ASSESSMENT OF THE PRODUCTION, NUTRIENT COMPOSITION AND SOME MINERAL ELEMENTS LEVELS IN CORN-MILL SWEEPINGS (CMS) FROM VARIOUS SOURCES IN THE KUMASI METROPOLIS

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ABSTRACT

This study was conducted to assess the production practices, nutrient composition and mineral elements status of corn mill sweeping (CMS). Twenty semi-structured questionnaires were administered to corn mill operators in the Oforikrom Municipality of the Ashanti Region. Data on their socio-economic characteristics, types of mills used, and management and production of CMS were collected and samples of the CMS were also collected for chemical analysis. Data collected were analysed by descriptive statistics outlined by Statistical Package for Social Sciences (SPSS) version 20. Results showed that almost all (95%) mill operators interviewed were males. A majority (65%) of the mill operators were below the age of 40 years. All mill operators interviewed had two or more different machine types and they included grinding mill, crushing mill, hullers and pounding machines. Most (95%) of the millers use locally manufactured grinding plates. Food and feed items that could form part of the milling processes were cassava, fish, groundnut, soya beans, cowpea, and paddy rice. The study further revealed that the majority (75%) of the millers produce between 6 - 25 kg CMS/day. The proximate analysis showed that the %CP, %Ash, %Ether extract, % CF, NFE and ME ranged between 8.53-14.51, 2.11-6.28, 1.05-3.66, 0.53-3.51, 76.34-84.62 and 3304.18-3574.65 kcal ME/kg DM respectively. The qualitative and quantitative mineral analysis revealed six minerals, namely; cadmium (0.06-0.61mg/kg), calcium (15,198-20,419mg/kg), phosphorus (2604.90-4291.50mg/kg), zinc (24.26-47.23mg/kg), iron (351.1-1781.50mg/kg) and copper (37.25-230.81mg/kg) to be present in the CMS. It was concluded that substantial quantities of CMS are produced daily by mill operators for feeding farm animals to meet their nutrients and energy requirements. Operators must however ensure that toxic materials do not contaminate the CMS.

Keywords: *Corn mill sweepings (CMS), mill operators, proximate analysis, food and feed materials, mineral elements*

INTRODUCTION

The price hike in the major conventional feed resources for example maize has led to an increase in the variable cost of the total production cost of farm animals. Consequently, farm animal production may become economically unattractive. A solution to the aforementioned problem is to make use of the wastes, by-products and alternative feed resources which are relatively cheaper and underutilized (Manu *et al*., 2015). A good number of agro-industrial by-products have been investigated and proven to be suitable alternatives to the very expensive major conventional feed resources (Devendra and Leng, 2011). Although there have been complications to the use of some (Boateng *et al*., 2014), others, for instance, brewers spent grains have still proven to be suitable surrogates. Corn mill sweepings (CMS), a by-product of the corn mill industry, have shown a lot of potential in this regard. Early reports by Okai *et al.* (2016), Boateng *et al.* (2014) and Boateng *et al.* (2015) have shown that it forms a major part of the diets of pigs. It is commonly referred to as "B-Co" due to the diverse nature of the by-product (Okai *et al.,* 2016), in terms of its ingredient composition. Most of the early reports had focused on the main product, especially corn dough, and the milling machines. For instance, research on the heavy metal contamination (Kwofie *et al*., 2011; Adeti, 2015 and Hinson and Darkwa, 2016) and anti-nutritional factors e.g. Aflatoxins (Agbeve, 2016) of the main product had been conducted, especially on corn dough but not on the CMS. Also, a report by Okai *et al*., (2016) focused on the usage and the potential contaminants that could be present in CMS. A research gap exists on the nutrient composition as well as the trace mineral elements status of this by-product. Knowledge of the nutrient profile of CMS would assist nutritionists to effectively characterize the product and also help in the optimum inclusion of the product in the formulation and compounding of diets by scientists and farm animal producers. This study, therefore, seeks to assess the production of the CMS in milling shops in the Oforikrom Municipality of the Ashanti Region as well as the nutrient compositions and mineral elements levels in the product from various sources.

