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An assessment of the magnitudes and factors associated with postharvest losses in off-farm grain stores in Kenya

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ABSTRACT

Off-farm grain storage is an important postharvest undertaking by government, traders and processors in Kenya. A survey was conducted in 2014/2015 to assess the kinds and magnitudes of perceived losses experienced in off-farm stores, and the factors associated with them. Store supervisors or key personnel charged with grain storage in 39 public and 74 private stores, spread across the six maize growing agro-ecological zones, were interviewed using a structured questionnaire. Total perceived losses averaged 17.6± 2.3%, and were attributed to insects (7.2± 1.0%), molds (5.7± 2.1%), moisture loss (3.4± 0.5%), rodents (2.0± 0.5%), spillage (0.50 ± 0.0%) and birds (0.10± 0.0%). Total losses experienced in public and privately owned stores were not significantly different. The losses attributed to insect and the vertebrate pests, moisture loss and spillage, were also not significantly different in the two storage systems. However, losses due to molds were significantly higher in the private stores. From regression analysis, higher losses were associated with the use of residual insecticides, purchasing low quality maize for storage, reuse of storage bags, untimely control of storage pests, and the agro-climatic conditions of the moist transitional, moist mid-altitude and dry mid-altitude zones. Relying on infestation reports to initiate pest control had the highest marginal effect (21.7%). Lower loss magnitudes were associated with cleaning and drying grain before storage, early pest control and storage periods shorter than two months. These findings provide important reasons for appraising current off-farm storage techniques with a view to taking possible actions for improvements. It is recommended that innovations to mitigate maize postharvest losses should also target off-farm storage, as the losses incurred are significant.

1. Introduction

Food grains support the nutrition of many households in Kenya (Jayne and Argwings-Kodhek, 1997). Consequently, individual farmers, traders, and the government undertake storage for food security or commercial reasons. Maize is the most important food grain followed by common beans (Mauyo et al., 2007). Other food grains include rice, wheat, sorghum, millet, green grams, cowpeas and pigeon peas. Local production of these commodities is, however, not sufficient to meet the local food demand. For this reason, imports are received from other countries to fill the demand gap (FAOSTAT, 2016). The government also maintains strategic grain reserves in public warehouses through the National Cereals and Produce Board (NCPB) to provide a buffer against extreme shortage, distribute as relief food in case of emergency, or intervene in markets when the need arises (Lewis et al., 2005).

Since liberalization of the Kenyan grain marketing system in the 1990s, private actors play a greater role in grain handling (Jayne and Argwings-Kodhek, 1997). The NCPB and large millers control 15–20% of locally produced maize (FAO, 2013), thus about 80% of harvested maize is handled or stored in less centralised systems by farmers and other small-scale grain handlers who include aggregators, wholesalers, retailers, and small millers. Storage is important because it evens out seasonal supply fluctuations (Adejumo and Raji, 2007). Inadequate storage facilities, however, encourage deterioration leading to quantity or quality losses (World Bank, 2010). During off-farm storage, losses may occur through spillage,

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defective bagging, slow delivery to store or market, and contamination or damage by pests. For traders, such losses lower their revenues because saleable weight is diminished, and low quality grain is sold, disposed at discounted prices (Compton et al., 1998) or discarded (Golob and Hodges, 1982). According to the African Postharvest Losses Information System (APHILIS, 2016) quantity losses of cereals in sub-Saharan Africa (SSA) accumulate to 10–23% from harvesting to market storage. This source attributes 2–4% of the losses to market storage. A recent meta-analysis (Affognon et al., 2015), however, revealed that data on grain losses at levels other than on-farm storage are rather limited, casting the need to generate more data so as to inform policy and postharvest losses mitigation decisions.

Traditionally in East Africa, the grain weevil (*Sitophilus* spp. Coleoptera: Curculionidae) and the Angoumois grain moth (*Sitotroga cerealella* (Olivier) Lepidoptera: Gelechiidae) on cereals, and three genera of the family Chrysomelidae, sub-family Bruchinae (*Acanthoscelides, Zabrotes* and *Callosobruchus*), are notorious insect pests in grain stores (Abate et al., 2000). In the early 1980s, the larger grain borer (*Prostephanus truncatus,* (Horn) Coleoptera: Bostrichidae) emerged as an even more harmful pest for stored maize in East Africa (Golob and Hodges, 1982). In addition to these pests, moisture loss, infection by molds and infestation by rodents and birds also cause significant losses especially on cereals (Lathiya et al., 2007; Edoh-Ognakossan et al., 2016). Molds may cause mycotoxin contamination (Wagacha and Muthomi, 2008), whereas rodents and birds may cause physical losses, and contaminate the grain with substances that degrade the quality (Cao et al., 2002; Gwinner et al., 1996).

