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Evaluation Of Metallic Irons Extracted From Ground Food Item Using Domestic Grinding Machine.

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ABSTRACT: This study quantifies the number of iron fillings and other metallic constituents extracted from the ground food item. The food items used for the experiments include millet, beans, and corn. These food items were separately ground in three different forms; wet, paste, and dry forms for up to 5 minutes. The locally fabricated domestic grinding machine that uses cast grinding discs was used for grinding the food items. 3 kg each of the food items was used for the experimental purpose. The same grinding contact was maintained, while the grinding time was varied. The millet was soaked for 24 hours before grinding to obtain the wet form of the millet. Beans were peeled and soaked for 30 minutes before grinding to obtain the paste form, while the corn was ground dry. Iron filings and other metallic inclusions were carefully extracted from the ground food items using a magnetic bed alongside with sedimentation and decantation technique. The metallic extracts were then quantified to ascertain the food form that produces the highest number of metallic contaminants. The results show that the millet in wet form has the highest amount of iron fillings and metallic inclusions of about 0.108g, beans in paste form with 0.094 g, and dry corn with 0.069 g.

Keywords: Iron fillings; Quantification; Extraction; Characterization and Health hazards.

I. INTRODUCTION

t [3, 4, 5]. During grinding, the food item passes through the space between the two grinding discs. Shear force is been applied in-between the discs causing the rubbing together of the disc through mechanical means, which in turn break down the food samples into a smaller form of fine powders before cooking for final consumption [6, 7]. Most of the grinding machine in Nigeria uses locally fabricated cast iron grinding discs which have poor wear resistance because of the materials used for their production, and they are usually fabricated with little or no quality assurance to ascertain some of their critical engineering properties such as hardenability, resistance to wear and corrosion [8, 9, 10]. However, the magnitude of the contact force and the grinding time affects the quantity of iron filling that gets into our food item during grinding [7, 11, 12]. Also, during grinding, some other contaminants are found in the ground food items [13, 14]. Some of these contaminants in grinded food items are usually through the metallic parts of the grinding machine such as the paints used as a coat for machine components, grease, bushings, bearings, and grinding discs that originate from aging and wearing [15,16]. Other contaminants from ground food items may also originate from dirt, sprays, and even powdered chemical use for crops preservation or pesticides [17, 18]. These contaminants get into the bloodstream whenever we consume these ground food items. Excessive intake of heavy metals also causes diarrhea, hypothermia, diphasic shock, metabolic acidosis, and premature death.

II. MATERIALS AND METHODS

A. Material

The materials used for the research include; 15 kg of millet (Pennisetum), 15 kg of beans, and 15 kg of white corn, three pairs of cast grinding disc(Fig 1), domestic grinding machine (Fig.2), weighing scales (Analog and digital Fig. 3&4), magnetic bed, stainless steel stirrer, measuring bowls measuring cylinders, buckets, and gloves.

Fig. 1: Grinding disc.

Fig.2: Domestic Grinding Machine **Fig. 4: 5kg electronic scale.** **Fig. 4: 25kg Analog weighing device.**

Methods

The experiment was carried out in four parts consisting of grinding of the food item in their various forms, extraction of the metallic inclusion, quantifications of the metallic extract, and characterizing the metallic extracts. The samples were cleaned and prepared by removing all foreign materials like stones that could cause damage to the grinding disc during the grinding operation. The grinding was carried out using three food items: millet, beans, and corn. These three food items were grinded separately in three forms; millet grinded in wet form, beans in paste form, and corn in dry forms using a locally fabricated grinding machine with a cast disc. The machine was thoroughly cleaned with a rubber broom to remove the remains of food items that could alter the weight of the grinded food items during and after grinding. The machine was cleaned before and after grinding to ensure all millet was removed before proceeding to the next grinding. The same grinding machine was used for grinding all three types of food items in their various forms. Separate pair of grinding discs from the same manufacturer was used to grind the food item in their various forms. 3kg of food item each were used for the experiments, while the same grinding contact was maintained throughout the experiment with the varying grinding time of three minutes intervals.