MATERIALS AND METHODS

Phases and study areas

A mixed-approach method, described as Phase 1 and 2, was employed for the study. Phase 1 was a survey and involved the collection of data from mill operators in the Oforikrom Municipality in Ashanti Region, Ghana on the type of machines used at their mill shops and the production, and storage of CMS, whilst phase 2 assessed the analysis of the proximate and mineral elements of samples of CMS collected from some of the mill operators during phase 1. Phase two was carried out at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Phase 1: Data Collection

Twenty mill operators from the Oforikrom Municipality were conveniently sampled and interviewed in their mill shops using semi-structured questionnaires. The places visited were Ayigya, Ayeduase New site, Atonsu, Anloga, Emena, Deduako, Kotei, and Sisakyi. Research questions asked were related to their demography, management and operation of the shops, number, and type of machines used, CMS production and storage as well as users of CMS.

Phase 2: Sample collection, proximate and trace mineral elements analysis

A kg, each, of CMS sample, was collected from seven mill operators in the Oforikrom Municipality into low-density polyethylene zip-lock bags. Each CMS sample collected was screened to remove extraneous and foreign materials from it after which it was milled to pass through a 2mm sieve with a hammer mill. Each screened CMS sample was divided into two, approximately 500g each, oven-dried at 60°C for 48 hours and stored at room temperature until needed for the subsequent studies.

Chemical analysis

The proximate analysis was conducted following the standard protocols outlined by AOAC (2002). The samples from the seven mill shops were assayed for percent moisture (MC), crude protein (CP), crude fibre (CF), crude fat or ether extract (EE) and the ash. The nitrogen-free extract (NFE) was obtained by subtracting the sum of the percentage of CP, MC, CF, EE and Ash from a hundred percent (100%) i.e., %NFE = [100% - (%MC + %CP + %CF + %EE + % Ash)] . The metabolizable energy (ME) of the CMS was estimated using the equation proposed by Pauzenga (1985) i.e., ME (kcal kg^{-1}) = [(37×%CP) + (35×%NFE) + (81.8×%EE)]. The qualitative and quantitative estimates of the trace mineral elements in the CMS was carried out using the atomic absorption spectrophotometry as outlined by the American Public Health Association [APHA] (1998).

Statistical analysis

Data obtained from the survey were coded into their similar views and analyzed by descriptive statistics of the Statistical Package for Social

Sciences (SPSS) version 20 (2011). Results obtained from the analysis were presented in tables and charts as frequencies and percentages. However, results from the proximate and trace mineral element analysis were presented as mean values in tables.

RESULTS AND DISCUSSION

Demographic statistics of mill operators

A majority (65%) of the respondents interviewed were found to be below the age of 40 years whilst about 35% of the respondents were between the ages of 40 and 59 years (Table 1). Earlier, Solomon-Ayeh *et al.* (2011) had stated that the economically active age group of street vendors in Ghana is between the ages of 18-45 years. Mill operation, like street vending, is energy-sapping and tedious and therefore requires labour force who are within the economically active group to ensure effective operation.

It was found (Table 1) that a major fraction (95%) of the mill operators were males with just 5% being females. Because of the labour-intensive nature of mill operation, more males were expected to be attracted to the work than females. An earlier report by Burton (2012) states that males are physically stronger than females perhaps because of the higher muscle mass coupled with their denser bones, tendons, and ligaments. Hinson and Darkwa (2016) found more females (68%) to be involved in corn dough production and utilization than males (32%).

The results (Table 1) revealed that 75, 20 and 5% of the mill operators in the Oforikrom Municipality were Christians, Muslims, and non-religious persons respectively. A similar trend, i.e., 94.9% and 5.1% for Christians and Muslims respectively, were found by Boateng *et al.* (2019) in a survey conducted to assess the incidence of blood and meat spots in eggs processed for sale by some food joints.

Results obtained for the educational background revealed that a good number (75%) of the mill operators have had some form of formal education ranging from primary, through junior high, to senior high and vocational levels (Table 1). A recent report by Khamila *et al*., (2019) revealed that the maize milling industry in Kenya is com-

Table 1: Demographic statistics of mill operators

Demographics	Category	Frequency (%)$^{\beta}$
Age, Year	Below 20	2 (10%)
	20-29	8 (40%)
	30- 39	3 (15%)
	40-49	5 (25%)
	50-59	2 (10%)
Gender	Male	19 (95%)
	Female	1 (5%)
Religion	Christians	15 (75%)
	Muslims	4 (20%)
	Non-Religious	1 (5%)
Educational background	Non- formal	5 (25%)
	Primary/ JHS	11 (55%)
	Secondary/ SHS/ Vocational	4 (20%)
Marital status	Single	11 (55%)
	Married	9 (45%)
Occupation	Owner	5 (25%)
	Manager	8 (40%)
	Employee	7 (35%)

