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Post-harvest insect infestation and mycotoxin levels in maize markets in the Middle Belt of Ghana

J.K. Danso [a], E.A. Osekre [a], G.P. Opit [b], N. Manu [a], P. Armstrong [c], F.H. Arthur [c, *], J.F. Campbell [c], G. Mbata [d], S.G. McNeill [e]

[a] Dept. of Crop and Soil Sciences, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
[b] Dept. of Entomology and Plant Pathology, Oklahoma State University, 127 Noble Research Center, Stillwater, OK 74078, USA
[c] USDA-Agricultural Research Service, Center for Grain and Animal Health Research, 1515, College Ave., Manhattan, KS 66502, USA
[d] Agricultural Research Station, Fort Valley State University, 1005 State University Drive, Fort Valley, GA, USA
[e] Biosystems and Agricultural Engineering, University of Kentucky, Research and Education Center, Princeton, KY 42445, USA

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ABSTRACT

This study focused on assessing maize post-harvest losses in three maize markets in the Middle Belt of Ghana during the storage periods after the harvest of major and minor cropping seasons, September to December and January to April, respectively. The major and minor cropping seasons in the Middle Belt occur during the periods April to August and September to December, respectively. Storage temperature of bagged maize, grain moisture content (MC), and relative humidity (r.h.) were monitored monthly, along with insect infestations, percentage weight loss of kernels (% WL), the percentage of insect damaged kernels (% IDK), and percentage of discolored grains (% DG). Aflatoxin and fumonisin levels were assessed at the beginning and end of the major and minor crop storage seasons. *Cryptolestes ferrugineus* (Stephens), *Cathartus quadricollis* (Guerin-Meneville), *Carpophilus dimidiatus* (F.), *Sitotroga cerealella* (Olivier), *Tribolium castaneum* (Herbst), and *Sitophilus zeamais* (Motschulsky) were found in all markets. Mean insect infestation levels varied throughout the sampling period and were generally similar in the three markets, but were not correlated with temperature, MC, or r.h. ($P \geq 0.05$). Mean % WL, % IDK, and % DG peaked in November and December and were usually correlated with total insect populations ($P < 0.05$). Aflatoxin levels of 2.9–3.4 ppb were found in all markets in the minor season maize samples, but levels ranging from 38.2 to 64.0 ppb were found in the major season samples. Fumonisin levels for all markets ranged between 0.7 and 2.3 ppm. Environmental conditions favor insect pest population development throughout the year in maize stored in markets in Ghana, thus the maize must be monitored regularly and appropriate interventions implemented to avoid product loss.

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1. Introduction

In Ghana, the maize market is dominated by small-scale traders, with women constituting the greater proportion of traders (Akowuah et al., 2015). Despite an increase in maize production in Ghana over the past few years, market demand is usually greater than supply (Angelucci, 2012). In most sub-Saharan African countries, post-harvest losses are estimated to be in the 20–30% range for staple foods such as maize (Yusuf and He, 2011; FAO, 2011). Major reasons for maize post-harvest losses are the informal marketing systems (open air market systems), biological agents (insect pests, fungi and rodents) and physical and environmental conditions in the market storage systems (Hell and Mutegi, 2011; Tefera et al., 2011).

Insect pests are the principal cause of post-harvest losses (Gwinner et al., 1996). *Sitophilus zeamais* (Motschulsky), *Prostephanus truncatus* (Horn), *Tribolium castaneum* (Herbst), *Rhyzopertha dominica* (F.) and *Sitotroga cerealella* (Olivier) are important post-harvest insect pests of maize in sub-Saharan Africa (Tefera et al., 2011). Insect pests cause damage that pre-disposes maize to mycotoxigenic fungi such as *Aspergillus flavus* (Link) and *Fusarium verticillioides* (Sacc Nirenberg) that produce aflatoxin and fumonisin, respectively (Pittet, 1998; Lamboni and Hell, 2009). Aflatoxin and fumonisin are natural carcinogenic substances that are

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* Corresponding author.
E-mail address: frank.arthur@ars.usda.gov (F.H. Arthur).

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detrimental to animal and human health and constitute a factor in economic losses; including income loss due to early sale or costs incurred from purchasing replacement maize (Magrath et al., 1996). Losses can also result from contaminated grain or rejection of products due to mold. Mycotoxins can restrict maize trade and limit income of smallholder farmers because of food safety concerns (Suleiman et al., 2013; Suleiman, 2015).

Both qualitative and quantitative post-harvest losses are challenges in the development of new market opportunities at national and regional levels. Post-harvest losses can be minimized when insect infestation, fungal infection and physical conditions of the market storage environment are monitored and appropriate interventions implemented. The objectives of this study were to: 1) determine prevalence and abundance of insect pest species in maize stored in commercial markets in the Middle Belt production zone in Ghana, 2) assess product damage and loss caused by insects, 3) determine if environmental conditions were correlated with insect pest populations, and 4) evaluate fungal contaminant levels in the stored maize.