Grinding

The experimental procedure to obtain the wet form of grinded millet was done by weighing 3 kg of millet and soaked in water for 24 hours to make it soft. The water was drained and the weight of the millet was noted and recorded. The grinding disc was positioned, ensuring uniform grinding contact between the grinding discs. The millet was grinded continuously for five minutes with three liters of water. This was achieved by adding the water intermittently at every 5 seconds for five minutes. The grinded millet in wet form is illustrated in Fig. 5.

Fig. 5: The grinded millet in wet form

The grinding disc was removed and cleaned to remove all the grinded millet that would have stocked to it during grinding of the millet. The grinded millet was weighed after grinding and the weight was also recorded. Same process was repeated with the same grinding disc for four more batches of 3 kg millet with grinding time of five minutes each while maintaining uniform grinding contact between the grinding discs. The grinding disc was weighed to ascertain the weight losses.

Experimental procedure to obtain the paste form of grinded beans was done by weighing 3 kg of beans and soaked in water for 10 minutes (Fig. 6) to make it soft. The water was drained and the weight of the beans was noted and recorded. The grinding disc was positioned, ensuring uniform grinding contact between the grinding discs. The beans were grinded continuously for five minutes with half liters of water. This was achieved by adding the water intermittently at every 5 seconds for a period of five minutes.

Fig. 6: Grinded beans in paste form

The grinding disc was removed and cleaned to remove all the grinded beans that would have stocked to it during grinding. The grinded millet was weighed after grinding and the weight was also recorded. The same process was repeated with the same grinding disc for four more batches of 3 kg beans with grinding time of five minutes each while maintaining uniform grinding contact between the grinding discs. The grinding disc was weighed to ascertain the weight losses.

During the grinding of corn in dry form, the grinding disc was weighed and positioned in the grinding machine. 15 kg corn was divided into 5 equal parts each to be grinded separately. The locknut was screwed to exert frictional contact between the grinding discs. 3 kg of corn was grinded continuously for 5 minutes. The grinding disc was removed and cleaned to remove all the grinded corn. The corn was weighed after grinding and the weight was recorded. The same process was repeated with the same grinding disc for four more batches of 3 kg corn with grinding time of 5 minutes each while ensuring uniform grinding contact between the grinding discs. The grinding disc was removed and weighed after each grinding to be able to calculate the weight losses.

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Fig. 7a: Millet

Fig 7b: Beans

Fig. 7c: White corn

Extraction

Magnetic bed: Here, a magnet is used to extract the iron fillings from the grinded food item (Fig. 8). During extraction of the iron filings, the wet millet and paste form of beans passes through the same process by placing the grinded food item in a big container, and water is added up to 10 liters. A magnet was used for continuous stirring for up to four minutes. During this period of stirring, the iron fillings and other metallic inclusions get attracted to the magnet. A surgical glove was used to wipe off the iron fillings and placed them in a paper before weighing.

Figure 8: Extraction using magnetic bed

Sedimentation and decantation: The sedimentation and decantation process were used in extracting the remaining iron fillings present in the grinded food item (Fig. 9).

Fig. 9: Sedimentation and decantation process

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For the wet and paste form, extraction of iron fillings through sedimentation was achieved by stirring the food item that has been mixed with 10 liters of water continuously for 3minute (Fig. 9). The iron fillings get settled at the bottom of the bowl and the grinded millet and beans were then carefully poured into another container separately (Fig. 9). This process was repeated severally while the sediments were poured in a separate container before using a magnet to collect the remaining iron fillings. This process was repeated until there are no remains of iron fillings. The extracted iron fillings were quantified by weighing extracts from each batch separately using an electronic weighing scale. Results obtained were recorded.

For the dry form of millet, this was achieved by mixing 10 liters of water with the grinded corn with continuous stirring for up to 3minute. The iron fillings get settled at the bottom of the bowl and the grinded corn 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 iron fillings. This process was repeated until no sediments of iron filings were found.

