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The Application of HACCP Principles to Evaluate Quality and Aflatoxin Levels in the Handling of Post Harvest Maize in Ghana

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ABSTRACT

This research provided a top-down management driven mechanism through HACCP principles for measuring quality indices and monitoring safety of the maize post harvest system in Ghana through the identification of critical control points and the utilization of critical legal limits for the evaluation of maize quality and safety. Major subsystems of maize handling; processing, storage and marketing were assessed through interviews and laboratory analyses. The human, environmental and micro-biological factors accounting for quality variations through-out the maize post harvest system were evaluated. Storage and the point of drying were identified as key critical point and aflatoxin which is the most significant public health hazard associated with poor post harvest handling of maize was identified to be highest during storage.

Key words: Maize, quality, safety, aflatoxin, hazard

Introduction:

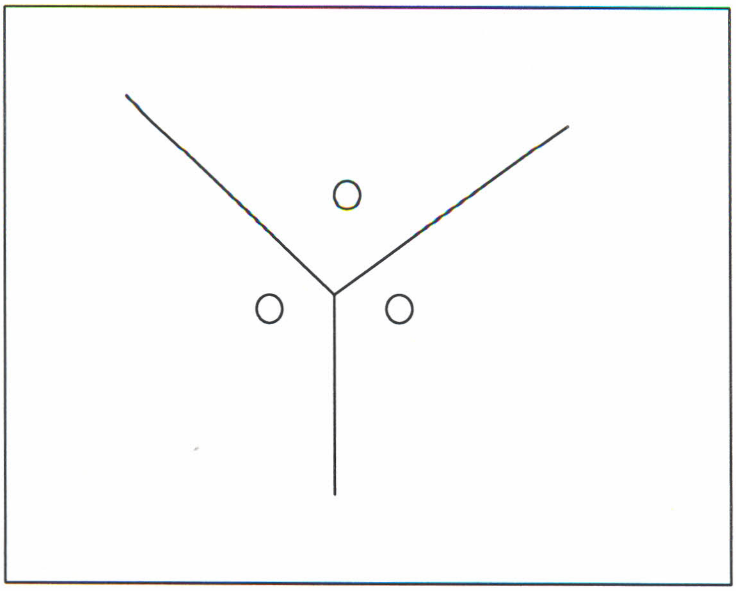
Maize is used by the agencies of the United Nations and other relief organizations for averting hunger disasters world wide.

Grain moisture, insect infestations, moulds and mycotoxins including aflatoxins from *Aspergillus sp.* are major problems in the maize post harvest system. With the exception of groundnut, maize constitutes the highest potential source of aflatoxin hazard and studies done in regions of Sub-Saharan Africa have associated aflatoxin ingestion with liver cancer in man (Pears and Lindsell, 1973).[1] Secondary factors such as temperature, humidity, rainfall patterns and other environmental conditions contribute significantly to mold, insect and pest infestation as well as the general quality and safety of post-harvest maize. Growth by post harvest fungi is governed by maize (nutrients) and biotic factors; insect, pest and adverse environmental interferences or competitions. A reduction in *Aspergillus flavus* inoculum would reduce aflatoxin production in storage. Other fungi associated with maize are *Fusarium sp.* (*F. moniliform, F. graminearum*), *P. verucosum* and *A. Ochraceus* which produce their own kinds of carcinogenic toxins causing human toxicosis and elevated rates of oesophagal cancers. Residues of aflatoxins and/or its metabolite aflatoxin M can occur in animal products including milk of mothers as a function of the dietary exposure of the mother to aflatoxin B, (IARC, 1993) [2]. If most mothers in the developing world survive on maize and wean their babies from maize based weaning foods then the safety of post harvest maize from mycotoxins in post harvest management of this commodity should not be compromised. This study applied the systematic scientific approach based on the principles of the hazard analysis and critical control point (HACCP), to evaluate the post harvest system of handling maize in Ghana and to determine the various factors and practices that influence the quality and safety of maize and to analyze the degree of impact and control measures at each sub-system level on the quality and safety of maize and based on Codex and Ghana standards recommended controls and monitoring strategies to minimize the hazards associated with post harvest handling of maize.

