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ASSESSMENT OF CHEMICAL CONTAMINANTS IN CORN DOUGH FROM SELECTED CORN WET MILLING PLANTS IN MANKESSIM

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Abstract

The chemical contaminants in corn dough systematically sampled from five corn wet milling plants were assessed using 3 experimental and 2 control groups. Samples were analyzed at regular intervals using QuEchERS, AAS, HPLC, gravimetric and cold maceration analytical methods. Hundred consumers and 5 wet mill operators were conveniently sampled and interviewed to obtain information on the milling process. The steps involved in preparing corn dough were observed to identify possible practices that introduced contaminants into the dough. Data collected were analyzed using SPSS version 21 and results presented in frequency and percentage tables. Contaminants identified in the dough were grease, aflatoxins, lead, iron and zinc. T-test was used to determine any significant difference in chemical contaminants in corn dough sampled from selected corn wet milling plants. Significant differences (p≥0.05) existed between contaminants obtained from selected corn wet milling plants. Cleaning materials, old locally- made grinding plates, petroleum-based lubricants, unwashed bare hands for lubrication and dirty milling plants were found to be highly contaminated above acceptable Ghanaian and International standards. Introduced interventions along the production line greatly reduced contaminants in the corn wet milling plants. From the findings, it can be concluded that levels of certain metals and substances found in some corn dough samples suggest possible health risk when consumed. Strict hygiene measures could help reduce this risk.

1. INTRODUCTION

Aflatoxins are produced by the fungus *Aspergillus flavus* and are associated with corn and other foods like groundnuts and milk. Aflatoxins are potent liver toxins and may be carcinogens in humans and animals. Thus, its contamination in corn or food can create significant economic losses for individual producers as well as health hazards for potential consumers. Aflatoxin contamination can occur at pre-harvest which is often linked to drought and high temperatures during grain fill and at postharvest when grain is inappropriately managed through the drying and

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storage process. Milling corn contaminated with Aflatoxin could also lead to spreading of the contamination through corn and other foods which are subsequently milled through the corn wet milling plant.

With recent increase in chronic diseases such as cancer, diabetes and hypertension in Ghana, providing safe food for the people of Ghana should be a priority. Corn is a major staple in Ghana consumed by all people from all walks of life. Before corn can be prepared into most foods in Ghana it has to be grinded. This is done using milling machines precisely the corn wet milling plants. Abrefah et al. (2011) highlighted the fact that corn milling plants are indispensable to the flour industry especially in milling cereals, grains, legumes, nuts and spices into flour. Fermented corn dough is used in preparing several Ghanaian dishes including kenkey (both Ga and Fanti), banku, etew and porridge. Tilapia and banku or etew has become a prestigious popular food in Ghana and is consumed by both indigenes and tourists.

To control pest and increase yield in corn production, pesticides are used a lot in Ghana. Humans can be exposed to residues of these pesticides via the consumption of corn grains which have been sprayed with these pesticides. These pesticide residues may enter into the human body directly when pesticide contaminated corn is eaten. Indirectly, pesticide contaminated grain fed to livestock could also be one of the sources that humans who consume these livestock could get exposed to pesticides. These pesticides can accumulate in animals and humans because of their lipophilic nature which easily allows them to be incorporated and accumulated in the tissues. When humans ingest pesticides more than the recommended maximum limits (MRL) it becomes hazardous to their bodies (Kibria, 2014). Pesticide Residues Committee (2001, 2002) cites that high levels of exposure to organochlorides cause cloracne, a type of acne caused by chlorine containing chemicals and skin rashes. There is some evidence that organophosphate insecticides affect the immune system and can cause psychiatric problems such as paranoid behaviour, disorientation, anxiety and depression. Other pesticides may cause muscle toxic itching, tremors, weakness, and inability to breath, blur vision, vomiting, cramps, excessive perspiration, unconsciousness and even death in cases of high exposure. Kibria (2014) reports that immediate health effects from pesticide exposure includes irritation of nose, throat and skin causing burning, stinging and itching as well as rashes and blisters. In addition, he adds that though symptoms of short term pesticide poisoning may be similar to colds and flu, its long term health effects may present more destructive diseases like cancer, brain and nervous system damage; birth defects; miscarriages, infertility, male sterility and other reproductive problems. It may also cause damage to liver, kidneys, lungs and other body organs (Kibria, 2014). Pesticides such as 2, 4-D; atrazine, DDT, endosulfan and simazine have been identified as endocrine disruptors (EDC), therefore measures are required to reduce risks from such chemicals (Kibria, 2014).