Quantification

The extracted iron fillings were quantified by weighing extracts from each batch separately using an electronic weighing scale. Results obtained were recorded.

Characterization

Chemical composition was carried out on a sample of the grinding disc to determine the weight percentage of each element contained in the grinding disc using optical emission spectroscopy (OES). Also, X-ray Diffraction (XRD) was used to determine the elemental composition/phase identification and grain sizes of the extracted iron fillings. Energy-dispersive X-ray Spectroscopy (EDS) was also used to determine their elemental compositions, respectively.

III. RESULTS AND DISCUSSIONS.

A. Chemical Composition

An optical emission spectrometer was used to determine the chemical composition of the cast grinding disc samples used during the experiment. Table 1 shows the results obtained which analyze the percentage by weight of each element present in the grinding disc samples. The elements present include carbon, silicon, manganese, chromium, copper, molybdenum, nickel, phosphorous, sulfur, niobium, arsenic, and iron as shown in Table 1. From the chemical composition obtained, the sample has a high percentage of iron of about 86.04% followed by carbon of 4%, and other elements exist in trace amount.

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

C	Si	Mn	Cr	Cu	Mo	Ni	P	S	Nb	S	Fe
4.00	2.20	0.41	0.66	1.02	2.03	1.11	0.03	0.01	0.01	0.02	86.04

B. Weight of iron fillings.

Table 2: The weight of the iron fillings extracted from grinded food items in the wet, paste, and dry forms with the grinding time.

Grinding time (minutes)	Weight of iron filings obtained from grinded millet in wet form (g).	Weight of iron filings obtained from grinded beans in paste form (g).	Weight of iron filings obtained from grinded corn in dry form (g).
0-3	0.019	0.016	0.012
3-6	0.021	0.017	0.013
6-9	0.022	0.019	0.014
9-12	0.023	0.021	0.015
12-15	0.023	0.021	0.015
Total	0.108	0.094	0.069

Table 2. Represents the weight of the iron filings and metallic extract from grinding food items with the grinding time in the wet, paste, and dry forms. From the weight of the iron fillings extracted, it reveals that the wear rate decreases as grinding time increases for the wet and paste forms of the grinded food. But in the dry form, the wear rate of the grinding discs increases with an increase

in the grinding time. The slow wear rate in the dry form at a lower grinding time may be due to the 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 pastes forms, the millet which was soaked for 24 hours is already soft which makes it grind easily and allow close contact between the two cast grinding discs. Figure 10 illustrates that the wear rate of the wet form is high at the beginning but decreases with time, also grinding a wet food substance with new grinding discs will result in a greater amount of iron filling and the grinding disc will quickly wear out. From the total amount of iron fillings calculated, it clearly shows that iron fillings if higher in wet form, followed by the paste form while the dry form has the least amount of iron fillings.

Table 3: Wear rate of the grinding disc in wet form

Grinding interval (minutes)	The initial weight of the grinding disc in wet form (g)	The final weight of the grinding disc after grinding (g)	Weight difference (g)	Wear rate (g/min)
0-3	2.6840	2.6794	0.0046	1.5333
3-6	2.6826	2.6757	0.0069	0.7667
6-9	2.6815	2.6731	0.0084	0.5000
9-12	2.6803	2.6710	0.0093	0.3000
12-15	2.6783	2.6686	0.0097	0.1333

Table 4: Wear rate of the grinding disc in paste form of beans

Grinding interval (minutes)	The initial weight of the grinding disc (g)	The final weight of grinding disc after use(g)	Weight difference (g)	Wear rate (g/minutes)
0-3	2.6940	2.6925	0.0015	0.5000
3-6	2.6930	2.6901	0.0029	0.4667
6-9	2.6913	2.6873	0.0040	0.3667

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9-12	2.6893	2.6846	0.0047	0.2333
12-15	2.6858	2.6808	0.0050	0.1000