Materials and Methods:

The study was linked to the major systems of grain handling in Ghana with aflatoxin being the focal index for hazard evaluation. Processing, storage and grain markets in the Northern, Middle and Southern parts of Ghana were evaluated for grain handling. Field surveys of grain processing, storage silos and marketing sites in Badu, Sunyani, Techiman, Nkoranza, Aboffour and Accra in the Northern, Middle and Southern parts of Ghana were carried out to ascertain and evaluate conditions of processing, storage and marketing and to observe HACCP pre-requisite programs. Twenty Questionnaires were administered to conduct interviews on the requirements of quality and safety practices during survey and Statistical Package for Social Scientist (SPSS) was used for data analysis.

Figure 1: Maize Sampling Plan



Random samples (Figure. 1) were pulled from various sections (top, middle and bottom of bins and bags) and stored in clean polyethylene bags for laboratory analysis of average percentage grain loss, moisture, acidity, mould and aflatoxin. Meteorological data of environmental conditions; rainfall, temperature and humidity from the Northern, Middle and Southern parts of Ghana on the possible quality and safety of maize were also assessed?).

Physico-Chemical Analysis

Total average percentage grain loss was based on moldy, insect damaged and chipped/shriveled grains. A digital grain master protimeter (model; Bucks 5c 7pls) was used for moisture content analysis. An electronic magnetic titrating installation was used to determine the total acidity of samples (Nestle LI 50.021) [3]. Ten grams of milled maize flour was mixed with 20ml boiled distilled water and 80ml distilled water added again on stirring. The initial pH was measured and the mixture titrated against 0.1m NaOH to pH 8.5.

$$\text{Total Acidity} = \frac{V \times 10 \times 10}{dm}$$

V = volume of 0.1N NaOH used, dm = dry matter content of flour (100- moisture content of maize)