With the associated health issues that come along with consumption of pesticide contaminated corn, the safety of corn foods is very important and need to be monitored. To protect consumers of corn dough products, the risks that are likely to be associated with consuming corn dough and other milled food products need to be assessed. WHO (1999, 2000) highlighted the benefits of chemical use but stressed that when these same chemicals are misused, they tend to cause adverse effects on human health and the integrity of the environment. Horváth (2011) reports several metals as toxic to humans especially when taken in overdose. Zinc is an essential element in human diet thus its deficiency in the diet may be detrimental to human health and lead to neurosensory changes, oligospermia, impaired neuropsychological functions, growth retardation, delayed wound healing, immune disorders and dermatitis (Institute of Medicine, 2001).

Sammon (2006) reports that long-term consumption of excess zinc may result in decreased iron stores. Hewitt (1988) and ATSDR (2005) earlier reported that the ingestion of high levels of zinc inhibit copper absorption through interaction with metallothionein at the brush border of the intestinal lumen. Both copper and zinc do bind to the same metallothionein protein; however,

copper has a higher affinity to bind metallothionein than zinc and thus displaces zinc. Thus, an excess of zinc can result in a decreased availability of dietary copper leading to the development of copper deficiency. Excess zinc may also alter the levels or activity of copper-dependent enzymes which include cytochrom C oxidase, superoxide dismutase, ferroxidase, monoamine oxidase and dopamine β-monoxygenase which results in anaemia and lencopenia.

Other probable contaminants have been identified as soaps and detergents which are used indiscriminately by operators to clean wet corn milling plants and poor quality oils used to lubricate the parts to prevent friction and enhance milling. The World Health Organization (WHO, 2000) and Ghanaian Standards have identified practices in the production of corn dough which are likely to introduce chemical contaminants. Thus adopting and applying preventative measures during production of corn dough using the wet corn milling process could help reduce or prevent such contamination. Most chemicals cannot be eliminated from the food processing system because the compounds are often heat stable thus focusing more on preventive measures where chemicals are prevented from entering the food system at unacceptable levels which becomes a priority (Lunning & Marcelis, 2011).

Skrbic (2012) and Traar (2013) highlighted the toxicity of mycotoxins to both humans and animals stressing that their toxicity is higher than that of synthetic contaminants. Traar (2013) reported that Aflatoxin B1 is one of the most potent hepatic-carcinogens known making high levels of it in diets an important issue to look at critically. Unlike most contaminants which can either be reduced greatly or completely destroyed by heat or high temperatures, aflatoxin easily survives high heat or temperatures and thus difficult to control. The ideal way to keep corn milled products safe from aflatoxin contamination would be to keep it from becoming moldy. Food standards establish requirements for the safety and quality of food. However, unless a food standard is part of food regulations, it is not a legal requirement.

The Ghana Standards Authority [GSA] (2009) has outlined safety requirements for safe food preparation and cautions that raw materials for making corn dough be clean, well dried and free from aflatoxin. Also, the materials should be free from damage, pest infestation, diseases and any foreign or extraneous materials. GSA (2009) indicated that under section 3.2.2 of the Ghanaian laws on food safety practices and general requirements, the owners of food businesses are held responsible for food handlers and supervisors' skills and knowledge in food safety. The purpose of this study was to examine chemical contaminants in corn dough from corn wet milling plants in Mankessim as a way of assessing health risk that may be associated with consumption of corn dough.

2. METHODOLOGY

2.1. Research design
A mixed-method approach was used. First, a descriptive survey was conducted to obtain baseline data from consumers' and wet corn milling operators. Practices of these groups were also observed to help identify those that probably contributed to the chemical contamination of the corn dough. A quasi-experimental pre-test, post-test control group design was employed to explore possible effects training had on trainees and the relationship that existed between the trained and the control group.
The design is illustrated below:

PR1   Xa   Po2
PR3   Xc   Po4

PR1 and PR3 represented the pre-test observations. Conversely, Po2 and Po4 represented the post-test observations. The Xa and Xc represented experimental conditions for both experimental and

control groups interventions. Training covered hot water, soap and sponge cleaning of milling units, as well as oil/shea butter lubrication of mill parts by the experimental group.