2. Materials and methods

2.1. Experimental locations and experimental design

The experiment was conducted in three markets located in maize growing areas in the Middle Belt of Ghana, namely, the Ejura market in the Ashanti-region, the Techiman market and the Amantin market, both in Brong-Ahafo region of Ghana. Market structure, storage management and practices in all the study sites were similar, with some variations in storage structures. The Ejura market had small warehouses and wooden stalls, the Amantin market was predominantly characterized by traders' resident storerooms and wooden stalls, and the Techiman market had sheds and open platforms with bagged maize stacked on either wooden pallets, old tires or bare concrete floors.

The study spanned September 2015 to April 2016. The experimental design was a two-factor factorial completely randomized design (CRD). Factors were month (cropping seasons) and market — two cropping seasons (major and minor) and three markets (Ejura, Techiman and Amantin). White maize varieties are cultivated and sold in markets in the Middle Belt of Ghana. Therefore, this study involved sampling white maize varieties from selected traders. The major and minor maize cropping seasons in the Middle Belt of Ghana occur during the periods April to August and September to December, respectively. The storage periods for the major and minor season maize crops are September to December and January to April, respectively. The sampling months for major season maize harvest comprised September to December while minor season harvest sampling months comprised January to April. In each maize market, ten maize sellers were randomly selected. For each maize seller, three bags containing 100 kg of maize in polypropylene or jute bags were randomly selected and sampled each month. This sampling protocol was repeated for all months. Sampling was done from the same traders; however, traders' stores may have been re-stocked when the quantity of the old stock diminished. Therefore, samples may not necessarily have come from the same batch but were mostly from the same source. Sources of maize in Techiman market were from both Northern and Southern Ghana while that of Ejura and Amantin were from Southern Ghana. All samples were generally processed within two weeks.

2.2. Temperature, moisture content, and relative humidity

The USAID Feed the Future Innovation Lab for the Reduction of Post-Harvest Loss (PHL-IL) moisture meter (hereafter referred to as the PHL meter) (USDA-ARS) was used to measure temperature of bagged maize, moisture content (MC), and relative humidity (r.h.). A full description of the PHL meter, and how it was calibrated in comparison to a commercial meter, can be found in Armstrong et al. (2017). The meter was inserted in a bag of maize, left to stabilize over a 3-min period, and temperature, and MC, and r.h. from the monitor display were recorded. For each selected bag, three lots of maize were taken with the probe; from the center and two sides of the bag. This was done to ensure that a representative sample was taken from the bag. Means were calculated from these three readings.

2.3. Sampling for insects and determination of mycotoxin levels

A 1.2-m open-ended grain probe (Seedburo Equipment, Chicago, IL, USA) was used to take maize samples from bags; each time a ~350 g sample was obtained using the grain probe. Samples were taken from the center and two sides of each bag. The three lots sampled from each bag were mixed thoroughly in a 5-L plastic container to ensure homogeneity. A sample of 500 g was weighed out using a dial spring weighing balance (SP, CAMRY, Yongkang, PRC) and placed in a labeled Ziploc plastic bag (39 cm × 25 cm). After 500 g were weighed out from maize collected from each bag, the leftover maize from all three bags sampled from each seller was combined, thoroughly mixed, and a second 500-g sample obtained. The second 500-g sample was used for mycotoxin analysis. Therefore, four 500-g samples were altogether obtained from each seller, each month; three 500-g samples for insect infestation level estimation and kernel damage assessment, and one for mycotoxin analyses. Maize samples for the mycotoxin analyses were kept in a portable 17-L Koolatron ® 12-V Compact Portable Electric Cooler (P75, Koolatron® Canada, Brantford, CA) to reduce further growth and development of fungi. Temperature inside the cooler was not monitored but the approximate temperature was about 4 °C. The samples were taken to the Insect Laboratory of the Department of Crop and Soil Sciences of Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana for processing.

2.4. Other variables assessed

Other variables determined were percentage weight loss, number of insect damaged kernels (IDK), and percentage IDK and percentage of discolored grains. Aflatoxin and fumonisin titers of maize samples were also assessed. Maize samples were sifted using U.S. Standard #10 (2-mm openings) and #25 sieves (0.71-mm openings) (Dual Manufacturing Co., Franklin Park, IL) to recover insects. Insect species were identified using the Grain Research and Development Corporation Stored Grain Pests Identification Guide (2011) and their numbers recorded. Each 500-g sample was poured on a tray and all kernels were examined using a hand lens (10× magnification) to identify kernels with holes created by insects. These damaged kernels were separated from undamaged kernels and numbers of kernels in each category recorded. Insect damaged kernels were weighed using an electronic balance (Mettler Toledo, No. PB302, Columbus OH, USA). Percentage IDK was estimated based on total number of kernels. From each 500-g maize sample previously collected from each bag, 100 kernels were randomly selected and examined using a hand lens (10× magnification). Discolored grains were counted and rated using the method of Neergaard (1977). All maize samples were processed at the Insect Laboratory, KNUST.