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Effects of Locally Manufactured Grinding Plate on the Depositional Level of Metallic Elements in dry Milling of Wheat Grain

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Abstract

This paper "effects of locally manufactured grinding plate on the depositional level of metallic elements in dry milling of wheat grain" was carried out to identify three locally manufactured grinding plates, identify the concentration level of different metallic element deposit in ground wheat from the plates and to compare the level of concentration to the normal threshold by the FAO/WHO. The result shows that As, Cd, Hg, Cr, Mg, Mn, Mo, Cu, Zn, Fe, Pb, and Ni were found in small amount, the first plate contain 0.084mg/kg, 0.001 mg/kg, 0.015 mg/kg, 0.017 mg/kg, 0.017 mg/kg, 0.009 mg/kg, 0.017 mg/kg, 0.034 mg/kg, 0.002 mg/kg, 0.105 mg/kg, 0.01 mg/kg and 0.015mg/kg, the second plate has a concentration level of 0.021 mg/kg, 0.001 mg/kg, 0.005 mg/kg, 0.023 mg/kg, 0.032 mg/kg, 0.041 mg/kg, 0.000 mg/kg, 0.127 mg/kg, 0.061 mg/kg, 0.013 mg/kg, 0.018 mg/kg, and 0.012mg/kg and the third plate was also found to have a concentration level of 0.018 mg/kg, 0.003 mg/kg, 0.013 mg/kg, 0.01 mg/kg, 0.002 mg/kg, 0.02 mg/kg, 0.004 mg/kg, 0.006 mg/kg, 0.01 mg/kg, 0.015 mg/kg 2, 0.004 mg/kg, and 0.018 mg/kg respectively. Heavy metals like As, Cd, Hg and Cr which are hazardous to human health when consumed above recommended threshold were identified in all the three plates in small tolerable amounts as compared to the provisional tolerable weekly intake by FAO/WHO which is 0.015mg/kg, 0.003mg/kg, 0.045mg/kg and 0.05mg/kg.From the result obtained the three grinding plates are safe to use for dry milling of wheat.

Keywords: Grinding plates, metallic elements, wheat and dry milling

1.0 Introduction

There is no doubt cereals are the main source of food in many countries. With regards to human diet, the most important cereals are wheat (*Triticum*), rice (*Oryza sativa*), oats (*Avena sativa*), barley (*Ordeum vulgare*), rye (*Secale cereale*), corn (*Zea mays*) and millet (*Panicummili- aceum*) (Gaia *et al*., 2005). Among them, wheat is one of the most consumed and widely spread all over the World (Aroujo et al., 2007). Cultivation of wheat dates to antiquity, when its harvest was essential for human diet. Today, wheat highly contributes to the economy and the social structure of many countries.

Wheat is an important source of carbohydrates. Globally, it is the leading source of vegetable protein in human food, having a protein content of about 13%, which is relatively high compared to other major cereals such as oat and barley but relatively low in protein quality for supplying essential amino acids, (CORDIS, 2017; FAO, 2017), when eaten as the whole grain, wheat is a source of multiple nutrients and dietary fiber, (Shewry and Hey, 2015).

Food processing is an essential part of Agricultural Engineering that involves the addition of value to food products and improves palatability for consumption (Jahun, et al., 2013). In all processes of food handling, safety should be of utmost priority to the handlers and the safety of food products especially for human and animal consumption must not be compromised (Zaidi, 2011).

The milling process reduces the mean particle size by cutting and crushing mechanism which could bring about abrasion (dry milling), and dissolution (predominantly in wet milling). Wear caused by the milling, causes a portion of the elements used in the manufacture of the grinders to exist in Free State which in turn come in contact and contaminate the food materials being processed (Haslina et al., 2008). The particles that get detached from machine members due to rubbing/ abrasion between surfaces in contact and dissolution in dry food materials are known as *Wear elements* (Mathieu et al., 2008).