2.2. Sample and sampling procedure

The study population comprised of all corn wet milling plants in Mankessim (N= 63). The multistage sampling technique was used to select the sample. First, all the 63 corn wet milling plants were purposively selected. Secondly, these 63 corn wet milling plants were ranked based on the following: type of lubricant, cleaning material, brand, origin and type of grinding plate used, material used for application of lubricant, care given to hands after lubrication before touching the milling plant and the general sanitation. The first 5 corn wet milling plants with high risk of chemical contamination were selected. Thirdly, 3 of the 5 corn wet milling plants were randomly picked to serve as the experimental group and the remaining 2 served as the control group. The following key was used to identify water from different sources, corn and corn dough samples.

2.3. Water samples

O – Source of water for soaking corn
A2 – Waste water collected from green plastic container
B2 – Waste water collected from black plastic container
C 2– Waste water collected from purple plastic container
D2 – Waste water collected from old metal container
E 2– Waste water collected from new metal container

2.4. Corn and corn dough samples

A1 – E1 soaked corn
A2 – E2 first sample collected
A3 – E3 second sample collected
A4 – E4 third sample collected
L   dry corn
M   corn dough processed in corn wet milling plant

2.5. Research instruments

Hundred corn dough consumers were purposively sampled for the study. Interviews, observation check list and laboratory analysis were used to collect data for the study. Samples collected from the corn wet milling plants were packaged in airtight polythene or bottles (water), stored in a cold chamber and transported to the following laboratories for analysis: Water Research Institute, Food Research Institute, Mycotoxin and Pesticide Residue Laboratories of the Ghana Standard Authority, Accra and the University of Cape Coast Chemistry Laboratory.

2.6. Data collection procedure

A survey interview was conducted at milling sites to collect information on milling practices from mill operators and an observation list was followed to verify information collected from corn wet mill operators. Samples collected from milling plants were transported to the laboratory for analysis. Consumers of corn dough products were also interviewed at their places of convenience to obtain information about processes that corn dough often goes through. Corn millers and consumers of corn dough products who offered to participate in the study were assured of confidentiality and anonymity. For all interviews, participants' responses were kept confidential and anonymous. Interviewees were given the opportunity to withdraw anytime they wanted to. Interviews and corn dough samples were all collected from the beginning of January to the end of February, 2016. The objectives of the study were explained and permission sought from participants observed prior to collecting samples from corn wet millers during the milling of corn into dough.

Twenty-eight samples were taken on different days in total. Triplicate samples were collected from each of the 3 experimental groups of the 5 corn wet milling plants at every sampling period and samples subjected to laboratory analysis. Duplicate samples were however collected from each of the 2 control groups and analyzed as well. The experimental groups included corn wet milling plants sited in Twafo, School Kessim and Anaafo and the control groups consisted of corn wet milling plants at Estate and New Nkusukum (Guaekyir). Water used in soaking corn prior to milling was sampled before soaking and after soaking prior to milling. A, B, C, D and E were used to represent each of the selected corn wet milling plants. Numerical subscripts were also used to indicate the different samples taken from the corn wet milling plants. The first three letters; A, B and C were used to represent the 3 selected experimental groups and D and E were also used to represent the selected control groups. Corrective measures were applied to the production processes involved in the production of corn dough for the control group.

Five different statistical analytic methods were used for the analysis. These included ISO 16050 method, the QuEChERS, Atomic Absorption Spectrophotometer, gravimetric method and cold maceration. Metals were tested for at the Food Research Institute, aflatoxin and pesticides at the Standards Authority Board, grease and oils at the University of Cape Coast Chemistry laboratory and metals, oils and grease at the Water Research Institute.

2.7. ISO 16050 method of determining aflatoxin

The method involved sample preparation, extraction and instrumentation. Dry and wet corn samples were milled into a coarse texture using a laboratory miller and packed into air tight polythene. Milled samples were further blended using a warring commercial laboratory blender and sifted into fine flour. The miller and the blender were both washed after each milling. Twenty grams of sample was weighed and 2g of sodium chloride (NaCl) added to prevent emulsion and enhance extraction of aflatoxin. A 100ml extraction solvent (80% methanol and 70% water) was added to the sample and homogenized for 3 minutes using a homogenizer. Homogenized sample was filtered into a 25g volumetric flask using a pyrex glass funnel and   glass micro-fibre filter (No 2235) to get rid of the residue. Then 20ml of the filtrate was collected using a 20ml pipette. The filtrate was added to 60ml of phosphate buffer saline at a pH of 7.4. Then 100ml of concentrated Phosphate buffer saline and 1000ml water were added and 10% of it was taken.

