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Postharvest Management Practices of Maize in Ethiopia: A Review

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ABSTRACT

Postharvest losses and their management practices of Maize production in Ethiopia were overviewed. Agriculture is vital for addressing food security problems in Ethiopia. Agriculture contributes to overcoming the food security problem through growth that distributes its benefits as widely as possible by increasing production and productivity. About 30 to 50 per cent postharvest loss is because of inappropriate collection, transport, storage and pest control systems in Ethiopia were found tremendous for different cereal grains. The review was done by collecting the various published and unpublished materials relevant information from different literature sources like libraries, research report, journals, books and Internet center. Postharvest quantity and quality loss of cereal grains in developing countries appear to be initiated mostly at the farm level, so the potential solutions for the problem are needed at the same level. To minimize losses and increase the shelf life of the food grains which inhibit the growth of pests and provide proper storage facilities, appropriate packaging materials and transportation facilities are required. A corrective suggestion on suitable approaches to loss reduction in postharvest handling of maize grains was reviewed. As the result of review, it concludes that further studies are needed concerning physical, bio-chemical *and* socio-economic aspects at each production level.

Key words: Abiotic, Agents, Biotic, Losses, Management, Postharvest.

Maize (*Zea mays* L.) was originated from tropical zones of America and has now become the very best production cereal grown worldwide. It has become particularly significant in developing countries and it's one among the foremost widely cultivated gramineous plants in East Africa (Acland, 1977). Maize was introduced to Ethiopia in the 1600s to 1700s and has become a significant cereal grain widely cultivated under a wide range of environmental conditions, between 500 to 2400 meters above sea level. According to the reports of the CSA (2014), maize is being grown in different parts of the country; Oromia and Amhara regional states are the major producers. Amhara and Oromia regions of Ethiopia are the main producers, those covered more than half of the national maize production in 2012. The ISSD project report notified that West Gojjam (5.6 million quintals), East Wellega (4.3 million quintals), Kaffa (3.8 million quintals), East Shewa (3.1 million quintals), West shewa (2.9 million quintals), West Arsi (2.7 million quintals), Illubabor (2.7 million quintals), East Gojjam (2.2 million quintals), West Wellega (2.1 million quintals) and West Harerghe (2.1 million quintals) are the top ten maize producing zones of the country. In addition, maize is also cultivated in the South, Tigray, Benshangul Gumiz and Gambela regional states.

Maize is the prime cereal in terms of production and is employed as human also as well as animal fodder in Ethiopia. It has an upright nutritional value and is one of the key sources of calories (Abebe *et al.,* 2009). It has starch (60%-80%), protein (8%-12%), fat (3%-5%) and minerals (1% -2%) (Sexena *et al.,* 2000). It is considered to be the cheapest source of calorie intake in the country, providing 20.6% of per capita calorie intake nationally (IFPRI, 2010).

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Hereafter, maize production has been increased progressively with 6.4 million tons produced on 1.994 million hectares of land in 2014 by 8.8 million farmers (CSA, 2014). However, the yield of maize remained very low due to many biotic and abiotic constraints, among which insect pests and diseases are the major causes.

The damage by insect pests is not only restricted to growing crops in the field but also extend after harvest at different stages of the post-harvest events. Post-harvest losses of the food being produced are significant in spite of the low total agricultural productivity, (World Bank and FAO, 2011). Any damage done on grains and the final product is severe because there will not be compensation for the losses. Besides the quantitative post-harvest losses, injured grains lose their viability, quality and nutritional values (Ezuch, 1983). According to Franzel *et al.* (1989), storage losses are substantial and that they are one among the explanations why farmers sell most of their maize produces soon after harvest and suffer food shortage within the later time of the year in Ethiopia. Post-harvest insect pests of maize such as *Sitophilus zeamais*, *S. oryzae*, *Sitotroga cereallela*, *Tribolium spp. and Ephestia cautella* are the main pests of stored maize and other cereal crops in Ethiopia (Abraham, 1997). Among these pests, the maize weevil *(S. zeamais*) causes very serious damage and it is a diverse pest (Longstaff, 1981).

A huge amount of losses occurs at different stages after crops are harvested and before consumption, after a large investment of time, labor *and* money in the production process. As many reports indicated that crop, losses occur in maize during cutting, drying, threshing, winnowing, transporting *and* storing. FAO (2016) estimated postharvest loss of maize was approximately 21.4%. However, these losses occurring in the postharvest system have not been given the attention they deserve and have even been neglected for a long time (Tadesse *et al.,* 2008). Many authors in the postharvest sector realize that appropriate postharvest management (PHM) is the missing link between production and consumption (Kitinoja *et al.,* 2011), contributing significantly to the food insecurity problem. According to Lisa *et al.* (2019) report, postharvest losses were measured about 13% during harvesting and 2 to 3.5% during handling and transportation; 15% an average post-harvest loss was recorded across the value chain.