$^{\beta}$ *Value in parenthesis refer to a percent value* posed of both skilled and unskilled labour. This means that the mill industry contributes to the efforts made to alleviate societal poverty by serving as an employment source to people with little or no formal education who ordinarily would have strived to get employed in the public and civil sectors. It was observed that even those (25%) with no formal education received some form of on-the-job training to equip them with the basic skills needed for the smooth operation of the mills. Mill operation requires some basic skills and technical-know-how to be effective. The level of education found in this study coupled with skills obtained through apprenticeship and on-the-job training give mill operators a good chance to fathom the dynamics and mechanism of mill operation, hence can operate the milling machines effectively.

Interestingly, about 55% of the mill operators audited were found to be single while 45% of them had married (Table 1). A report by Hinson and Darkwa (2016) found, rather, the majority (80%) of corn dough producers to be married and some 20% being single.

About 25, 40 and 35% of mill operators interviewed were owners, managers, and employees respectively. This quite supports the earlier assertion made that the mill industry employs an appreciable number of Ghanaian citizens. A report by Khamila *et al.* (2019) showed that 45, 23.6 and 30.4% of respondents interviewed, in a study conducted to assess the characteristics of the maize milling industry and the status of flour fortification practice among commercial mills in Kenya, were company directors, managers, and millers as well as quality control personnel respectively.

Operation and management of mill shops

Results obtained for the number and nature of the machine used in the mill shops visited are tabulated as Table 2 whilst the origins of the milling machines and grinding plates are shown in Table 3. It was realized (Table 2) that all mill operators had 2 or more milling machines in their shops. Again, all the mill shops visited had a grinding mill in the shop while 90%, 90% and 20% of the mill shops had crushing, pounding and hulling machines respectively. Data on the number of machines used by the mill operators is a suitable indicator of the production level of CMS whilst the nature and/or type of machines used by operators also gives an indication of the type of foodstuff or items that are being processed at the shops and the potential constituents of the by-product (CMS).

Table 2: Number and nature of machine

Number of machines	Frequency (%)$^{\beta}$
2	2 (10%)
3	8 (40%)
4	4 (20%)
5	2 (10%)
6	2 (10%)
>6	2 (10%)
Nature/Type of machines	
Grinding	20 (100%)
Crushing	18 (90%)
Pounding	18 (90%)
Hulling	4 (20%)

$^{\beta}$ *Value in parenthesis refer to a percent value*

For instance, grinding machines, according to the mill operators, are used to mill maize, millet, and groundnut, etc. while crushing mills are commonly used to process foodstuff like cassava. Hullers, on the other hand, are used to remove the husk of grains especially rice. Table 3 shows that a majority (55%) of the mill operators used only locally manufactured machines whilst 10% and 35% use imported and both im-

Table 3: Origin of milling machines and grinding plates

Origin of machine	Frequency (%)$^{\beta}$
Locally manufactured	11 (55%)
Imported/foreign made	2 (10%)
Both local and foreign-made	7 (35%)
Origin of grinding plate	
Locally made plates	19 (95%)
Imported plates	1 (5%)

$^{\beta}$ *Value in parenthesis refer to a percent value* ported and locally made machines respectively. Also, the majority (95%) of the mill operators used locally manufactured grinding plates while 5% use imported grinding plates.

This result supports the findings of Kwofie *et al*. (2011) that mill operators prefer locally made plates to foreign ones because they are relatively inexpensive and readily available.

Ages of machines in mill shops

Except for 35% of the mill operators who had milling machines of the ages between 1 and 10 years, a majority of the mill operators' machines were between the ages of 11 and 40 years (Figure 1). It was realized that the ages of the machines varied within and among mill shops, perhaps because machines from various shops were purchased at different times. The ages of the various machines may be an indication of how long the milling has been going on as well as the operational efficiencies of the machines. The reasons given for the very old machines were that they were inherited from older generations of millers and the newer types are the ones that were bought at the beginning of their businesses.

Potential ingredients in CMS

The ingredients and the form in which they are received and milled by operators is shown in Table 4 and Figure 2, respectively.