It was then filtered into a transparent plastic container using glass funnel and glass microfiber filter (Whatman paper). After, 20ml of the filtrate was pipetted into a transparent plastic container. Immno Affinity Clean up Columns (that is Aflastar) were fixed onto a manifold where the samples were first run. Pasteur pipette was used to draw and deposit the filtrate gradually into the columns ensuring that the columns were wet and not dry. The columns contain antibodies which did bind and trap the aflatoxin (antigen) in the sample. Water (10ml) was used to wash the sample (aflatoxin) in the columns. To remove all traces of water from the column, air was blown twice into it using a syringe. Methanol (1.5ml) and 0.5ml of water were added to the sample (aflatoxin) in the column. The sample (aflatoxin) was then collected into a 2ml volumetric flask, transferred into vials and vortexed to evenly mix the sample. The analyte and reference materials were analyzed concurrently using High Performance Liquid Chromatography (HPLC).

2.8. Determination of pesticide residue using the QuEChERS method

Samples were prepared, extracted and analyzed. Dry and wet corn samples were blended into fine flour using a warring commercial laboratory blender. Then 5g of the sample was weighed and 10ml of chilled distilled water added to cool it. Acetonitrile (10ml) was added to extract the residue and vortexed for a minute.

Magnesium sulphate (4g), 1g tri-sodium citrate dehydrate, 1g sodium chloride and 0.5g sodium hydrogen citratesesquihydrate were mixed together in a centrifuge tube and added. Sodium chloride was added to absorb moisture from the sample whereas the tri-sodium citrates dehydrate

and sodium hydrogen citratesesquihydrate formed a buffer which neutralized the pH in the sample. Subsequently, the sample was vortexed for a minute then centrifuged at 3000 rpm for 5 minutes. The centrifuging enabled the inorganic layer (water and the sample) to settle at the bottom of the centrifuge tube leaving the organic layer (acetonitrile) at the top. About 6ml of the organic layer containing the residue was transferred into a centrifuge tube containing 900ml of magnesium sulphate and 150m of Primary – Secondary Amine (PSA). The magnesium sulphate and PSA were used to absorb any impurities (co-extracts) that were present in the sample then shaken and vortexed for 30 seconds. This process of clean-up is referred to as Depressive- solid phase. After vortexing, the sample was centrifuged again at 3000 rpm for 5 minutes then 4ml of the extract was pipetted into a pear-shaped flask and 40ml of concentrated formic acid added and dried on a rotary evaporator. Residue obtained was redissolved in 1ml of ethyl acetate. A Pasteur pipette was used to draw 2ml into vials and analyzed in the Gas chromatograph concurrently. The Gas chromatography detectors; Electron Captures Detector (ECD) and Pulsed Flame Photometric Detector (PFPD) detect organo-chlorides, synthetic pyrethroid and organo-phosphorus pesticides.

2.9. Atomic absorption spectrophotometry (AAS) method for water analysis

The flame method was used to analyze metals in the water samples. Samples were put in cleaned translucent bottles and nitric acid added to break down the electron bonds and free them to be analyzed. Standards of concentrations 0.5ml, 1.0ml and 2.0ml; were prepared to run alongside the samples. The AAS was connected to a computer monitor and started. D2 hollow cathode lamps were selected and set in their respective positions. Calibration was done using the monitor and the wavelengths for lead, iron and zinc selected. Water samples were placed in the AAS and aspirated into glowed flames representing the concentration of each metal. The intensity of the flame indicated higher metal concentration in the sample. As the sample was aspirated the absorbance was indicated on the monitor and recorded. A blank sample (standard) was also analyzed alongside. A calibration graph was drawn in order to get the absorbance to calculate the amount of metals in the samples.