Moreover, postharvest losses cause not only loss of the economic value of the food produced but also the waste of scarce resources such as labor, land *and* water, as well as non-renewable resources such as fertilizer and energy, all of which are used to produce, process, handle *and* transport food (FAO, 2011). To effectively reduce postharvest losses, the first thing is knowing the cause and the scale of these losses across the different stages then can be controlled and improved the whole postharvest process.

Literature review

Origin and distribution of maize

Origins and taxonomic organization of maize were hotly debated until the late 1970s after which genetic studies, including the use of molecular markers and comparative DNA sequence data, allowed break throughs in the taxonomy and phylogeny of maize and its wild relatives, including the identification of specific loci involved in the domestication process (Heerwaarden *et al.,* 2011).

Maize was domesticated in the tropical lowlands of southwest Mexico with subsequent introgression from teosinte (Piperno *et al.,* 2009; Huford *et al*., 2013). Maize diversified under genetic drift and selection as it was carried through a diverse habitat during its spread by humans both south and north from its origin, including its arrival in the southwestern region of North America by 2260 BC (Merrill *et al*., 2009). Maize is propagated by seed. Maize seed needs soil that is warm moist well-aerated and fine to give enough contact between the seed and the soil. As Bouchet *et al.,* 2013 reported the initial selection for adaptation to a temperate environment then occurred during the next 2000 years in North America. Maize (*Zea mays* L.) has become adapted to the broadest range of climatic conditions of all crops, from the 40S in Chile to 50N in Canada and Russia, from sea level within the West Indies to elevations above 3400 m within the Andes (Bouchet *et al.,* 2013).

Status and importance of maize production

Maize (*Zea mays* L.) is that the third important cereal crop globally after wheat and rice (FAO, 2011). Maize is one among the foremost important cereal crops cultivated within the world and it constitutes one among the main diets of many people. In Africa, small-scale farmers for utilization as both human food and animal feed mainly grow maize. In Africa, small-scale farmers for utilization as both human food and animal feed mainly grow maize. Maize is the leading cereal crop in terms of production in Ethiopia. It is an important and cheapest caloric source among all major cereals (Demeke, 2012), providing 20.6% of per capita daily calorie intake nationally (IFPRI, 2010). Over half Ethiopian farmers grow maize, mostly for subsistence. In 2013/2014, 8.8 million farmers produced 6.5 million plenty of maize across 2 million hectares of land (CSA, 2014). Between 2000 and 2013, maize production doubled, due to increases in both per hectare yields and area under cultivation. It is reported that maize production expanded from 2.5 million tons in 2003/04 to five million tons in 2010/11 (Demeke, 2012) and to 6.5 million tons in 2013/2014 (CSA, 2014). Within the category of grain crops, cereals are the major food crops, both in terms of the area they are planted and the volume of production obtained. They are produced in larger volumes compared with other crops because they are the prime staple crops. Tadesse *et al.* (2011) indicated that five major kinds of cereal (Teff, wheat, maize, sorghum *and* barley) are the core of Ethiopia's agriculture and food economy, accounting for about three-fourths of the entire area cultivated, 29% of agricultural gross domestic product (GDP) in 2005/06 (14% of total GDP) and 64% of calories consumed.

In Ethiopia, about 290.39 million quintals of grains were produced from 12.57 million hectares of land in private peasant holdings in 2016/17. Of the 81.27% of land covered by cereals, the share of teff, maize, sorghum and wheat contributed 29.53, 20.89, 18.42 and 16.59%, respectively. Regarding production, of the 87.42% contributed by cereals, the share of maize, teff, wheat and sorghum was 30.91, 19.78, 17.88 *and* 18.72%, respectively (CSA, 2017).

Substantial growth in cereals, in terms of area, cultivated, yields and production since 2000, but yields are low by international standards and overall production is very vulnerable to weather shocks, particularly droughts (Tafesse *et al.,* 2011). In the past decade, the production of maize has been increased due to increases in the area cultivated. However, little suitable uncultivated land remains in the highlands, apart from pastureland. Soil degradation from erosion and soil compaction also threatens crop yields (Hamza and Anderson, 2005; Tadesse, 2001). Moreover, uncertain rainfall and really low levels of irrigation make intensive cultivation with improved seeds and fertilizer risky (McCann, 1995). Hence, increasing production and productivity is faced with serious challenges in improving food security through ensuring adequate food availability and increasing household incomes (Tafesse *et al.,* 2011).