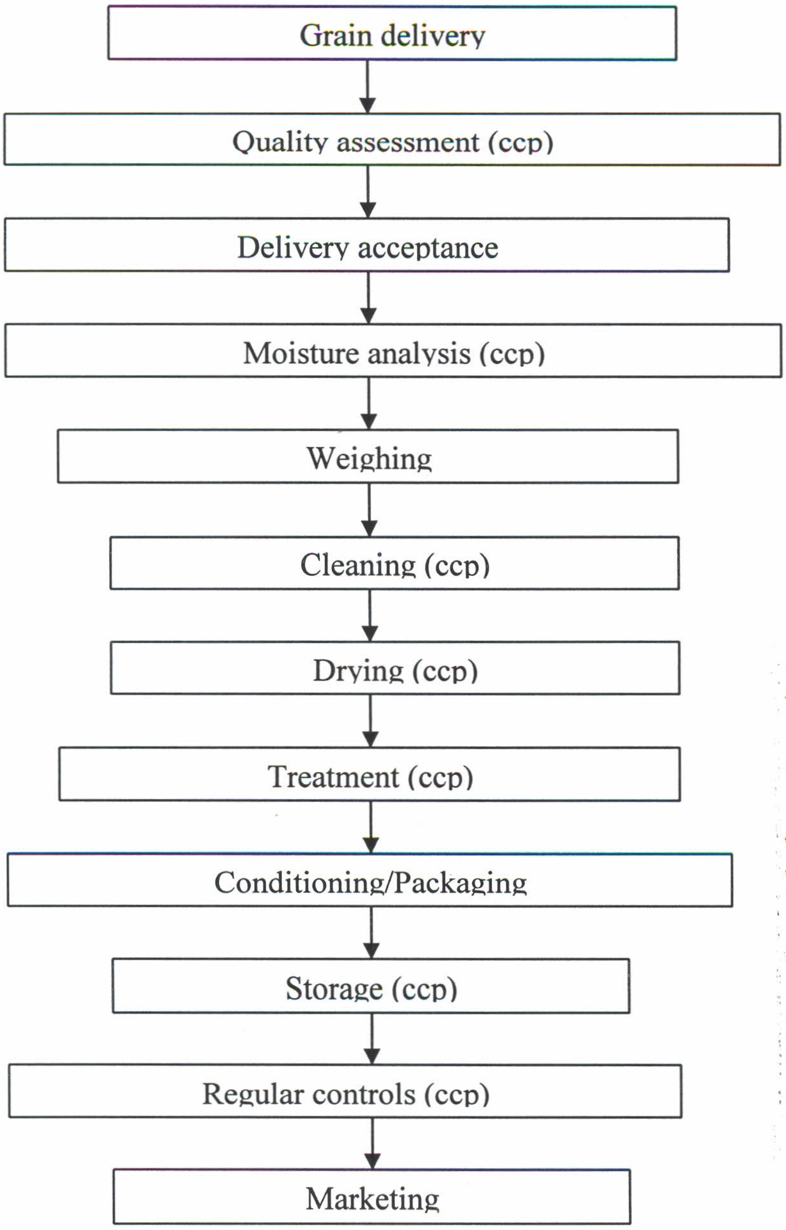
Microbiological and Aflatoxin Analysis

Mould analysis was by the International Commission of Food Mycology (ICFM) method used for food with water activity below 0.60 ($a_w < 0.60$) and the standard laboratory legislative instrument of Nestlé (Nestlé LI No. 00.740.2; 2007402, 1995) [4].

Quantitative analysis of aflatoxin was by the method of AOAC (1975/1980) corresponding to the procedure of Nestlé (PLF 83-21, 1983) [5, 6].

Results of Identified CCPs

Figure 2: Process flow with critical control points (CCPs) of maize grain handling



Discussions:

Conditions of Maize Processing, Storage and Marketing Facilities

A total of 20 maize processing, marketing and processing points were reviewed during the study and a cross functional set of individuals including storage officers, silo technicians, technical officers and traders and marketers of grains, interviewed.

Respondents understood the technology and operations of post harvest maize handling. The study revealed that, grain handlers at silos kept some form of records whereas grain traders at markets hardly kept any records on their operations.

The surroundings of most processing sites were weedy, littered with waste and powdered grain debris. Most of the facilities had obsolete equipment and storage facilities which were in a state of disrepair. The major outlet markets purchase maize directly from farmers to supply their customers. About 90% of grain handled by silos and processing establishment were obtained directly from farmers. Thus farmers after harvesting their maize supply them out to the nearest silos or markets to be processed for storage or sale. This relieves them of the hustle of prolonged manual drying and threat posed by rain and pest; factors which generally affect grain quality and aflatoxin levels. Equipment listed in use for the processing of maize included; aeration fans, Alvan Blanche dryers, discharge augers, generators, hydrometers, kornskilde dryers, cleaners, moisture meters, motor sprayers, pallets, sampling horn, stitching machine for bagging, storage bins, storage ware-house and scales. None of the respondents mentioned the use of thermometers and only 2 indicated the use of moisture meters and hydrometers, an indication that, the influence of temperature and water activity was not very important to grain handlers.