2.10. Gravimetric method for analyzing oil and grease in water

Empty glass dishes were lifted with forceps and weighed (W1). A glass separating funnel was used to measure 50ml of the sample adding 20ml petroleum ether and 1ml hydrochloric acid was pipetted and added. The sample was vigorously shaken to ensure homogeneity and built up pressure gradually released by opening the side stopper on the separating funnel. A pop-sound indicated release of in-built pressure. The sample settled at the bottom of the separating funnel leaving the ether at the top and was collected into a round bottomed flask, filtered using a glass funnel and glass microfiber filter paper. After filtration, 10ml of petroleum ether was added to the residue and a second extraction done. The filtrate was placed on a hot water bath for the ethyl to evaporate leaving the grease. The sample was dried in a Binder (oven) at a temperature of $100\,^{\circ}C$ for 30 minutes, allowed to cool in a desiccator for 30 minutes. The dish containing the content (grease) was reweighed and the new weight (W2) recorded. The old weight (W1) was deducted from the new one (W2) to get the quantity of grease in the sample.

Calculation

$$\frac{W2 - W1}{V} \times 10^6$$

Where,
W2 – The final weight of dish + oil
W1 – The weight of empty dish
V – Volume of the sample taken
10^6 - Constant

2.11. Determination of moisture content in corn dough

In determining moisture content of the sample, empty cans were washed and dried in a furnace for 20 minutes at a temperature of 550°C. Dried cans were weighed using a weighing balance and recorded. Empty cans were weighed and recorded. Three grams of fresh samples were weighed into the cans and weight recorded. Weighed samples were placed in hot air oven at a temperature of 103°C for 4 hours to dry. Dried samples in cans were removed from the hot air oven using a tong, placed in a desiccator and allowed to cool for 20 minutes. After cooling, the samples were reweighed and the new weights recorded.

2.12. Calculation for % moisture

Crucible weight = 21.676
Crucible weight + sample weight = 24.6812
Weight of fresh sample = 3.0043
Dry sample + crucible = 23.2787
Loss in weight = 1.4025

$$\% \text{ moisture}: \frac{Loss\ in\ weight}{Dry\ sample\ weight} \times 100$$
$$= \frac{1.4025}{3.0043} \times 100$$
$$= 46.683038$$
$$= 46.683$$

2.13. AAS method for determining metals in corn dough

The method involves ashing, digestion and metal analysis.

2.14. Ashing of samples

Crucibles were first washed, dried in a furnace at a temperature of 550°C for 20 minutes and cooled in a desiccator. Cooled crucibles were reweighed and weight recorded. Three grams of the sample was weighed into the crucibles and placed in a furnace at a temperature of 550°C for 6–8 hours till ashed. After ashing, they were removed from the furnace using a tong and cooled in a desiccator.

2.15. Calculation of ash

Weight of ash = weight of ash + crucible weight − weight of empty crucible
$$\% \text{ ash} = \frac{weight\ of\ ash}{weight\ of\ sample} \times 100$$

2.16. Digestion of sample

Acid digestion was carried out after ashing the sample. Concentrated nitric acid (5mls) was pipetted into the ashed sample in the crucible and placed on a hot plate at a temperature of 80°C and allowed to digest for 10 minutes. Dilute nitric acid (10mls) was pipetted into a beaker and the digest transferred into the beaker containing the dilute nitric acid. The sample was then filtered into a 50ml volumetric flask using a glass funnel and glass microfiber filter paper. The sample in the volumetric flask was topped up with dilute nitric acid to make up a volume of 50ml. After topping, the sample was homogenized by shaking and analyzed using AAS.

2.17. Metal analysis using AAS

AAS was put on, followed by air and acetylene gas. The D2 hollow cathode lamps were put in place and set into their respective positions. A calibration was done and the wavelengths for lead, iron and zinc were installed. The digest was transferred into the AAS and aspirated into glowed flames representing different concentrations of each metal. While the sample was been aspirated the absorbance was indicated by the machine and recorded. A blank sample was also analyzed the

same way. A calibration graph was drawn in order to get the absorbance to calculate the amount of metals in the samples.