Major factors causing postharvest losses of maize

Postharvest loss is often defined because the degradation in both quantity and quality of a food production from harvest to consumption. Postharvest loss preliminary at the time of harvest until its consumption or end uses could occur end to end in the supply chain of crops (FAO and World Bank, 2010). The factors that affect the nutrient/caloric composition, the acceptability and the edibility of a given product encompassed in quality losses. According to Kader, (2002) reported that these losses are generally more common in developed countries. Quantity losses refer to those factor that consequence in the loss of the amount of a product. Loss of quantity is more common in third world countries (Kitinoja and Gorny, 2010).

Postharvest losses occur at different points (harvesting, drying, threshing, winnowing, transportation and storage) (Harris and Lindblad, 1978). On the opposite hand, an enormous amount of losses occurs at different stages after crops are harvested and before consumption, after an outsized investment of your time, labor and money in the production process. Kaminski and Christiansen (2014) estimated losses to be as high 37% in sub- Saharan Africa. As Kumar and Kalita (2017) indicated that more than one-third of food is lost every year in postharvest operations. According to Demissie *et al.* (2008) reports due to poor storage techniques and inadequate pest management systems grain is not frequently stored for more than eight months in Ethiopia. Inappropriate storage techniques rodents and insect pests deterioration and abiotic factors lead to postharvest losses (Abass *et al.,* 2014). As Bekele *et al.* (2003) reported post-harvest yield losses of maize reached 26.4% in central Ethiopia which is very high as compared to 5 to 15% post-harvest loss of rice in Asia (Singleton, 2003).

In Ethiopia, particularly in West-Gojam Zone postharvest losses ranging between 30-50% in the major stages of maize (Tadesse and Regassa, 2013). According to AGRA (2014), postharvest losses of all the crops in Ethiopia have been estimated to be between 10 to 50%.

The internal factor causing postharvest losses of maize

Transportation postharvest losses

Primary challenges within the transportation stage of the availability chain include poor infrastructure (roads, bridges, *etc*.), lack of appropriate transport systems and a scarcity of refrigerated transport. In most developing countries, horticultural crops are not properly transport due to the lack of infrastructure. There is also a lack of transport vehicles and other types of transport, specifically those appropriate for perishable crops. This is truthful both for local marketing and export to other countries. Most have small holdings and have not enough money to purchase their transport vehicles. Marketing organizations and cooperatives are ready to acquire transport vehicles during a few cases but cannot alleviate poor road conditions (Kader, 2002).

Biological postharvest losses

Biological causes of degradation comprise respiration rate, ethylene production and action, rates of compositional changes (related to color, texture, flavor and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders and pathological breakdown. According to Kader (2002) and Gross *et al,* (2002) discussed, the speed of biological deterioration depends on several environmental factors, including temperature, ratio, air velocity and atmospheric composition (concentration of oxygen, carbon dioxide and ethylene) and sanitation procedures. Microorganisms like fungi and bacteria cause damage to stored foods. Usually, microorganisms affect directly a small amount of the food but they damage the food to the point that it becomes unacceptable. Toxic substances elaborated by molds (known as mycotoxins) cause a loss in food quality and nutritional value. Entomopathogenic fungi are important against different insect pests of stored grains may hold products in Ethiopia as many types of research indicated.

Chemical postharvest losses

Many of the chemical ingredients naturally existing in stored foods spontaneously react producing losses of color, flavor, texture *and* nutritional value. One such reaction is the Maillard relation' which causes browning and discoloration in dried fruits and other products. According to Atanda *et al.* (2011) report, there are harmful chemicals such as pesticides or obnoxious chemicals and lubricating oil.

The external factor causing postharvest losses of maize

Climatic conditions, including wind, humidity, rainfall and temperature has effect on both the quantity and quality of a harvest (Grolleaud, 2002).

Temperature and humidity

High temperatures and low relative humidity can trigger an alteration of certain biochemical processes such as oxidation and fermentation that can lead to a deterioration of the grain in storage. The shorter the storage lifetime of grain in storage and therefore the greater the quantity of loss within a given time, as most factors that damage the commodity its quality occur at a faster respiration rate as the temperature increases and the relative humidity decreases (Atanda *et al.,* 2011). As Bern *et al*. (2013) reports respiratory and/or metabolic processes of maize and the grain of maize weevils were attributed by the temperature values. Both mold and insects release heat which may cause temperature gradients within the stored grain thus creating convection currents in the stored grain commodity, encouraging warm moist air movement from the heating section to cooler sections where moisture is dropped as the air cools (Navarro, 2006).