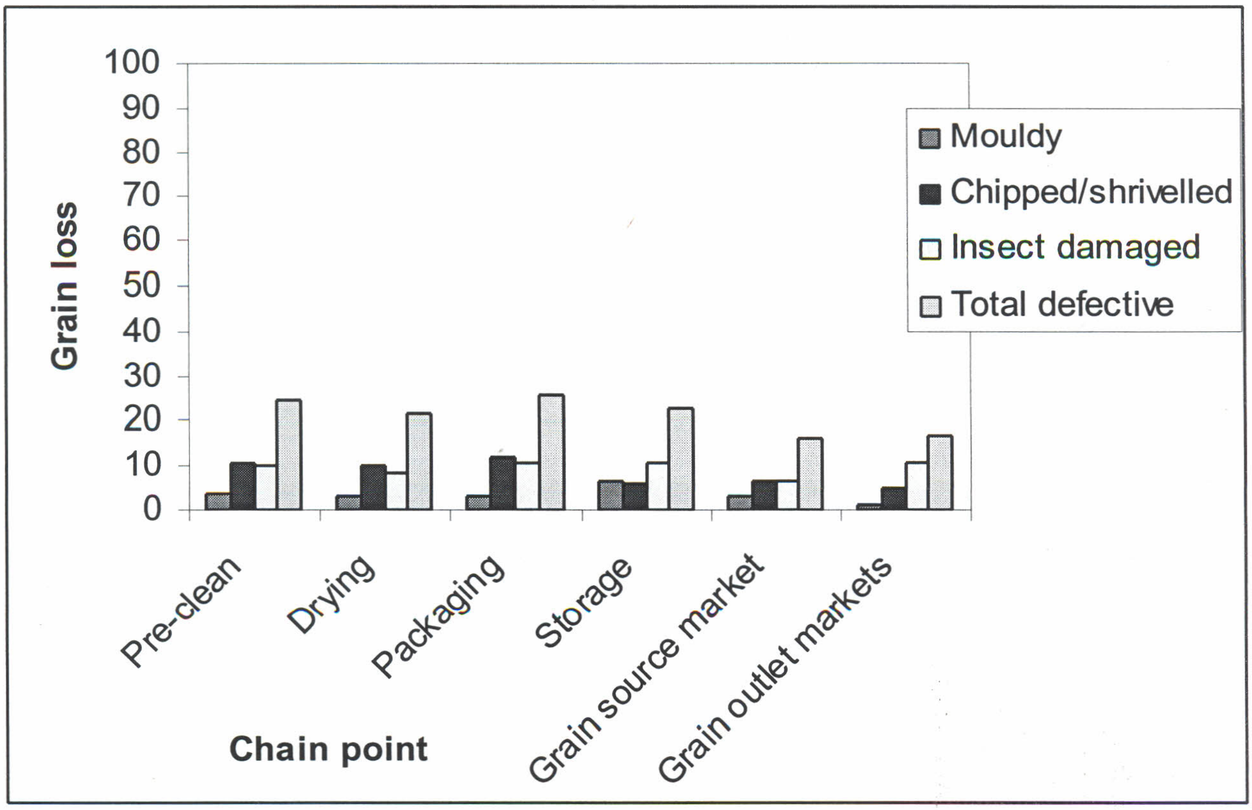
A total of 13 processing steps were identified in the handling of post harvest maize and 100% of respondents ensure that maize is dried to safe moisture levels, (<13%mc) but only 20% keep records on operations, 80% clean grains, 70% do quality grading, 50% carry out some form of moisture analysis, 60% store maize and 50% have periodic quality assessment of stored maize. Of the 13 identified steps, 7 critical control points were identified, as indicated on Figure 2. Eighty percent of respondent felt that drying was a critical control point, 70% indicated quality assessment as a CCP and 60% believe storage was a CCP in the post harvest handling of maize. Maize free from mold was viewed as the highest quality characteristics by respondents (80%) and other qualities such as low mechanical damage, cleanliness, absence of bad odor and level of dryness being significant indices. Actions taken to ensure good quality maize included; inspection and disinfesting, proper drying techniques, hygiene practices, provision of good aeration and application of pesticides. Perfect storage hygiene is the basic pre-requisite for effective processing and storage in avoiding pest and contamination of maize. Hygiene requires knowledge, attention, diligence, surveillance, responsibility and thoroughness on the part of all personnel especially store keepers. Maize handlers did not have record keeping procedures to practice first-in first out system of stock management or quality checks. The highest form of maize storage was in bins, mostly aluminum metal silos of 250 ton capacity. Kpodo and Halm (1990), observed that convection current produce pockets or layers of high moisture grains in these bins which must be constructed to prevent leaking or diffusion of moisture [7]. Odamten *et al* (1994) also discovered that maize of 12% moisture in polypropylene bags heated during storage, turning maize color into light brown [8]. Material of construction of storage facility should aid in keeping grains dry, cool, and free from pests. Proper design and orientation are essential to minimize temperature variation within storage. Short harvest seasons and long storage of grains require maximum precautions to prevent grain deterioration and ensure grain quality. Monitoring of climatic conditions, storage hygiene, turning of maize in storage, fumigation and routine quality checks must be ensured for grain quality and safety. Moldiness and high moisture as well as pest and rodent attack on storage were the prime problem areas for maize post harvest handlers and factors such as rainfall, temperature and humidity could aggravate these problems and during bumper harvest of maize, the few available processing facilities become overburdened.