Table 5: Wear rate of the grinding disc used for dry corn

Grinding interval (minutes)	The initial weight of the grinding disc (g)	The final weight of grinding disc after grinding, (g)	Weight difference	Wear rate (g/min)
0-3	2.7060	2.7057	0.0003	0.1000
3-6	2.7026	2.7019	0.0007	0.1333
6-9	2.7015	2.7003	0.0012	0.1667
9-12	2.6958	2.6939	0.0019	0.2333
12-15	2.6926	2.6898	0.0028	0.3000

Table 3, 4, and 5 shows the wear rate of the grinding disc when grinding the food item in wet, paste and dry form. The grinding was done with grinding intervals of 3 minutes each. The wear rate decreases as grinding time increases during the grinding of millet in wet form and paste forms of the grinded beans. But in the dry form, the wear rate of the grinding discs increases with an increase in the grinding time. This slow wear rate in the dry form at a lower grinding time may be due to the inability of the grinding discs to have close interaction and contact with each other due to the hardness of the corn. This makes the number of iron fillings and metallic inclusions to be higher in value in wet and paste form as compared to the dry form which has a lower wear rate.

B. **Energy-Dispersive X-ray Spectroscopy**

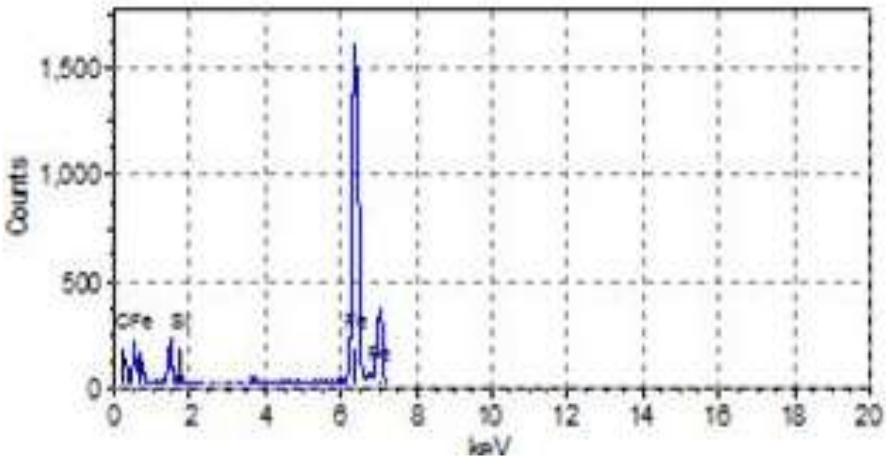

Fig. 10: EDS spectrum of the extracted metallic inclusions.

Fig. 10 shows the analysis of the elemental composition of the sample of the iron fillings from grinded food items using Energy-Dispersive X-ray (EDX). The result shows that the extracted iron fillings composed mainly of iron (Fe) with many strong peaks with a little amount of carbon and silicon as depicted by their very few weak peaks. This reveals that metallic iron is the main constituent of iron fillings and this metallic iron is very dangerous to human health. If it is ingested it does not digest into the bloodstream. It gets accumulated and results in many deadly diseases.

C. X-ray Diffractogram (XRD)

X-ray diffractogram (XRD) is an analytical tool that is employed to calculate the average particle sizes of the extracted iron filings. From the standard data that was obtained from the XRD analyses, Debye Scherer's formula was used to calculate the average particle size of the metallic extract.

Debye Scherer's formula in Equation (1) [29].

$$l = \frac{k\lambda}{\beta\cos\theta} \quad \textbf{(1)}$$

The average particle size of the iron filings obtained from the wet, paste, and dry forms were 11.025 nm, 7.043 nm, and 3.4215 nm respectively. It was deduced from the result that the food form ground in wet form contains the largest size of iron filings and metallic inclusions, followed by the paste form while the dry form has the least particle size of iron filings. When these iron extracts are ingested, they cannot be digested in the bloodstream and may lead to several health challenges such as hemochromatosis [7, 30, and 31]. This suggests that the consumption of iron filing and other metallic contaminants is dangerous for human health [32, 33, and 34].