Altitude

Within given latitude, the prevailing temperature depends upon the elevation when other factors are equal. Storing food at high altitudes will therefore tend to extend the storage life and reduce the losses in food provided it's kept out of direct rays of the sun. There is on the average a drop by temperature of 6.5°C (Atanda *et al.,* 2011) for every kilometer increase in elevation above water level.

Post-harvest losses of maize in Ethiopia

Post-harvest losses occur between the completion of harvest and the moment of human consumption (Gabriel and Hundie, 2006). Magnitudes of this loss along the value chain of selected crops in Ethiopia production of the selected crops in Ethiopia have been above 5,000 metric tons per annum for all crops and their post-harvest losses have been estimated between 10 to 50 per cent (FAO, 2009). Some of these factors are associated with the technologies, methods, techniques *and* practices as they are arranged and employed by the actors within the system, like mechanization, agronomic practices *and* farm management practices.

Other factors relate directly to the natural environment, such as insects, molds, temperature, weather conditions *and* humidity, or the socio-economic environment, such as access to market information. In Ethiopia, the typical grain losses as a result of storage pests are about 12% of the entire grain produced in some cases, the losses could rise to 50% (Gabriel and Hundie, 2006). As many researcher surveys depicted the majority of farmers (93.3%) are using various traditional grain storage structures that expose their stored grains to be attacked by storage pests and other factors that contribute to deterioration. According to Sori and Ayana (2012) reported, in Jimma Zone the average quantitative maize grain storage loss of 41.0 to 80.0% and on average 64.5% of grain damage was assessed in 2004 from 50 traditional farm stores within 3 to 6 months of which maize weevil (*Sitophilus zeamais*) followed by angoumois grain moth (*Sitotroga cereallela* (O), rice weevil (*Sitophilus oryzae*) and flour beetle (*Tribolium confusum*) were recognized as major storage pests.

Management practices for the reduction of postharvest losses

Physical control

The traditional method of warming grain on a clay pan over fire and exposure of grain to the sun was found to be effective for the control of insects on stored grain. Effectiveness was improved by spreading infested grain on a black polyethylene sheet, covering them with a sheet of translucent plastic *and* weighing down the edges with stones (Tadesse *et al.,* 2008). During grain handling and storage, the physical control methods is defined as effective and alternative methods to pesticides to prevent and control pests (Jayaprakash *et al.*, 2010). Studies on physical methods of pest management generally involved heat treatment and testing the effectiveness of solar radiation, although few studies also evaluated the role of oven heating. Another method that has gained importance in industrialized countries in recent years is the heat treatment of empty structures (Beckett *et al.,* 2007).

Biological control

Biological control is a method of controlling pests that relies on predation, parasitism, herbivore *and* other natural mechanisms and can be an important component of integrated pest management (IPM) programs. Classical biological control (the introduction of a natural enemy to control an introduced pest) is being used against the larger grain borer in several African countries. The larger grain borer, which was accidentally introduced in Africa in the 1970s, has now reached 20 countries, including Ethiopia. It was not recorded until 2008 in this country despite its presence in neighboring Kenya (Tadesse *et al*., 2008).

Natural enemies undoubtedly play a part in reducing pest numbers in many traditional storage systems, but they may not give an economically acceptable level of control. Tadesse (2003) recorded six species of wasps from farm-stored maize in Ethiopia. *Anisopteromalus calandrae* (Emana and Assefa, 1998) and *Choetospila elegans* (Abraham, 1997) was the most common natural enemies of farm stored maize.

Entomopathogenic fungi such as *Beauveria bassiana* and *Metarhizium anisopliae* are known for their effectiveness against different insect pests of stored grains. Kassa et al. (2002) assessed the efficacy of 13 isolates of entomopathogenic fungi belonging to Beauveria, Metarhizium, or *Paecilomyces* spp. from Ethiopia against *S. zeamais* and *P. truncatus* in the laboratory.

Treatment with botanicals

Mixing a local plant or plant powder with the grain is a common practice of traditional farmers in Ethiopia. Several attempts have been made to evaluate different botanicals as grain protectants under natural and artificial infestations in the laboratory and storehouse. In Ethiopia, several research findings have exhibited that botanical plants are commonly used to prevent infestation during storage. According to Almekinders and Louwaars (1999) showed that traditionally farmers use various cultural practices and herbs to produce a great potential botanical plant powder as seed protectants against S. *zeamais* products for the control of postharvest insects. The powder prepared from J. curcas seed and *A. indica* seed was indicated total (100%) control of *S. zeamais* within a short period.