At the market, grains are sorted and sieved clean to improve the grain physical quality before retailing to consumers. Poor loading and packing of grains may result in breaking and cracking of grains and grain merchants indicated that they reject poor quality grains and where possible re-dry and ensure quick turn over of stock since they mostly do not have storage facilities for prolonged storage. Grain merchants have very negligible knowledge on the effect of factors such as temperature and humidity on mycotoxin and the impact of this hazard to the health of consumers. The traditional method of drying maize by sun-drying in open space is besieged with inadequate drying especially during prolonged rainy seasons. The time farmers harvest maize is also critical to the quality and safety of the maize since maize left unduly on farm for delay harvesting become prone to continuous mold contamination and attack by pest such as weevils and grain borers. Appropriate storage structures with adequate pest management were also of critical concern to grain handlers.

Physical Quality of Maize

Grain storage facilities had the highest levels of moldy grains. The level of moldiness of storage facilities is above twice those for marketing and far above those for processing points. Factors such as poor monitoring of storage hygiene, pest infestation, high temperatures and humidity contribute to hysteresis in maize in storage and increase in the level of mold. The harsh processes of emptying grains into intake pits, turning in drying bins, transportation, loading and off-loading, bagging off accounts for the very high levels of chipped and shriveled grains at processing point of pre-cleaning, drying and packaging by bagging or binning. Controls and monitoring is therefore required to ensure the quality of maize at processing points. From Figure 3, the level of insect was almost even across the various stages except at the grain source market where grains had minimal insect infestation. This could be attributed to early attack by pest such as weevils and grain borers. Appropriate storage structures with adequate pest management were also of critical concern to grain handlers.

Figure 3: Grain loss during post-harvest handling of maize



Activities of insects could aggravate levels of aflatoxin and therefore safe measures should be used to control insect infestation of grains. The percentage of average grain loss fell above the Ghana standard of 10.5% throughout the maize post harvest system of Ghana. Maize traders however ensured that maize had the highest percentage of purity at both source and outlet markets (Figure 3). Processing and storage are critical points, requiring great control and monitoring to ensure reduction in grain loss whilst markets should make effort to bring quality requirements below regulatory limits.

Aflatoxin and Biochemical Quality of Maize

The maximum level of aflatoxin permitted by FAO is 30µg/kg, but in Ghana, the national standard is set at 15µg/kg [9, 10]. Epidemiological data available, suggest a significant association between aflatoxin intake and liver cancer in man (WHO, 1979) [11]. Mold growth and mycotoxin contamination could occur prior to purchasing maize from farmers. Results of this study indicated that all the maize samples from processing and storage facilities had high aflatoxin levels above critical regulatory limits (Figure 4). The maize from storage facilities were observed to have extremely high levels of aflatoxin as indicated by means plotted in Figure 4. This could be due to associated factors such as increase mold infestation in storage, caused by high moisture increases, insect and pest damage, poor storage hygiene and climatic changes. Maize at the market level however had aflatoxin levels falling below regulatory limits. Grain traders usually have quick turnover and do not store grains for long periods and maize from different sources are not always mixed contrary to high mixing of grains from different sources by processing and storage facilities. These results confirm the findings of Kpodo (1990) for the aflatoxin quality of Ghanaian maize [12].