Table 4: Major ingredients milled by operators

Ingredients	Frequency (%)[β]
Maize	20 (100%)
Millet	18 (90%)
Cassava	16 (80%)
Fish	11 (55%)
Groundnut	11 (55%)
Soya beans	7 (35%)
Cowpea	5 (25%)
Rice	2 (10%)
Pepper	17 (85%)
Ginger	4 (20%)
Tomatoes	17 (85%)
Onion	17 (85%)
Garlic	1 (5%)
Cocoyam leaves	1 (5%)
Garden eggs	1 (5%)

[β] *Value in parenthesis refer to a percent value*

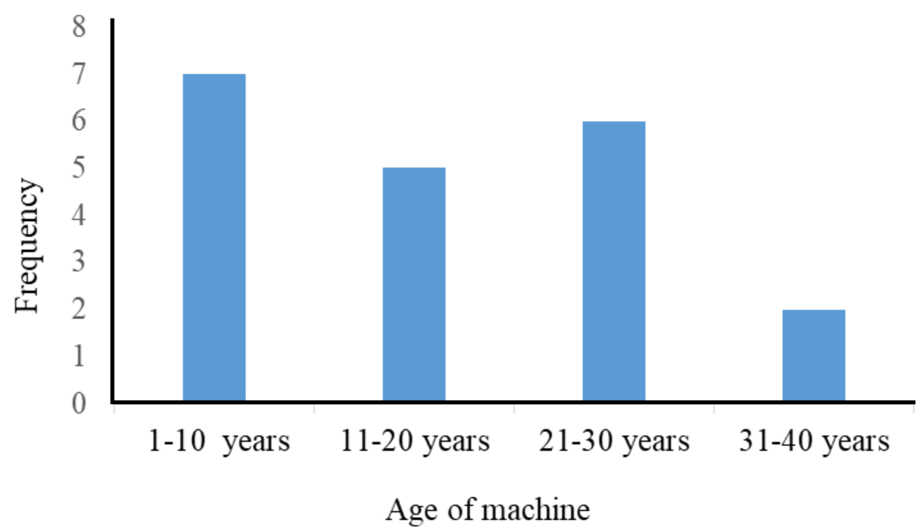

Figure 1: Average age of Machines

All mill operators audited indicated that they processed maize at their shops. According to MoFA (2001), over 95% of all Ghanaians enjoy delicacies prepared from milled maize. For instance, '*banku*', '*kenkey*', '*akple*', '*aprenprensa*', '*etew*' and maize porridge are all prepared from milled maize (Kwofie *et al*., 2011 and Hinson and Darkwa, 2016). About 90, 80, 55, 55, 35, 25 and 10% of the mill operators indicated that they mill millet, cassava, fish, groundnut, soya beans, cowpea, and rice, respectively. Abrefah *et al.* (2011) and Adeti (2015) stated that corn milling plants are indispensable to the flour industry especially in processing cereals and grains, legumes, nuts and spices into flour. It was observed that not all the food items come as a single entity always but sometimes it comes as a mixture. For instance, millet, pepper, Negro pepper, and ginger may come as a mixture especially from millet porridge producers. Also, tomatoes, onions, and pepper may come together as one entity to be processed. The type of ingredients or food items milled by the operator could be a useful indicator of the various materials that may form part of the by-product (CMS) during and after processing. Okai *et al*. (2016) had stated earlier that CMS is obtained after the processing of food items like maize, sorghum, millet, cassava, etc.

It was realized (Figure 2) that 100, 100, 100, 30 and 30% of the respondents receive and process food items that have been dried, soaked, roasted, boiled and smoked respectively. According to Kwofie *et al*. (2011), corn is generally milled either dried or wet (soaked).