Powders of some plants/seeds were found to be effective in controlling insect pests in storage. These include neem seed powder, Chenopodium plant powder, Pyrethrum flower powder and many others (Tadesse *et al.,* 2008; Demissie *et al.,* 2008b). Different vegetable oils were evaluated and recommended for use against some major pests of stored grains. Higher rates (5-10 ml/kg) are required for more effective results. However, oil treatment can reduce seed germination (unless reduced rates are used) (Tadesse, 2003; Tadesse *et al.,* 2008; Demissie *et al.,* 2008). Farmers use plants like *Lantana camara* L. (Verbenaceae) and *Tephrosia vogelli* Hook (Fabaceae) as grain protectants to control effectively maize weevil (Midega *et al.,* 2016).

Chemical control

Synthetic insecticides can effectively control storage pests. However, resistance development by pests, environmental contamination, health hazards, *etc*. associated with their use should be minimized as much as possible. Chemical treatment includes the preventive application of residual insecticides that are designed to limit the invasion and development of damaging insect infestations and remedial fumigation that provides rapid control of existing insect populations. The use of chemical insecticides in the form of sprays, fumigants, or specks of dust against stored grain pests has been reported by many workers, each with varying degrees of effectiveness and applicability.

Different insecticide chemicals can be used in storage. Insecticide clouds of dust are easily applied, relatively free from hazard *and* readily accepted by farmers because they closely resemble the traditional practice of using sand or ash with grain. Dilute clouds of dust are the most commonly recommended formulations for use on small farms, because of their lower toxicity, simplicity of handling (no need for spraying equipment) and the ease with which they fit into many traditional storage practices. The organophosphates pirimiphos-methyl, fenitrothion and Malathion specks of dust are the commonly recommended insecticides. They are effective against most stored grain pests, but less effective against larger grain borers.

Use of resistance variety

Varietal resistance plays a significant role in pest management. The use of resistant cultivars can reduce the severity of an infestation. Unfortunately, traits that contribute to improved grain storage have been largely ignored by breeders until recently. Since infestation by some of the major insects starts in the field, the use of maize varieties with tight and complete husk cover that extends beyond the tip protects the grain better than those with bare tipped ears (Demissie *et al.,* 2008).

Tefera *et al.* (2011) described that host plant resistance could be used as an important part of an integrated pest management approach against larger grain borer and maize weevil. Mechanisms of resistance to the maize weevil and larger grain borer are similar. Among maize genotypes, there are differences in resistance potential to weevils (Demissew *et al.,* 2004). Resistant varieties are an integral part of integrated pest management of storage pests substantial data has been accumulated from varietal screening researches in Ethiopia.

Integrated pest management (IPM)

Integrated pest management attempts to integrate available pest control methods to achieve an economical and sustainable combination for a particular local situation. Often, emphasis is placed on the use of resistant crop varieties, biological control, cultural methods and other non-polluting methods. In integrated pest management, pesticides are used as a last option, it is better when they can be integrated with other control methods. The integrated pest management concept emphasizes the integration of disciplines and control measures such as varietal resistance, cultural methods, insecticidal plants, natural enemies and pesticides into a total management system to prevent pests from reaching damaging levels.

Conclusion and Recommendation

Generally, it is important to understand those postharvest losses in both quality and quantity since it is related to lost income and /or value of commodities produced and hence part of the measure and primary concern to bring a food secured nations through modern agricultural production. In developing countries, the quantitative and qualitative postharvest loss of maize grains appear to be introduced mostly at the farm level, thus the potential solutions for the problem are desired at the same level. In Ethiopia, numerous factors cause post-harvest losses for those possible remedies have been prepared basis on the maize production potential and multiple suitable agro-climates. These are important in quantifying the national magnitude of losses, the prevailing loss agents and relate the same to food security in the country. In a country where production is much lower than the national demand and is characterized by the level of post-harvest loss stated above, a great effort is required in the area of constructing technology that diminishes this loss. To conclude technologies, which inhibit the growth of pests and provide proper storage facilities, appropriate packaging materials *and* transportation facilities are required to minimize losses and increase the shelf life of the food grains.

Regarding the current information of the postharvest loss, require model management practices including value chain points for all stakeholders on maize and other target staple grain crops of Ethiopia. Address demonstration of maize grain postharvest loss mitigating technologies to individual and grouped farmers. Further studies are needed concerning physical, bio-chemical and socio-economic aspects at each production level.

Conflict of interest: None.

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