Figure 4: Aflatoxin level of maize at various stages of processing

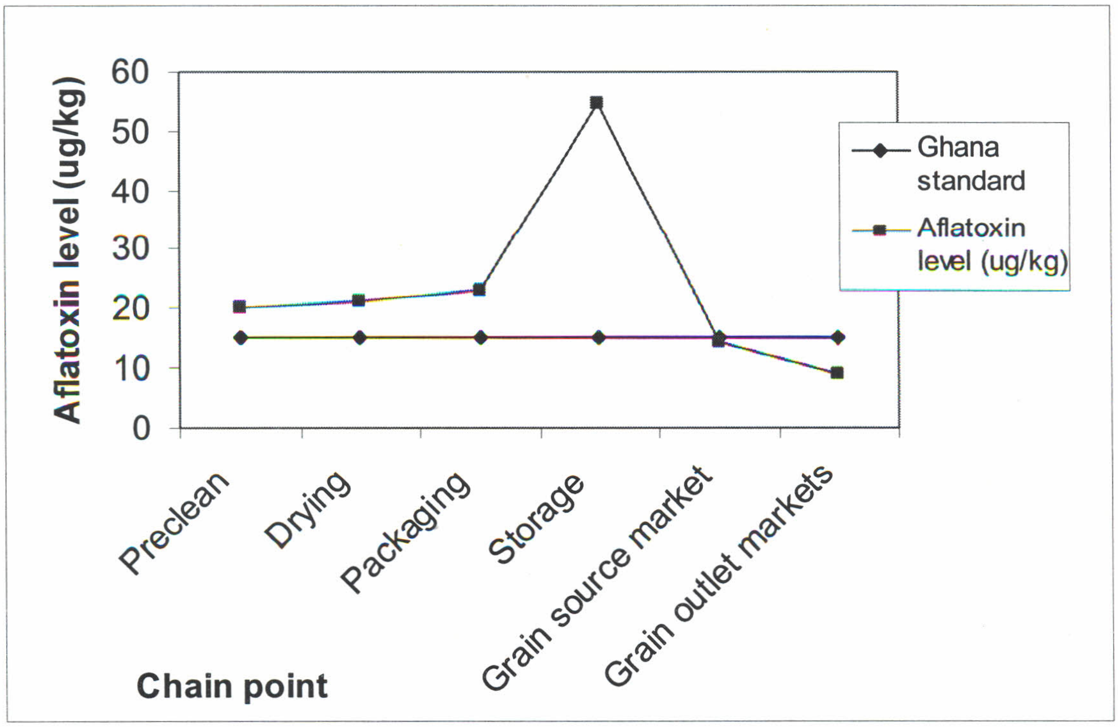
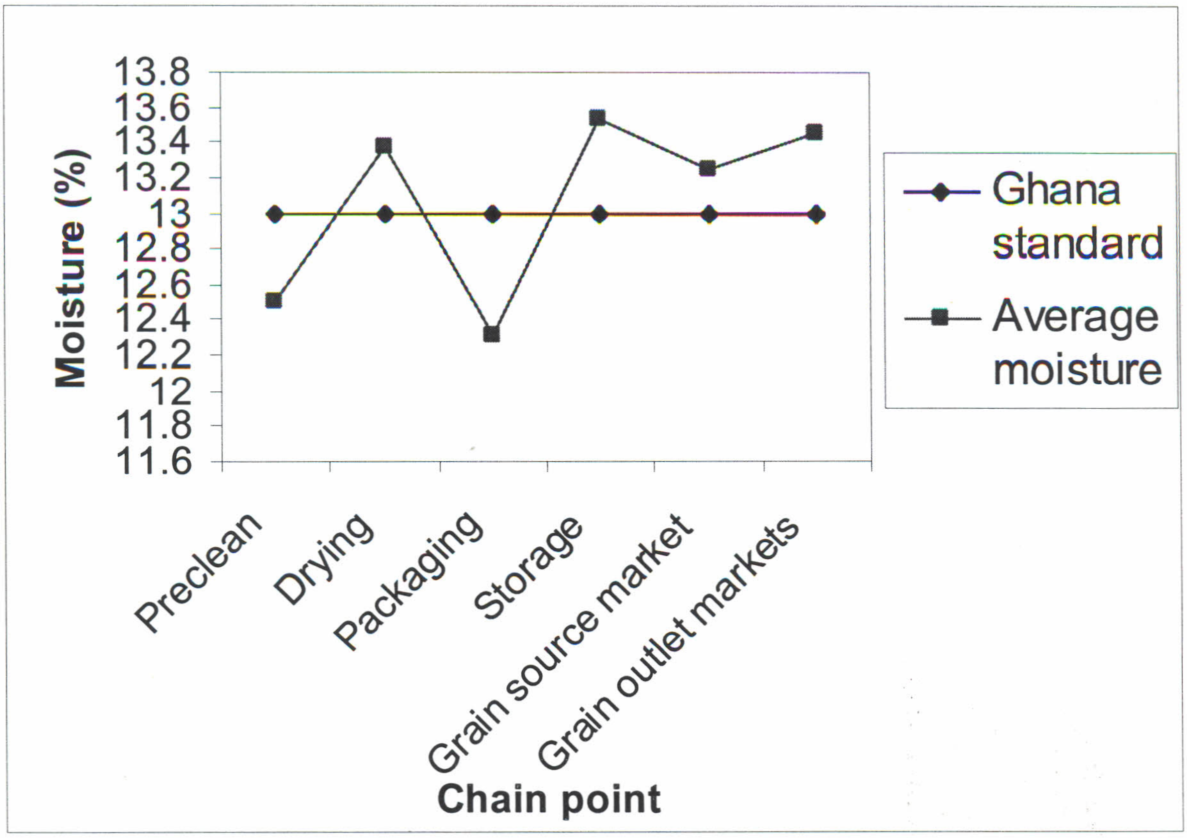