Food contamination by metals is inevitable in modern technology (Nriangu and Azcue, 2016; WHO) reported that the diet of man is a major exposure route for most of the unknown toxic contaminants in the environment. Among these contaminants, heavy metals have contributed markedly to the contamination of foodstuffs. It has been reported that Hg, Pb, Cd, Ni, Cr, Co, V, Mn, Fe, Zn, Sn and several other metals appears in processed food every day (lawal and Audu, 2011), but concentrations vary greatly (AAP, 2016).

Food processing equipment has long been recognized as a source of metal contamination of foodstuffs (Jamp, 2003). The major concern of the food processing and safety engineer is to see that the product is free of toxic or harmful metals or even of essential metals in quantities great enough to cause poisoning. Alloway, (1990) has reported that heavy metals are common components of natural systems, but man's activities have increased the quantities and distribution of these metals in the site (water, rivers, lakes, streams and seas) and in the atmosphere. Heavy metals are highly toxic when present in these systems in high concentration, and when they accumulate above maximum levels in any physiological system, they tend to be highly injurious to health (Alloway, 1990). The toxicity of heavy metals is one of the major current environmental health concerns and potentially dangerous because of bioaccumulation through the food chain (Rajaganapathy et al., 2011). The uptake of these heavy metals especially into the human food chain is done through the food processing, and they have a harmful effects on human health (Jarup, 2003). The presence of heavy metals in food is highly significant, they can cause serious health problem depending on the nature of the heavy metal. They do this through interfering with the normal biological

functioning of the human health. The heavy metals linked most often to human poisoning are lead, mercury and arsenic. These metals tend to accumulate in the brain, kidneys and immune system where they can severely disrupt normal function (Ebenezer, O. O, 2018).

Heavy metal release from equipment contributes a substantial proportion to total contamination in humans. Food processing methods involve many operations, which include coarse grinding of food material called size reduction. Grinding of foods (size reduction) as part of food processing operation in the past was completely done by using traditional methods, which include stones, bricks, pestle and mortar (Yahaya et al., 2012). These methods were effective but rather slow, time consuming and unhygienic (Ehiri et al., 2010). As the need of the people for food increased, new technologies were developed and modern methods of grinding foods were invented such as blenders, mills and crushers. These mills make use of toughened steel, stones and hardened steel, toothed discs (Yahaya et al., 2012). When these machines are in operation, the plates revolve and rub against each other as the food stuff is being crushed into powder or paste. The sliding process of the plates generates friction which leads to wear and tear thereby introducing contaminants into the milled foodstuffs (Cheftel J.C., 1988). Common contaminants in processed (grinded) food item are most likely from the metal components of the mill, the soil, the paints used as a coat for machine components, bushings, bearings, grease and grinding discs that originate from ageing and wearing (Sule &Odugbose, 2016, Normanyo et al., 2010 and Ehiri et al., 2012). Ehiri et al, (2010) reported that improvements in the food production and processing, technology have increased the chances of contamination of food with various environmental pollutants, especially heavy metals.

Recent studies carried out by Doe et al., (2013), in analyzing heavy metal content of flour on the Ghanaian market, (one made in Ghana and another made in Turkey) an atomic absorption spectrophotometric analysis of milestone acid digested flour was used with the appropriate standards. With a 9% - 100.4% recovery rate, Fe, Zn, Mn, Cd, Pb were detected at varying concentrations in both flour brands, while Co, Ni, Cu, Cr, As, Hg were below detection limits. The levels of the nutritionally important elements such as Fe and Zn would be beneficial to human health, while those of the toxic element present are not likely to pose any health risk to consumers of this flour.

Kwofie et al., (2011), Studies on the quality of locally manufactured corn mill grinding plates, the results showed that iron particles from milling plates contaminates the milled maize and that the level of contamination increases with the quantity of milled maize. This is the case in both ‘wet’ and ‘dry’ milling. However, the relationship between the mass of elemental iron (Fe) in milled maize and mass of milled maize in ‘wet’ milling differed from that of ‘dry’ milling. That is, in ‘dry’ milling the rate of metal loss decreases at first and then increases with mass of milled maize, whereas in ‘wet’ milling, the rate increases monotonically with mass of milled maize.