2.18. Determination of oil and grease in corn dough using cold maceration

Round bottomed flasks and crucibles were washed with clean water, rinsed with petroleum ethyl and allowed to dry. About 10g of samples were measured using a weighing dish and weighing balance and poured into a 100ml round bottomed flasks. About 100ml petroleum ethyl was measured using measuring cylinder and a glass funnel, and added to the samples in the round bottomed flasks. The flasks were sealed with cotton wool and aluminum foil to prevent the petroleum ethyl from evaporating and air from entering. The samples were shaken using a mechanical shaker for 24 hours. Crucibles were weighed and weights recorded. After shaking, the samples were filtered into the crucibles using glass microfibre filter paper. The filtrates were placed on hot water bath to dry. The samples were put in a desiccator to cool. After cooling, the samples were reweighed and the new weight was recorded. In order to get the oil weight, crucible weights was subtracted from crucible plus oil weights.

2.19. Data analysis

The Statistical Product for Service Solutions (SPSS) software version 21.0 was used to analyze the data. Analyzed data were presented in percentages and frequency tables. Data from interviews was input into excel and analyzed using descriptive statistics. The samples collected were analyzed using 5 analytical methods including QuEChERS, HPLC, and AAS; gravimetric and cold maceration. Data obtained from the laboratory tests was input into excel spread sheet and analyzed using a Statistical Product for Service Solutions (SPSS version 21.0). Analyzed data was presented as means in tables and figures. Means of chemical loads in the samples were compared to both pre and post intervention using descriptive statistics. The significant differences between means were calculated by Analysis of Variance at $p \leq 0.05$.

3. RESULTS & DISCUSSIONS

Females (68%) interviewed in the study turned out to be more than males (32%) as shown in Table 1 below. This is probably because more females are known to engage in kenkey production than males and would be involved more in corn dough production and use. The educational background of the respondents could be described generally as average with slightly more than half (64%) having some form of formal education ranging from basic education, through middle, vocational and technical education to undergraduate level of education (Table1). Only 20% of the respondents had no formal education. Majority (about 50%) were married which increases their chances of using large quantities of corn dough for cooking for their families as compared to single (20%) respondents who may not necessarily be obliged to cook much using corn dough but rather buy other foods for convenience (Table 1).

About 50% of the respondents were traders probably trading in corn dough and its food products and as a result may be more familiar with corn dough production and use. Unfortunately, getting the ages of this group of people was very difficult. Either some did not know exactly when they were born especially the 20% who had no formal education; others who knew were uncomfortable giving out such information. A few did though but because majority did not, age was left out of the demographic table. However, looking at the physical features of the respondents, they could be easily classified as adults.

Table 1: Demographic characteristics of study respondents

Variables	Frequency	Percentage (%)
Gender		
Males	68	68
Females	32	32
Educational Level		
No formal education	20	20
Basic/Middle school	32	32
Secondary/Technical/Vocational	14	14
Undergraduate	30	30
Graduate	4	4
Marital Status		
Single (never married),	20	20
Married	50	50
Widows	8	8
Separated/ Divorced.	22	22
Total	100	100

Source: Field data, 2016

Table 2: Mean number of contaminants in water samples tested

	O	A2	B2	C2	D2	E2
Oil/grease (mg/l)	0	30	110	90	9..4	48
Lead (mg/l)	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Iron (mg/l)	0.019	1.14	2.29	1.88	1.87	2.20
Zinc (mg/l)	0.015	1.46	1.98	1.70	1.72	1.95

Source: Field data, 2016

Sample O (ordinary potable water) had no traces of oil and grease while the remaining samples had (i.e. A2, B2, C2, D2 and E2) Table 2. Looking at the variations in the levels of grease found in the different waste water samples, one could clearly speculate that the type of containers used for steeping the corn or the treatment of corn prior to soaking could probably introduce some amount of grease into it. The difference between 110mg/l and 30mg/l is about 80mg/l which is quite significant and shows that the presence of oil in corn dough could be greatly reduced if clean containers and water are used in steeping corn prior to milling. Similar trends in variation are shown for iron and zinc (Table 2). Although waste water from metal containers was expected to have the highest level of metals, this was not the case. This is coherent with findings reported by Mensah *et al.* (2002), Abrefah *et al.* (2011) and Tawiah (2010), in studies where contamination of food was linked to utensils used in preparing and processing food.

Due to the use of old and weak milling plants, lubricant leakage from the plant directly into the dough could be high. This could be exacerbated by possible leaching of metals and other substances into the dough as a result of wear and tear of the grinding plates due to friction from continuous use of the milling plants without much maintenance. The fact that corn wet milling plants are versatile and used for milling several other foods, the risk of chemicals from other foods cross contaminating corn dough is high. Also, flavours from other foods could mask that of corn dough if mixed.