IV. CONCLUSION

The result of the analysis indicates the presence of iron filings in our grinded food item which results from the grinding disc used for the material which is made from cast iron. These grinding disc materials are susceptible to easy wear thereby resulting in the introduction of iron fillings into our grinded food. The amount of iron fillings in the wet form of millet is more compared with that present in the beans in paste form and corn in dry form has the least amount of iron fillings. As the grinding time increases, the percentage of iron fillings introduced into food items also increases. This increase in the number of iron fillings in wet form is due to more quantity of water introduced during grinding which was able to wash off all food items along with the iron fillings due to the high surface area which enables enough water to flow through. When grinding a food item in its dry form, the gap between the mating grinding discs is not close enough to enable rubbing together of the discs. This in turn reduces the wear rate of the grinding disc and thus the little amount of iron filling gets into our food item. in the wet form of grinding is higher since there is enough clearance for water to flow through. From this research, the quantification and characterization confirm the presence of iron filings which is heavy metallic iron (Fe), and when this is ingested, it cannot pass through most of the human organs as it cannot be digested. Thus, the iron and other metallic inclusions from the grinded food get accumulated and result in adverse health effects that have been mentioned earlier.

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REFERENCES

[1]. J.G. Brenan, J.R Butter, N.D. Cowell, and, A.E.V. Lilly (1981), "Food Engineering Operation", Applied Science, England. (2), 60-64.
[2]. R.S. Kirik, and R. Sawyer, (1991), "Pearson's Composition and Analysis of Food", 9th edition, Longman Scientific and Technical.
[3]. D.B. Yahyay, D.A. Aremu and I. Abduullahi (2012): Investigation of metal contaminants in locally grounded foods (beans and tomatoes): journal of emerging trends in engineering and applied sciences (JESTAS), 3(1), 339-345.
[4]. Bello et al., (2007): Levels of calcium, lead, and zinc introduced as contaminants into foodstuff during processing. Science Focus, 12 (2): 1-5
[5]. B. Anthony Ojekale, G. Chioma, O.K. Chukwu, O. Oladipo Lawal and Titilola Osinaike (2013). Some Nigerian Traditional food milling techniques and cookwares increase concentrations of some heavy metals in milled food. IOSR Journal of Pharmacy, Vol. (3), 6-13.
[6]. L.P. Kwofi Dabonne, S.A. Kouadio, and A. kouame (2010). Traditional utensils as potential sources of poisoning by heavy metals. British Journal of Pharmacology and Toxicology. (2), 90-92.
[7]. Jimoh W. and mamud I.M (2012): Assessment of cadmium and lead in soil and tomatoes grown in irrigation farmland of Kaduna metropolis, Nigeria. Research