Odusote et al., (2017), in a study assessment of metallic contaminant in grinded millet using domestic grinding machine, report that the wet form has the highest amount of metallic contaminant 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.

1.2 Metals as Contaminant in Food

Metals such as arsenic, cadmium, lead and mercury are naturally occurring chemical compounds. They can be present at various levels in the environment, e.g. soil, water and atmosphere. Metals can also occur as residues in food because of their presence in the environment, because of human activities such as farming, industry or car exhausts or from contamination during food processing and storage, People can be exposed to these metals from the environment or by ingesting contaminated food result from milling or water. Their accumulation in the body can lead to harmful effects over time.

Contamination of foods by heavy metals has several different sources. The most significant ones are: contamination of the soil from which foods are produced; milling of grain, residual muds; chemical fertilizers and pesticides used in agriculture; the use of other materials; etc. Since this contamination has so many different sources, there is a wide range of foods contaminated by heavy metals, including products of plant origin (cereals, rice, wheat, edible roots, mushrooms, etc.) as well as foods of animal origin (fish, crustaceans, mollusks). Many high-density metals are not especially toxic. Several of them are essential elements for human beings, though at certain concentrations they may be toxic in some of their forms. However, there is a series of elements that, regardless of their form, could represent a major health and environmental problem. These are commonly referred to with the generic term “heavy metals” (Ebenezer O.O, et al., 2018).

1.3 Effects of Wear Elements on Humans

Kwofie et al., (2011) reported some harmful metallic elements in food, these elements are Arsenic (As), Cadmium (Cd), Lead (Pb), and Mercury (Hg). There had been substantial expenditure on measures to reduce human exposure. Although toxic effects are clearly established for occupationally exposed people and for people in locations where particularly high levels are present, demonstration of harmful effects population-wide has been more difficult.

Kalasuramath et al., (2015). They reported the observation of Lung inflammation and damage to the nasal cavity in animals exposed to with high concentration of nickel compounds. The lung damage is severe enough to affect lung function. Oral exposure of humans to high levels of soluble nickel compounds through the environment is extremely unlikely. Chronic exposure to Arsenic (As) has been associated with diabetes (Del Razo et al., 2011; Islam et al., 2012), cardiovascular disease (Baccarelli et al., 2010; Wang et al., 2017), intellectual impairment in children (Sinayobye & Saalia, 2011); (Juhasz et al., 2013), and lung and bladder cancers (Phipps et al., 2012). Cadmium (Cd) primarily affects the kidneys, with tubular proteinuria providing a useful marker of the renal damage. Studies in Cadmium-polluted areas have reported an excess mortality risk among people showing tubular or glomerular proteinuria, but the causes of this excess mortality are unclear (Wilker et al., 2011). Other adverse effects of Cadmium include low bone-mineral density and osteoporosis (Vanderveen et al., 2012) and lung cancer (Phipps et al., 2012). Mercury (Hg) has been implicated in severe but localized poisonings (Tarasuk et al., 2015). Widely publicized concerns about effects of Mercury from vaccine preservatives have been refuted (Ahmed et al., 2016), but effects on intellectual functioning or behavior have been reported or suggested (Arora et al., 2008); (Abkenar et al., 2011). Cardiovascular (Téllez-Rojo et al., 2004) and renal (Chen et al., 2016) disease have been associated with low-level Mercury exposure. For Lead (Pb), the main concerns have been about impaired intellectual development in infancy and childhood (Bandeen-Roche et al., 2009) but adult cognitive function may also be affected (Qian et al., 2010). There is also evidence that higher lead values are associated with

hypertension (Jamali et al., 2012), peripheral vascular disease (Kiran et al., 2008), increased adult mortality (Cao et al., 2010), and cognitive decline in older people (Lemos & David, 2010). Studies on overall and cause-specific mortality suggest a 40–60% increase in adjusted mortality with increasing lead concentration in the U.S. population (Cao et al., 2010; Khani et al., 2011; Manton et al., 2003).