Production and storage of CMS

A major (60%) fraction of the mill operators collected CMS from the floor only whilst some 40% collected from both the floor and from the machine (Table 5). Those collected from the machine, resulting from when food items get stuck in the machine (Okai *et al*., 2016) which becomes accessible after the machine has been opened or dismantled. The place of collection of the by-product could influence the extent of further contamination of the CMS. For instance, in an attempt to remove food that is stuck in the machine, pieces of metals from the plate or collection area may get mixed with the food which will further adulterate the food and eventually the CMS. Results on the prices at which the CMS (per kg) is sold ranged from free, through 20, 30, 40 to 60 pesewas. The average price per kg (35.50 pesewas) of CMS found in this study is above the ranges of CMS price i.e., 20-30 pesewas reported by Okai *et al*. (2016). The increase in the price of the CMS in this study could be due to the increase in both demand and the quantity demanded of the CMS by the consumers. The study revealed that some 85% and 15% of the mill operators audited sell CMS in wet and dry form respectively (Table 5). An earlier report by Okai *et al*. (2016) stated that 88.89% of pig farmers sampled in the Ejisu-Juaben Municipality collected both dry and wet forms of CMS while 5.56% each preferred either dry or wet CMS only. The form, whether dry or

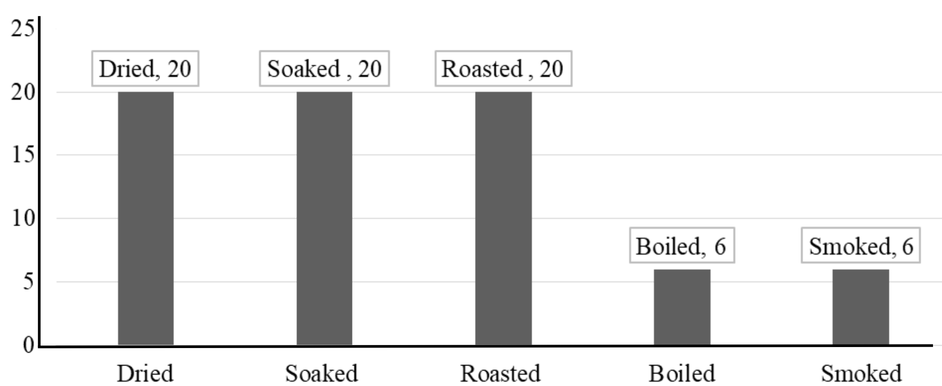

Figure 2: Forms of the ingredients received and milled by operators

Table 5: Collection, price and consumers of CMS

Parameter	Category	Frequency (%)[β]
Place of collection	Floor only	12 (60%)
	Floor and machine	8 (40%)
Price (¢) of CMSkg^{-1}	Free	1 (5%)
	0.20	1 (5%)
	0.30	5 (25%)
	0.40	12 (%)
	0.6	1 (5%)
Form sold	Wet	17 (85%)
	Dry	3 (15%)
Buyers/Consumers of CMS	Pig farmers	20 (100%)
	Poultry farmers	15 (75%)
	Goat farmers	5 (25%)
	Rabbit farmers	1 (5%)

[β] *Value in parenthesis refer to a percent value*

wet, in which the CMS is stored and/or sold could affect the storability of the product. For instance, El-Shafey *et al*. (2004) iterated that feed ingredients with high moisture content are prone to spoilage, especially mould infestation. About 100%, 75%, 25% and 5% of the mill operators indicated that the major consumers or buyers of the CMS are the pig, poultry, goat and rabbit farmers respectively. According to Balogu *et al*. (2017), corn mill waste is commonly used by livestock and poultry farmers. Okai *et al*. (2016) also found that about 94.7% of the pig farmers in the Ejisu-Juaben Municipality use CMS as part of their pigs' diet. Also, Frimpong *et al*. (2017) found mill waste to be one of the feed materials given to ruminant livestock in Ghana.

It was realized that about 80%, 15% and 5% of the mill operators keep and/or store the CMS in polythene bags, plastic buckets and on the floor, respectively (Figure 3). Frimpong *et al*. (2017) reported that about 3% of ruminant livestock farmers in Ghana store their feeding materials in plastic containers.