Journal of Environmental and Earth Sciences, 4 (1), 55-59.
[8]. Odusote JK, Soliu GA, Ahmed II, Abdulkareem S, Akande KA (2017) Assessment of metallic contaminants in grinded millet using domestic grinding machine. Nigeria Journal of Technological Development 14 (1), 13-17.
[9]. E. Beutler and F. Fairbanks (1980) The effects of iron deficiency, in iron in Biochemistry and medicine II (Jacobs A. and Wordwood M.) pp 393 – 425, Academic press, Inc., New York.
[10]. A. Edem Christopher and I. Dosunmu Miranda. Determination of heavy metals in cobs of maize (zea mays) from Calabar south local Government area of Cross River state Nigeria. IJRRAS, 13, 346-348.
[11]. Somers E (1974): The toxic potential of traced metals in food, Journal of science, 39, 215-217.
[12]. C.Cabrera, F. Lloris, R.Gimenez, M. Olalla and C. Lopez, 2003. Mineral content in legume and nuts: Contribution to the spanish dietary intake. Sci. Total Environ, 308: 1-14.
[13]. J.M. Llobet, G. Falco, G. Casas, A Teixido and J.L. Domingo, 2003.Concentrations of arsenic, cadmium, mercury, and lead in common foods and estimated daily intake by children, adolescents, adults, and seniors of Catalonia, Spain. Food Chemistry. 51, 838-842.
[14]. P. Rajwanshi, V. Singh, M.K. Gupta, R. Shrivastav, V. Subramanian, S. Prakash, and S. Dass, 1999. Aluminum Leaching from Surrogate Aluminum Food Containers under Different pH and Fluoride Concentration. Bull. Environ. Contam. Toxicol. 63, 271-276.
[15]. E. Normanyo, E. K. Esiam, K. Amankwa-Poku, I. A. Adetunde. Redesign of a grinding mill for the minimization of iron filings production. Researcher, 2 (7), 60-75.
[16]. L. Hulthen. Iron Deficiency and Cognition (2003). Scandinavian Journal of Nutrition. pp. 152-156
[17]. Sule, O. Shakiru Odugbose, D. Babasola Assessment of Dry and Wet Milling using Fabricated Burr Mill. Food Science and Quality Management. 31: 1-12.
[18]. J.N Umbreit, M.E. Conard E.G. Moore and L.F. Latour (1998) Iron absorption and cellular transport. The Mobiferrin paraferritin paradigm. Semin Hematol. Vol.35, 13 – 26.
[19]. P. Cutler 1994. Iron Overload as the Missed Diagnosis Consumer Health. Vol. 17 (11), Http://www.consumerhealth.org/articles/display.cfm.
[20]. M.H.A. Kampster, (1976), "Materials for Engineers, Hodder and Stoughton", London.
[21]. J.A.T Pennington (2000). Total diet studies-experiences in the United States. J. Food Composition analysis. Vol. 13, 539-544
[22]. A.B.C. Emedo, B.C. Maduka, and S.C. Oranekwulu, (1985). Comprehensive Agricultural Science for West African Senior Secondary School, De Diamand (J.M.B.), Onitsha.
[23]. A.L. Ihekoronye, and P.O. Ngoddy, (1985). Integrated Food Science and Technology for the Tropics. Macmillan, London and Basing stroke.
[24]. A.O.A. Ibhodode, (2001), "Introduction to Manufacturing Technology", 2nd edition Ambik, Benin City, Nigeria.
[25]. J.N Umbreit, M.E. Conard E.G. Moore and L.F. Latour (1998) .Iron absorbtion and cellular transport: The Mobiferrin paraferritin paradigm. Semin Hematol 35, 13 – 26.
[26]. P.J. Fellows, (2003). Food Processing Technology: Principles and Practice 2nd Edition 2000, Woodhead. Publishing Ltd and CRC Press LLC. Pp 98-117.
[27]. B.J Alloway (**1990**), heavy metals in soils, Blackie academic and professional publisher, 1st edition pp 100.
[28]. R. Conor (**2002**) metal contamination of food. Wilky printing press, UK, 2nd edition pp 36.
[29]. K. Cheney, C. Gumbiner, B. Benson, and M. Tenenbein. (1995). Survival after a severe iron poisoning treated with intermittent infusions of deferoxamine. PP 61–6.
[30]. N.M. Anon (2009): About Iron: Iron Disorder institute publication. (18) (2005); Normal Iron absorption and storage of iron fillings.
[31]. Perry, R.H and Green, D.W (1997). Principles of Size Reduction and Size Enlargement, Chemical Engineering Handbook 7th Edition McGraw-Hill, New York.
[32]. G.I. Ehosum, (2002). Trace metal levels in soils and crops around Ishiagu rock mining site: status of Pb, Fe, Cu, Zn, Cd, and As.

M.Sc Thesis, Michael Opara University of Agriculture Umudike, Nigeria.
[33]. Beavington F. (1975) Heavy metals contamination of vegetation and soils in domestic gardens around a smelting complex. Environmental pollution 9:211-221.
[34]. Richard C.E Ugochukhu G.M and Amaka M.O (2010): Food grinding stone as a source of heavy metal contaminants of diets, Journals of science and multidiscipline research Vol. 2.