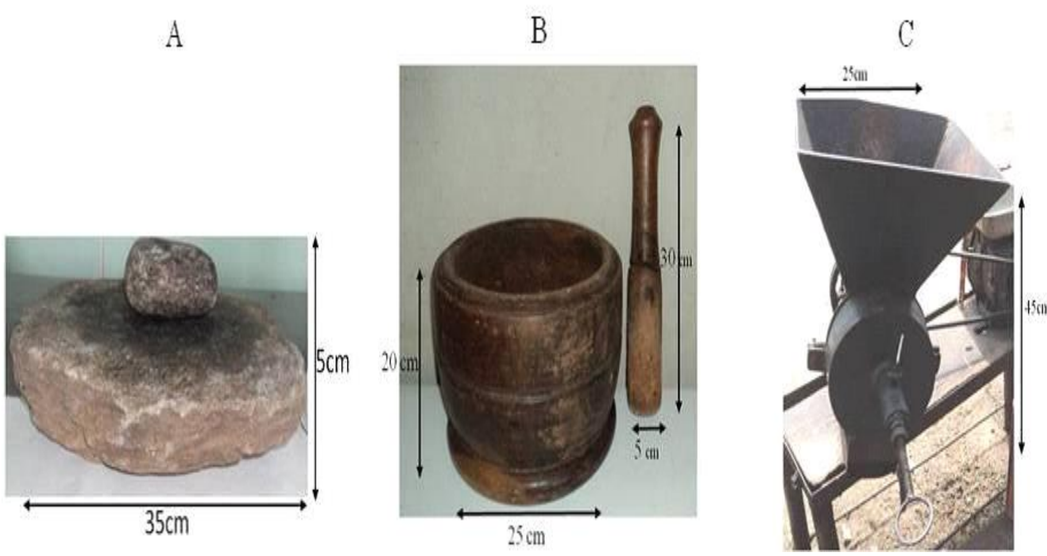

Figure 1: Grinding methods: (A) grinding stones; (B) mortal and pestle; and (C) modern grinding machine.

Figure 2: Grinding Machine Discs.

Figure 3: Electronic weighing machine for measuring the weight of the metallic contaminants.

III. RESULTS AND DISCUSSION

A. Chemical Composition

Table 1 shows the chemical composition of the grinding disc samples that was obtained using optical emission spectrometer. The result revealed the percentage by weight of each element present in the grinding disc sample. The major elements present were found to include carbon, silicon, manganese, chromium, copper, molybdenum, nickel, phosphorous, sulphur, niobium, arsenic and iron. The result of the analysis (Table 1) shows that the sample has a high percentage of iron with 88.48 %, followed by carbon with 3.64 wt % indicating that the grinding disc is made from unalloyed cast iron (Ibhodode, 2001). The main elements of unalloyed cast iron are carbon (C), silicon (Si), sulphur (S), manganese (Mn) and phosphorous (P). All other elements in unalloyed cast iron are considered as impurities in as much as they do not directly influence the properties of the sample.

Table 1: Chemical Composition of the Grinding disc sample (weight %).

C	Si	Mn	Cr	Cu	Mo	Ni	P	S	Nb	S	Fe
3.64	2.56	0.31	0.76	1.02	2.03	1.11	0.03	0.01	0.01	0.02	88.48

B. Grinding and Quantification of the Extracted Metallic Contaminants

During grinding of the millets, the shear force applied by the machine caused the grinding disc to rub against each other, and possibly caused wear and tear on the grinding disc. This wear and tear of the grinding disc was thought to be responsible for iron filing and other contaminants extracted from the grinded millet. The extracted metallic contaminants were measured using digital electronic scale and the results obtained were presented in Figure 4. From the figure, it was observed that the quantity of metallic contaminants was more during grinding in wet form than in paste and dry forms at all the grinding times. The rate of materials loss during dry grinding is slow compared to other forms possibly due to the fact that the dry form of the millet may be serving as dry lubricant and thus preventing close contact between grinding discs during operation. In addition, the quantity of metallic contaminants increased with increased grinding time. Thus, it could be deduced that as the frequency of usage of the grinding disc increases, the continuous abrasion between the disc shaft and other machine parts also increases level of materials loss thereby increasing the amount of metallic contaminants in the grinded food (Sule *et al.* 2014).