Effective control of pests and contaminations during storage is a challenge in SSA. Infestations begin on the farm, continue in farmers' stores, and end up in off-farm storage facilities. One challenge of off-farm grain storage in SSA is the lack of purpose-built storage facilities (World Bank, 2010). First, small and medium grain handlers frequently store in unsuitable spaces, usually created by converting existing idle premises. Such stores may not meet the requirements for good grain storage (Wilkin and Row lands, 1988). Secondly, in the majority of commercial stores, insect infestation is destroyed by fumigation, occasionally combined with spray treatment of bag stacks and store surfaces with synthetic insecticides as hygiene measure (World Bank, 2010). If proper treatment regimes are not consistently followed, insects may evolve resistance against the fumigants (Benhalima et al., 2004; Taylor, 1991; Chaudhry, 1997) or residual insecticides (Odeyemi et al., 2010) further complicating the problem. Furthermore, the storage of large volumes of grain increases the difficulties of detecting and dealing with infestations in many stores (Wilkin and Row lands, 1988). To the best of our knowledge, no systematic studies have assessed losses in off-farm grain stores in Kenya; most past assessments targeted on-farm storage. The aim of the present study was therefore to assess the kinds and levels of postharvest losses in government and privately owned stores as perceived by the persons directly responsible for grain storage. A further objective was to identify the factors associated with the losses. Making such information available is important because it will enable the postharvest sector to contribute more reliable data to forecasts of food availability, while enabling relevant actors to take practical decisions to mitigate the losses.

2. Materials and methods

2.1. Study area

The study was carried out in six maize Agro ecological zones (AEZs) of Kenya (Fig. 1). The AEZs are classified according to maize production potential (Hassan et al., 1998), and include: the highland tropical (HLT), moist transitional (MT), moist mid-altitude (MMA), dry mid-altitude (DMA), dry transitional (DT), and the lowland tropical (LLT). Characteristics of the six zones are described in Table 1. The HLT and MT are high potential zones; together they represent 64% of the total production area and account for approximately 80% of Kenya's maize production. The DMA and MMA zones have medium potential, whereas LLT and DT zones are low potential areas (De Groote, 2002). The HLT zone experiences a uni-modal rainfall pattern whereas the rest have bimodal rainfall patterns. Storage begins in March/April and August/September in regions that have bi-modal rainfall pattern and in October/November in regions with mono-modal rainfall.

2.2. Sampling and data collection

A survey was conducted between October 2014 and March 2015. First, a literature search was conducted to establish a comprehensive list of documented grain warehouses and stores in Kenya. Key data sources included the National Cereals and Produce Board (NCPB; http://www.ncpb.co.ke/), the Eastern Africa Grain council (EAGC; http://eagc.org/), Regional Agricultural Trade Intelligence Network (RATIN; http://www.ratin.net/), and previous grain value chain reports (e.g. USAID). From these sources, a list of 336 stores comprising 110 public warehouses (PWs) and 226 private stores (PSs) was compiled. Using the formula described by Yamane (1967), with a precision level of 10% where confidence level is 95% and $p = 0.5$, a sample of 121 stores was determined to be sufficient. The sample was purposively drawn so as to obtain representation of all agro-ecological zones. Out of this sample, 31 (25.6%; N = 121) of the stores declined to participate in the survey and these were replaced using the snow ball sampling technique, in which the respondent in a store included in the sample referred the research team to other stores in the locality from which a suitable replacement was made. A final sample of 113 stores comprising 39 PWs and 74 PSs was surveyed. Face to face interviews were conducted using a structured questionnaire. Data on socio-economic characteristics of respondents, warehouse/store characteristics, grain sources and target markets, storage practices, storage problems experienced, strategies for coping with the storage problems, and the proportion of grain lost during the immediate previous storage season as recalled by each respondent were recorded. To assist in estimation of losses, respondents were each taken through a brief training session on storage losses. Pictorial images of different storage pests and loss scenarios were presented to help them recognize various forms of losses they may have experienced. Respondents were then asked to estimate the number of bags lost due to different causes relative to the number of 90 kg bags initially stored.

2.3. Data analysis

Data on socio-demographic characteristics of respondents, warehouse characteristics, storage practices, storage problems, and the various approaches used to address storage problems were expressed as percentages, and summarized in contingency tables or graphs. Differences within categories in each warehouse type, as well as the overall sample were determined using the Chi-square test followed by pairwise comparisons using "chisq.multcomp" function with Bonferroni *p*-values adjustment in the RVAideMemoire package in R 3.2.5 software. Losses data, which were reported by respondents as percentage of the total amount of grain stored, were presented as means. Prior to analysis data on loss magnitudes (%) were arcsine square root (x/100)-transformed and tested for normality using the Shapiro-Wilk test. The data were not normally distributed even after transformation: $df = 113$,