1.4 Grinding Plate/Disc

Locally fabricated mills make use of grinding discs that are locally produced by casting method using cast iron as casting material. Metal casting is described as shape forming process, where molten metals are poured in a prepared mould and allowed to solidify such that the shapes of the solidified objects is determined by the shape of the mould(Hitomi, 2017). Cast iron is an alloy of iron and carbon in which crude iron is melted in suitable furnace and modified by addition of scrap or steel scrap before it is cast (Ihekoronye and Ngoddy, 2015). When special properties are required in cast material, alloying elements are added to cast iron such as nickel, chromium, silicon, molybdenum, and copper to improve its mechanical properties (strength, hardness, corrosion resistance, response to heat treatment and special properties). If these are added to the grinding disc cast material, they may sometimes cause contamination of food samples due to ageing and wear of the disc (Creus, 2010).

1.5 Equipment/Materials

Equipment required for analyses are available in Federal Polytechnic Bali and Abubakar Tafawa Balewa University Bauchi and the sample will be source directly from the wheat farmers located in Taraba.

The required Equipment for this work includes but not limited to: Size reduction/Grinding Machine, Grinding Plates, Top Loaded Digital Weighing Balance, Desiccators with desiccants, Atomic Absorption Spectroscopic Machine (AAS), Set of Sieves and the Sieves Shaker, pH metre, Sampling Polythene bags, Distilled water, Sampling bowls, Conical flasks, Beakers, plastic Pestle and Mortar, Tongs and Spatulas, Statistical Analysis software (SPSS/ GenStat), A4 paper rim, Chemicals and Other Consumables.

3.0 Materials and Method

The research work was carried out at Food Processing Laboratory of Department of Agricultural and Environmental Engineering, School of Engineering Technology Federal Polytechnic Bali Taraba State. The laboratory and surrounding is situated at 7.8841^{o}N, 10.9776^{o}E with average relative humidity and 16% and average temperature of 33^{o}C and Crop Processing and Storage Laboratory at the Department of Agricultural and Bio-resources Engineering, Faculty of Engineering and Engineering Technology Abubakar Tafawa Balewa University Bauchi located at 10.2801^{o}N, 9.7945^{o}E with average relative humidity 75% and average temperature of 32^{o}C.

Materials used for this research work include but not limited to the following: Models of Grinder/Milling Machine (GX200 Chitex models), Sample (Wheat), Sulpheric Acids, Nitric Acids, Peroxide Acids, Hydrochloric Acids, Distilled water, and Nitrogen gas. Other Equipment needed are atomic absorption spectrophotometer (AAS), Desiccators, Conical flasks, Hot air oven, Top loaded weighing balance, Pressure gauge and Tachometer.

3.1 Sample collection and preparation

Three different models of grinding discs (Guk, Adex and Nass) were purchased for use in the study. Wheat (*Triticum*) of no specific variety would be bought from farmers in Taraba state and will be ground using the selected grinding mill for the investigation (GX200 Chitex model). The grains was cleaned mechanically with de-stoning machine and Material Other than Grain (MOG) were manually winnowed, the sample was grinded with the purchased grinding machine.Ground samples was taken to the laboratory to determine the depositional level of the metallic elements from plates after grinding.

3.2 Sample Digestion

The samples were digested according to the method described by the Association of Official Analytical Chemist (AOAC). 2g of the milled samples each were weighed into 250ml beaker, 10ml of the oxo-acidic mixture (HNO_3 acid and $HClO_4$ acid) in the ratio 4:1 10ml of this acid mixture were added to each of the samples and stirred. They were evaporated on a hot plate in the fume cupboard until the black fume disappeared leaving only the white fume. The samples were allowed to cool and deionized water were added to dilute the resulting solution. These were filled into 50ml volumetric flask each for the maize and wheat sample respectively, then made up to mark in 50ml volumetric flasks using deionized water. The samples were transferred into clean sample bottles for atomic absorption spectrophotometer (AAS) analysis.