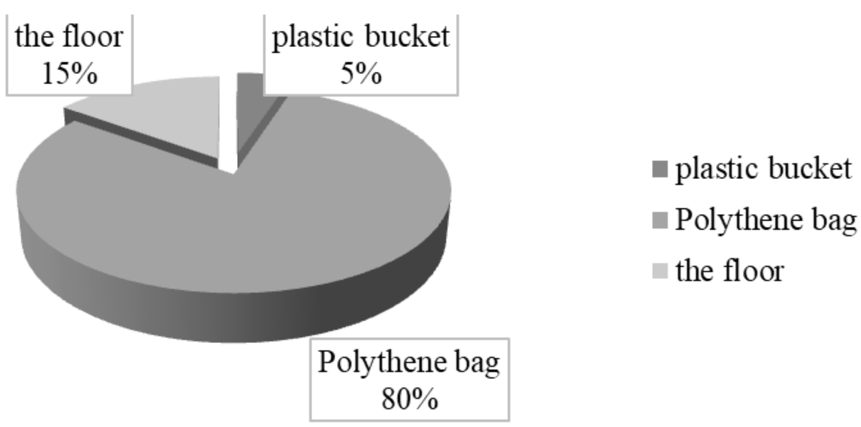

Figure 3: Storage of CMS by respondents

Figure 4 shows the quantities of CMS produced in a day by the mill operators. About 75% of the mill operators produce between 6 and 25 kilograms of CMS in a day whilst 25% produce less than 6 kg of CMS in a day. It was observed that as the number of machines increases, the quantity of CMS produced in a day also increases likewise higher quantities of CMS are produced in a day in mill shops close to residential areas.

Proximate compositions and mineral elements levels in the CMS

Results obtained from the proximate analysis are presented in Table 6. The percentage crude protein and metabolisable energy (kcal/kg) contents of the CMS found in this study ranged between 8.53 - 14.51% and 3304.18 - 3574.65 kcal/Kg respectively. The protein and energy contents of the CMS is comparable to that of maize hence could be a useful energy source in the diets of farm animals. Balogu *et al*. (2017) had stated that corn mill waste, waste and/or leftover obtained from the mill industry (Joy, 2014), is low in protein.

The qualitative and quantitative minerals analyses of the seven CMS sampled from the mill shops assessed are presented in Table 7. The identified mineral elements and range of concentrations in the CMS were cadmium (0.06 - 0.61mg/kg), calcium (15,198 - 20,419mg/kg),

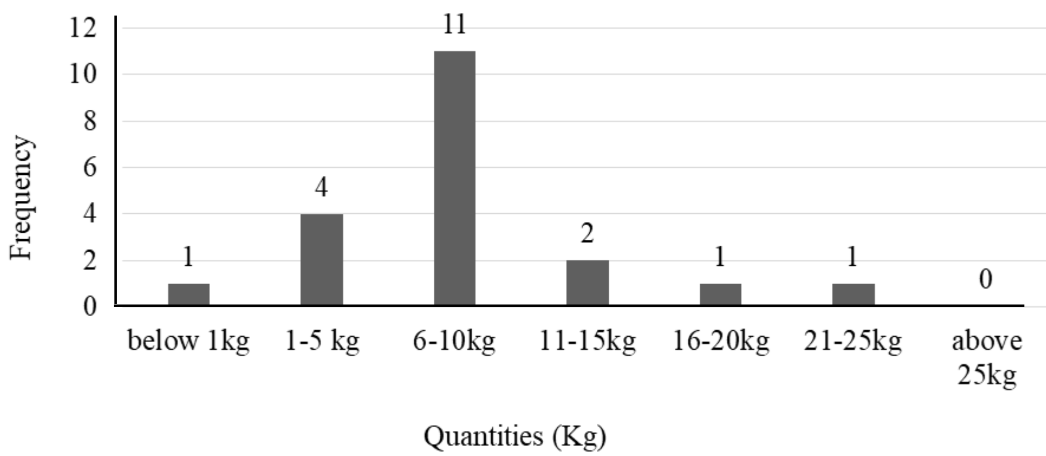

Figure 4: Quantities of CMS produced in a day

Table 6: Nutrient composition of the seven CMS samples collected from the mill operators (% "Dry matter" basis)

Proximate parameter (%, Dry matter basis)	Mill shops[β]						
	A	B	C	D	E	F	G
Moisture	4.50	5.00	5.00	4.00	4.50	7.50	4.50
Crude protein	10.92	11.06	9.58	8.53	10.52	11.65	14.51
Crude fibre	0.78	0.53	0.53	0.78	2.36	3.51	1.83
Crude fat	1.57	2.11	3.16	3.13	1.05	2.16	3.66
Ash	6.28	3.16	2.11	3.65	5.24	3.24	3.66
Nitrogen–free extract	80.45	83.14	84.62	83.91	80.83	79.44	76.34
Metabolizable Energy (kcal Kg^{-1})[¥]	3348.22	3491.72	3574.65	3508.49	3304.18	3388.14	3508.16