Figure 5: Moisture content of maize at various stages of processing



In a related survey conducted by Kpodo (1990), it was discovered that the moisture content of maize, purchased from farmers ranged between 13 to 24% but soon after harvest the range fell within 18 to 24% and this was reduced to 13% at the end of purchasing season in February [13]. Maize in storage through to marketing had moisture ranges above regulatory limits with exception occurring at the packaging and pre-cleaning stages. The highest moisture level was in storage which could account for the high aflatoxin levels.

In the presence of alkali, reduction of aflatoxin occurs with opening of lactone ring whilst acid promotes closing of the ring. A reduction in pH could therefore result in the reformation of any hydrolysed aflatoxin molecule to give higher aflatoxin levels (Kpodo et al., 1995) [14].

Figure 6: The total acidity of maize at different stages of the post harvest system

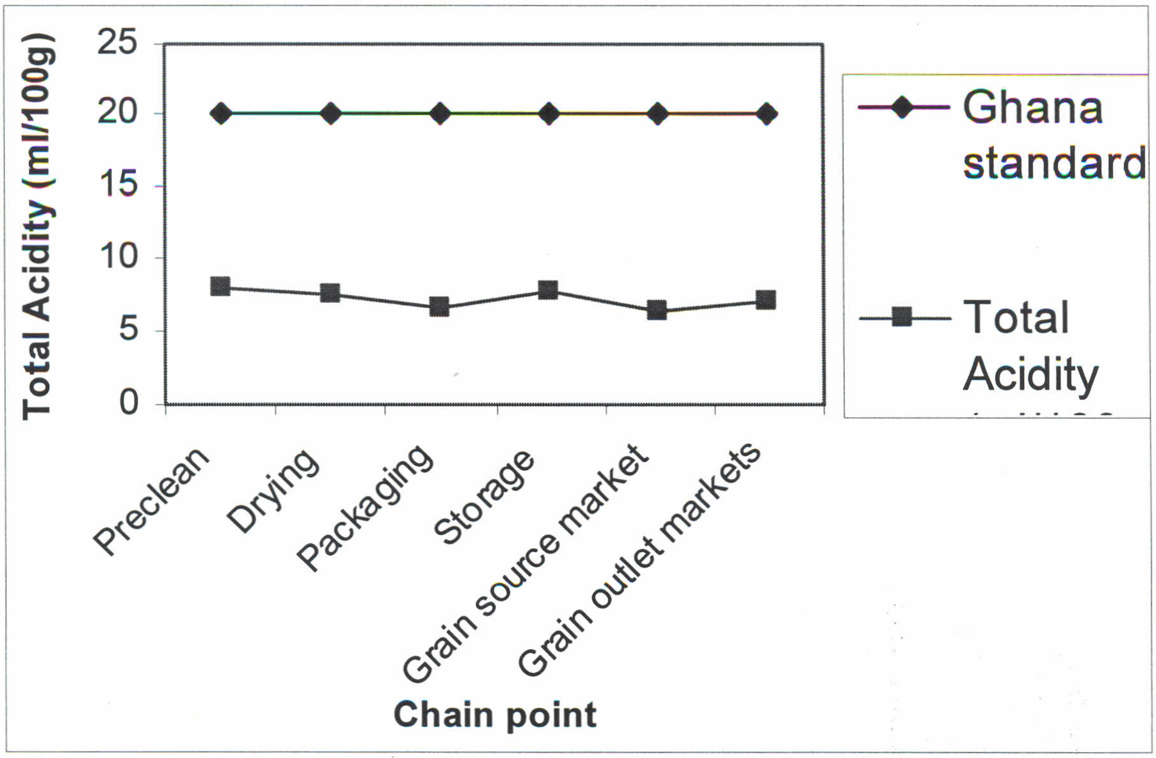


Figure 6 however shows acceptable limits of below 20ml/100g total acid level for all samples. Results of mold counts indicated high levels of mold for grain storage facilities with the highest being 2.08 x 10^4 colony forming units. The lowest count for storage facilities was 1.9 x 10^4 and grain source markets recorded a low value of 3.0 x 10^3 cfu. The results of mould correlated positively with aflatoxin levels of samples. According to Pixton and Warburton (1971), the effect of atmospheric changes in temperature on the walls of storage bins and heat produced by local pockets of insects infestation frequently cause temperature gradient in stored grains leading to translocation of moisture and deteriorative changes caused by excessive moisture [15]. The moisture and temperature of the grains are the main factors regulating fungi growth and aflatoxin production. Climatic data from the Meteorological Department indicated high humidity levels resulting from high rainfall patterns for most parts of the year in Ghana; an obvious reason for the high levels of aflatoxin in some Ghanain stored maize. The mean annual rainfall for the central north portion of the country were 71.57ml and temperature and humidity were 27°C and 97% respectively whilst the mean annual rainfall in southern Ghana registered 95.6ml with annual mean temperature and humidity of 27.25°C and 86.33% respectively. The high level of humidity also impacted on the quality and safety limits for mould and aflatoxin levels of maize in storage.

Conclusion

Control measures for managing critical control points in the post harvest handling of maize are not adequate to prevent the mycotoxin contamination of maize and grain handlers lack adequate skills and knowledge on risk factors of post harvest maize handling. The high relative humidity in Ghana requires that necessary pre-cautions are taken to ensure the safety and quality of maize especially during storage. Storage facilities should be properly designed taking into account environmental conditions and grain handlers trained on post harvest management of maize stocks and HACCP teams set up for grain handling establishments and equipped with adequate resources for quality and safety management with proper record keeping procedures. Laboratory findings correlated positively with responses of maize handlers interviewed.

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