3.3 Absorption Spectrophotometer (AAS) Analysis

Atomic absorption spectrophotometer instrument was used to determine the trace elements in the aliquots of the digested samples (Sinayobye & Saalia, 2011). The elements determined include chromium, nickel, mercury, Arsenic, Molybdenum, Zinc, iron, magnesium, lead, copper, cadmium, and manganese. The hollow cathode lamp used to determine metal element was be fixed. The fixed lamp supplied suitable light was used in determining a particular metal element and changed continuously with other hollow cathode lamps and determine other elements. Each tagged bottle of sample solution was introduced into the instrument that had been set for the analysis and later led to the burner tip where atomization and evaporation of the solution took place. High intensity radiation produced by each cathode lamp would be sent out to the slot flame where some of them would be absorbed by the atoms of the elements to be detected, thereby reducing the intensity of the radiation. The reduced intensity of the radiation was then passed through lenses, mirrors and diffraction gratingto the recorder where concentration of the element concerned wereobtained. The same process was carried out to determine each of the elements concerned using different lamps. This same procedure was replicated three times for different conditions of the milling plate;Amount of wear elements particles that end up in a milled wheat (Triticum) were tested and determine to see if they are within the acceptable standard.

3.4 Result and Discussion

Table 1:Concentration of Metallic Element in Grounded Wheat from Three Different Plate

Element	Plate 1 GUK	Plate 2Adex	Plate 3Nass
	concentrations mg/kg		
As	0.084	0.021	0.018
Cd	0.001	0.001	0.003
Hg	0.015	0.005	0.013
Cr	0.017	0.023	0.01
Mg	0.017	0.032	0.002
Mn	0.009	0.041	0.02
Mo	0.017	ND	0.004
Cu	0.034	0.127	0.006
Zn	0.002	0.061	0.01
Fe	0.105	0.013	0.152
Pb	0.01	0.018	0.004
Ni	0.015	0.012	0.018

ND: not detected

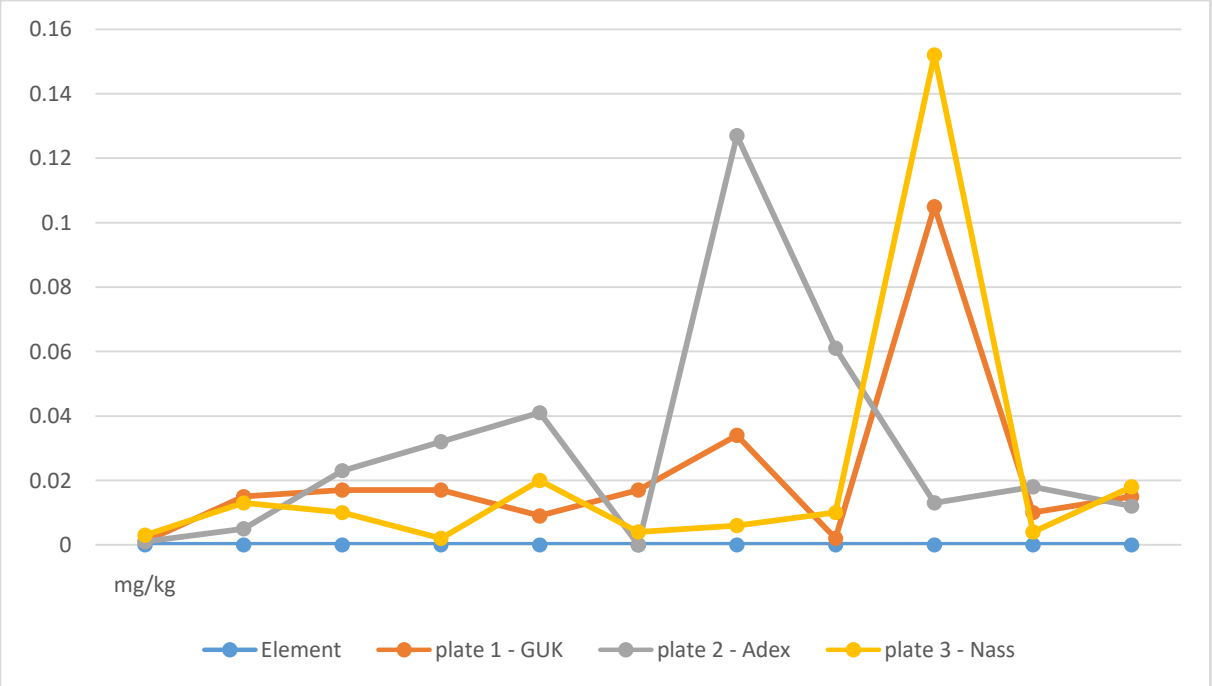


Figure 1: Shows a graphical relationship of concentrations of metals in tested samples. The results were discussed below and all samples were checked for compliance against tolerable limits laid down by FAO/WHO