[¥]*Metabolizable energy for the CMS was estimated using Pauzenga (1985) equation:*
ME (kcal kg^{-1}) = [(37×%CP) + (35×%NFE) + (81.8×%EE)]
[β]*Mill shops have been denoted with alphabets because of confidentiality*

Table 7: Mineral elements in the seven MS samples collected from the mill operators

Parameter (mg/kg)	Mill shops[β]						
	A	B	C	D	E	F	G
Cadmium	0.435	0.550	0.115	0.060	0.540	0.295	0.605
Calcium	12083	18421	20419	17184	18419	16398	15198
Copper	45.245	230.810	52.830	37.245	45.800	39.355	58.800
Iron	1781.500	786.750	341.300	817.000	1446.700	351.100	476.500
Phosphorous	3308.700	4225.900	3497.200	2604.900	2789.300	4061.600	4291.500
Zinc	32.115	35.320	47.230	25.875	35.595	24.255	35.470

[β]*Mill shops have been denoted with alphabets because of confidentiality*

phosphorus (2604.90 - 4291.50mg/kg), zinc (24.26 - 47.23mg/kg), iron (351.1 - 1781.50mg/kg) and copper (37.25 - 230.81mg/kg). Minerals serve many important functions in pig nutrition. Andrews (1999) and Bhaskaram (2001) stated that iron (Fe) is an essential element in humans. Iron toxicity is the most common metal toxicity worldwide (Crisponi *et al*., 2013 and Kontoghiorghes *et al.*, 2004).

The World Health Organisation (WHO, 1973) reported that an excess amount of Fe could result in toxicity and even death. The concentration of Fe in the seven CMS samples was higher than the 30.90mg/kg Fe in corn dough reported by Hinson and Darkwa (2016). Earlier, Kwofie *et al*. (2011) had reported that the estimated concentration of Fe metal particles in dry and wet milled maize to be 0.083 mg/g and 0.053 respectively. The values obtained for Fe concentration in this study is above the Fe requirement of pigs at any physiological state. This higher Fe concentration in the CMS could be attributed to the intensive wear and tear rate of the locally made plates found to be used by the majority of the mill operators interviewed as well as potential further contamination by the environment. Kwofie and Chandler (2006) had stated that locally manufactured grinding plates wear and tear between about 3-10 times faster than their imported counterparts. Also, the range of values obtained for copper in this study for the CMS was higher compared to what was reported by Kwofie *et al*. (2016) i.e., 15.04 mg/kg to 10.21mg/kg in maize milled in Ghana using locally manufactured grinding plates. An earlier report by Afal and Wiener (2014) stated that larger amounts of heavy metals in the system of humans may cause acute, severe or chronic toxicity. For instance, Wu *et al*., (2012) reported that chronic heavy metal exposure may increase the risk of some cancers while Bronstein *et al.*, (2011) stated that an acute cadmium intoxication is potentially fatal. The values obtained in this study for all the minerals, in general, are high and could pose a health risk to the animals especially pigs when it is being fed to them since these concentrations are above the requirement of minerals by pigs at any physiological stage.

CONCLUSION AND RECOMMENDATION

In summary, corn mill operators in the Oforikrom Municipality are dominated by males. Again, almost all the mill operators are within the economically-active age. Most of the operators use locally manufactured machines and grinding plates. Furthermore, only a small fraction of the mill operators had machines that were less than 11 years old. Wide varieties of food items are being milled in the mill shops audited and by-products during and after processing of most food and feed items are included in the CMS. Some of the mill operators collect and keep CMS on the floor. Wet forms of CMS are usually sold to users with pig, poultry, goat and rabbit farmers as the major users of CMS. Reasonable quantities of CMS are produced by the mill shops in a day. The nutrient composition of the CMS samples suggests that the product is a useful energy source. Six mineral elements namely; cadmium, calcium, phosphorus, zinc, copper, and iron were found in all the seven samples of CMS analyzed. Moreover, the levels of these elements in the CMS samples were considered to be relatively higher.

It was recommended that efforts should be made by mill operators to collect and store the CMS properly to minimize contamination. Machines and grinding plates should be serviced appropriately by mill operators and grinding plates with low wearing rates are recommended to operators to minimize the mineral elements contamination as a result of wear and tear. Furthermore, research should be conducted to assess the insects, microbial and mycotoxin profile of CMS from various sources.

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