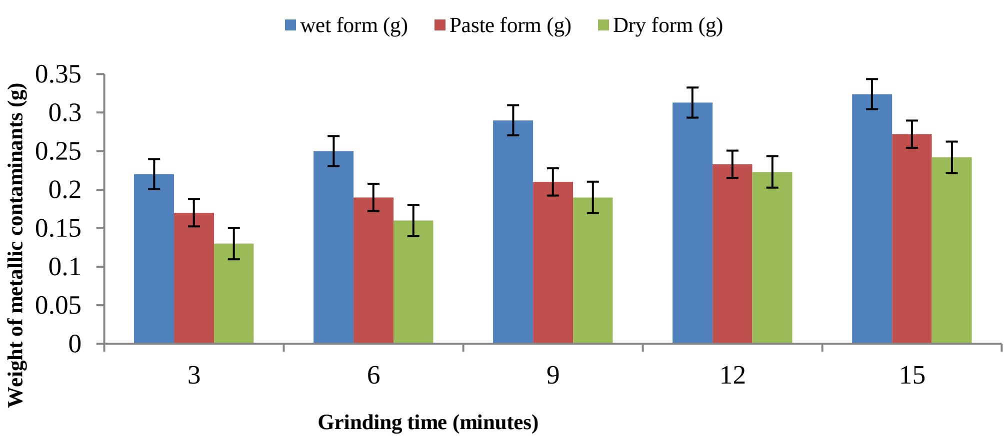

Figure 4: The relationship between the extracted metallic contaminants and the grinding time.

C. Relationship between the Wear Rate of the Grinding Discs and the Grinding Time

Figure 5 shows the wear rate of the grinding disc in relation to the grinding time in wet, paste and dry forms. The Figure revealed that the wear rate decreases as grinding time increases for the wet and paste forms of the grinded millets. But in the dry form, wear rate of the grinding discs increase with increase in the grinding time. The slow wear rate in the dry form at lower grinding time may be due to inability of the grinding discs to have close contact due to the hardness of the millet. However, as the grinding continues, the size of the grains reduced leading the closer contact between the discs and thus increased wear rate. But as time increases for wet and paste forms, the millet which was soaked for 24 hours will easily grind and allow close contact between the two discs.

Furthermore, in the wet form, the water reduces the friction between the discs and the grinding speed is higher in the wet form than in the paste form so the wear rate in wet form is higher than the paste form. As shown in Figure 5, the wear rate of the wet form is higher at the beginning but decreases with time because grinding a wet food substance with new grinding discs will result in a greater amount of metallic contaminants and the grinding disc will quickly wear-out.

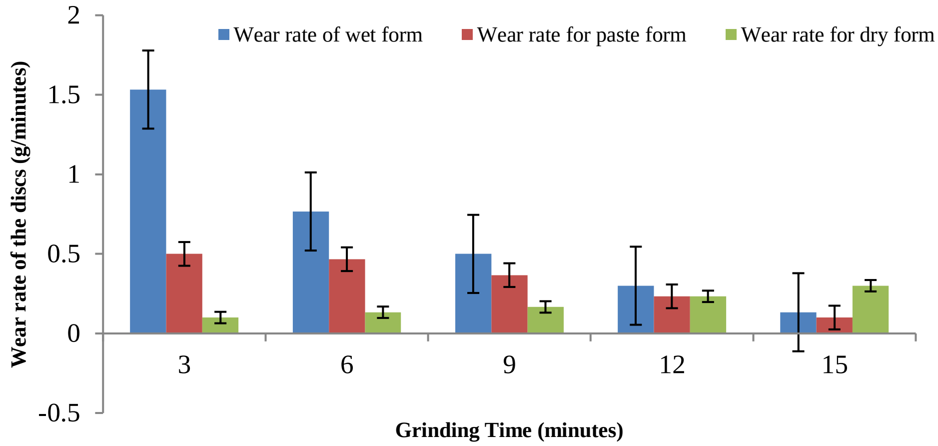

Figure 5: The relationship between the wear rate of the discs and grinding time

IV. CONCLUSIONS

From the study, it can be concluded that the millet grinded using locally fabricated grinding machine with cast iron grinding discs contained metallic contaminants. The amount of the contaminants in the grinded millets was found to be dependent on the form of the grinded form. The results revealed that more contaminants are present in the millet grinded in the wet form than in the dry and paste forms. It is therefore recommended that food should be better processed in dry and paste forms if local grinding machine will be used. In addition, consumption of non-mineral metallic contaminants may result into health challenges and thus efforts should always be made to extract metallic contaminants in the grinded food using magnetic bed and sedimentation methods.

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