Three locally producedgrinding plates namely, GUK, Adex and Nass were used for this experiment to ascertain the concentration level of metallic (heavy and trace) element contained in the plates. The presence of As, Cd, Hg, Cr, Mg, Mn, Mo, Cu, Zn, Fe, Pb, and Ni were identified in small quantities mostly below the tolerable intake limit as stipulated by FAO/WHO. Heavy metals like As, Cd, Hg and Cr which are hazardous to human health when consumed above recommended threshold were identified in all the three plates in small tolerable amounts. The joint FAO/WHO expert committee on food additives (JECFA) has

evaluated arsenic, cadmium, mercury and lead established a provisional tolerable weekly intake (PTWI) of 0.015mg/kg, 0.003mg/kg, 0.045mg/kg and 0.05mg/kg, this is an estimated amount of a contaminant that can be ingested over a lifetime without appreciable risk.

3.5 GUK Grinding Plate

A sample of wheat was grounded using the plate to ascertain the types and amount of heavy metals and trace element composition especially those that are harmful or hazardous to human health. The amount of deposit were obtain and compared to the tolerable intake level as stated by FAO/WHO.

As, Cd, Hg, Cr, Mg, Mn, Mo, Cu, Zn, Fe, Pb, and Ni were found in a trace amount of 0.084mg/kg, 0.001mg/kg, 0.015mg/kg, 0.017mg/kg, 0.017mg/kg, 0.009mg/kg, 0.017mg/kg, 0.034mg/kg, 0.002mg/kg, 0.105mg/kg, 0.01mg/kg and 0.015mg/kg.Among all the elements identified, heavy metals like Arsenic, Cadmium, Chromium, mercury and lead are found to be most hazardous to human health.

3.6 Adex Grinding Plate

Dry wheat sample was grounded using the Adex plate and the following elements of different concentrations were found As, Cd, Hg, Cr, Mg, Mn, Mo, Cu, Zn, Fe, Pb, and Ni with a concentration level of 0.021mg/kg, 0.001mg/kg, 0.005mg/kg, 0.023mg/kg, 0.032mg/kg, 0.041mg/kg, 0.000mg/kg, 0.127mg/kg, 0.061mg/kg, 0.013mg/kg, 0.018mg/kg, and0.012mg/kg respectively.

3.7 Nass Grinding Plate

The Nass grinding plate was used for dry milling of wheat sample to investigate the concentration level of metallic element contamination in the sample. The concentration levels in the following elements As, Cd, Hg, Cr, Mg, Mn, Mo, Cu, Zn, Fe, Pb, and Ni were found out to be 0.018mg/kg, 0.003mg/kg, 0.013mg/kg, 0.01mg/kg, 0.002mg/kg, 0.02mg/kg, 0.004mg/kg, 0.006mg/kg, 0.01mg/kg, 0.015mg/kg2, 0.004mg/kg, and 0.018 mg/kg.

4.0 Conclusion

Grinding is one of the most widely used methods for the postharvest processing of food products for consumption, mainly grains and some vegetables. As such there is need for choice of materials for grinding of food product to prevent large deposit of harmful element in food products.

The study has widen our understanding of the wear element, how these element come in contact with food and its hazardous effect on human, the permissibletolerable weekly intake (PTWI) as recommended by the FAO /WHO to prevent damage cause to internal organ and sometimes the whole body when consumed in large quantities. Also some of these elements presence in food product might not be from the grinding plates but from the product itself, so, It is recommended that further research should be conducted in the areas where such crops are planted to trace the genesis where some of these wear elements have been absorbed before being subjected to laboratory analysis.

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