From Table 3 below, aflatoxin B1 levels ranged from a high of 137.7µg/kg in dry corn (L) to a low of 8.7µg/kg in well sorted, winnowed and washed corn (B_1). The same trend was observed for the levels of aflatoxin B2 with the highest at 12.2 µg/kg for dry corn (L) and the least at 0.7 µg/kg for well sorted, winnowed and washed corn (B_1). This finding is in line with the Corn Refiners' Association report (2011) which indicated that corn wet milling plants promote incidence of

aflatoxin in corn dough. Aflatoxin G1 and G2 however were very low below the detection limits and so could not be captured.

Table 3: Mean number of aflatoxin from dry, steeped and milled corn samples tested.

Sample	Chemical Parameters				Total
	AFB1 µg/kg	AFB2µg/kg	AFG1 µg/kg	AFG2µg/kg	
L	137.7	12.2	<LOQ	<LOQ	149.9
A1	20.8	1.5	<LOQ	<LOQ	22.3
B1	8.7	0.7	<LOQ	<LOQ	9.4
C1	14.5	1.1	<LOQ	<LOQ	15.6
D1	33.4	2.9	<LOQ	<LOQ	36.3
E1	22.1	1.8	<LOQ	<LOQ	23.9
M	29.8	2.6	<LOQ	<LOQ	32.4

Source: Field data, 2016

Mean aflatoxin level in the corn dough was 32mg/kg which is unacceptable because by the Ghana Standards Authority (2009) and the Australia/New Zealand standards (2002), the level of aflatoxin in any food should be '0' meaning no level of aflatoxin is acceptable in food (Table 3). Thus the figures obtained in this study are unacceptable because they exceeded the acceptable limits. Similarly, the mean levels for iron (30.95mg/kg), zinc (7.17mg/kg) and grease (1.16mg/kg) were way above the acceptable levels according to Codex Alimentarius Commission (2011) and EFSA (2012) who recommend total absence of these substances. Lead was the only substance that was not found in the corn dough samples tested and thus its level could be acceptable according to standards.

Table 4: Comparing mean test numbers for chemical parameters in corn dough to standards

Chemical parameter	Ghana/International standards	Test mean
Aflatoxin	15µg/kg	32.4µg/kg
Organo-phosphorus	0.005mg/kg	<0.005mg/kg
Organo-chlorides	0.010mg/kg	<0.010mg/kg
Synthetic pyrethroids	0.010mg/kg	<0.010mg/kg
Iron	0.2mg/kg	30.90mg/kg
Zinc	0.03-1mg/kg	7.17mg/kg
Lead	0.05mg/kg	ND
Grease	0.05mg/kg	1.12mg/kg

Source: Field data, 2016

The level of organo-chlorides such as p, p'DDT, p, p' DDE, p, p 'DDD, endo-sulfate and endo-sulfan sulfate is < 0.010mg/kg which is within the MRLs. The level of synthetic pyrethroids residues such as permethrin, cypermethrin and bifenthrin is < 0.005mg/kg which is also within the MRLs. However, residues from organo-phosphorus pesticides were not detected. All the chemical parameters determined in the corn dough samples obtained from the different plants ended up far exceeding the recommended standards or limits with the exception of pesticide residues. These high figures may compromise the safety of the corn dough for human consumption.

Corn dough from plant E had the highest grease level 1.46 and plant A had the least 0.46 (Table 5). Subsequently, plant E still had the highest level of iron (48.91) and plant D (19.89) the least respectively. The high level of iron concentration in plant E could probably be due to the fact that the grinding plate was sharpened prior to the sample being collected without being washed. This could introduce iron dust into the corn dough during milling. The milling plant was also used to process other products like legumes, fish and wheat which may have also contributed to the high contamination with iron. Furthermore, the high concentration of iron in plants A, B and C could also be attributed to the age of the milling plant, grinding plate as well overheating of the plant.

According to Abrefah *et al.* (2011) and Ampofo (2012) old milling plants and grinding plates easily wear out and as they wear out, it can result in leaching of metals into the corn dough. Also during milling the grinding plates rub against each other and as a result heat is produced causing migration of metals into the corn dough. The zinc concentrations were highest for Plant A (14.19), followed by a drastic reduction in zinc concentration by plant D (6.71) ending at a least of 3.95 for plant E. Earlier in a similar study, Conor (2002) reported that the use of atlas machine introduced some toxic metals into food during food processing because of friction. Lead however was not detected from any of the samples.

Table 5: Chemical parameters mean concentration levels for corn dough samples obtained from selected wet milling plants.

Chemical Parameters	Corn Wet Milling Plants				
	A	**B**	**C**	**D**	**E**
Grease	0.46	1.2	0.6	2.1	1.46
Iron	26.97	31.2	27.77	19.89	48.97
Zinc	14.19	6.12	4.9	6.71	3.95
Lead	ND	ND	ND	ND	ND
Moisture	41.13	40.27	42.6	42.27	39.13

Source: Field data, 2016

3.1 Consumers' knowledge on food hygiene and food-borne diseases

From observation and analysis of corn dough samples obtained from different wet milling plants risk posed by the level of metals like zinc and iron was established. As to whether consumers of corn dough products know about these risks or not was important to know. Thus, it was important to find out from the respondents if they had knowledge about food hygiene and food-borne diseases. All the 100 respondents mentioned that they had knowledge on food hygiene and food-borne diseases and supported the fact that poor hygiene often resulted in contamination of food and subsequently incidence of food-borne diseases which could be fatal if left untreated. Following this, respondents were asked how they learned about food hygiene and food borne diseases. Majority (90%) mentioned formal education as their source of information with only 10% reporting their main source of information as parents. Although nothing much has been publicized about these contaminants in food, consumers in a way have ideas about them. More education on how these contaminants could be minimized or completely removed from the process of producing corn dough and thus promote better health among consumers.

Table 6:   Control measures necessary to improve the quality of corn dough

Control Measures	Frequency	Percentage (%)
Observe personal hygiene	30	30.0
Clean corn milling plant	10	10.0
Assign a machine strictly for milling corn	10	10.0
Use quality corn for dough	8	8.0
Avoid dough storage in rusted containers	8	8.0
Avoid soaking corn more than 3 days	6	6.0
Salt can be added to preserve dough	4	4.0
Cover dough with net to reduce heat	4	4.0
Avoid use of grease	4	4.0
Minimize water used to mix dough	4	4.0
Wash corn before and after soaking	4	4.0
Use clean water/bowl to prepare dough	8	8.0
Total	100	100.0

Source: Field data, 2016

3.2. Some consumer suggestions on measures to improve corn dough quality and safety
About a third (30.0%) of the respondents suggested strict observation of personal hygiene as important in improving the quality of corn dough (Table 6). Fewer respondents (10.0%) suggested frequent thorough cleaning of the corn milling plants and the use of the milling plants solely for one food item rather than multiple food items. Other suggestions included the use of good quality corn grains for milling into dough, use of non-rusting or non-corrosive containers for steeping the corn prior to milling and for storing the corn dough after milling. The following were also provided by the respondents:

i. Clean water and container should be used in the preparation of corn dough
ii. Corn dough producers should stop using waste water from soaked corn for mixing dough
iii. Corn should be washed before and after soaking with fresh clean water
iv. The dry corn must be soaked in water first for two or three days to dissolve pesticides before using it for the dough and not crush them into grits before milling as dough.
v. Very little water should be used to mix dough to reduce fermentation and spoilage
vi. Salt could be added to corn dough as a preservative to prevent spoilage
vii. Corn dough should be well covered and protected from pests
viii. Avoid the use of lubricating grease which may leak into the dough during milling

4. CONCLUSION

From the findings, it is concluded that corn dough can be contaminated by chemical contaminants from various sources. These sources include metals from the wear and tear from the blades of mill plants, grease that is used to lubricate the parts of the mill, metallic containers in which corn is steeped and dough stored. Aflatoxin level of 32μg/kg, iron, 30.90mg/kg, zinc, 7.17mg/kg and grease, 1,12mg/kg found in some corn samples were over the limits or standards considered as safe and could pose a health risk if consumed. Considering the fact that these metals are not easily destroyed by heat increases its associated health risks because even after cooking the contaminated corn dough, these metals will still be available in the food. Strict adherence to food hygiene could help reduce the levels of these contaminants and make the corn dough food products safer to eat.

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