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Impact of grain storage method on sorghum grain quality in Ethiopia: A review

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Abstract
Sorghum (*Sorghum bicolor* L.) is the fifth most valuable cereal next to rice, wheat, maize, and barley. It belongs to the grass family, Gramineae. The three main components of grain are pericarp, endosperm and embryo. Sorghum is originated in Ethiopia or East central Africa as many scholars believed. Therefore, the objective of this paper is to review grain storage methods and their effect on grain sorghum quality. The majority of the people store sorghum grain in underground pits. Pits usually elevate grain moisture and storage temperature to levels that suitable for insect pests and fungi, causing grain spoilage. Information on pit environment, effects of storage methods on sorghum quality and postharvest losses of sorghum at different handling, transportation and storage areas are important factors. Sorghum and millet grains are mixed with wood ash and stored in clay pots in some countries of West Africa. Gotera, which is made of bamboo sticks, wood and/or mud are known storage material that store their seeds and grains in the aboveground bin in the central, northern, southern and western parts of Ethiopian farmers. Control of grain moisture is the first step toward successful storage. Other steps incorporate an integrated pest management strategy that includes sanitation, bin loading, aeration, and monitoring strategies is also necessary proven to reduce storage problems. Comparative studies of lining methods of the aboveground bins themselves also help identify the lining materials that would allow longer grain storability and maintenance of grain quality.

Keywords: sorghum, grain quality, storage method

Introduction
Sorghum, (*Sorghum bicolor* L.) is the fifth most important cereal crop next to rice, wheat, maize, and barley. Sorghum belongs to the grass family, Gramineae. The producer understands the feature of the crop they are cultivating in order to develop the most effective production practices. Sorghums have a structure which is largely alike to that of other cereals. The main components of the grain are the pericarp (outer covering), the testa between pericarp and endosperm (which may or may not be present), the endosperm, and the embryo. Pericarp is consisting of the epicarp, hypodermis, mesocarp and endocarp and the outermost layer of the seed. The testa is located directly under the endocarp and encloses the endosperm. The endosperm consists of hard and soft endosperm. The endosperm supplies the seedling with nutrients until it can take up its own nutrient. The roots of the sorghum plant can be separated into a primary and secondary root system. Its leaves are typically green, glass like, flat, and not as broad as maize leaves. The stem of the plant is solid and dry, succulent and sweet. The inflorescence of sorghum is a compact panicle. Glumes are removed during threshing and/or harvesting that partially enclosed the ripe seed (grain) of sorghum (ICRISAT, 1981).
Sorghum is indigenous to Africa. Semi-arid tropics of Africa, Asia, and Latin America over 750 million people is the main depend on sorghum food grain. The largest group of producers is small-scale subsistence farmers with minimal access to production inputs such as fertilizer(s), pesticides, improved seeds (hybrids or varieties), good soil and water and improved credit facilities for their purchase. It is an important source of food, feed and forage worldwide (ICRISAT, 1980) [16]. During the first millennium sorghum was taken from East Africa to India. The arid and semi-arid tropics of the world are beneficial from sorghum because they get food for men and, fodder and feed for animals. It is a stable food for rural poor in the country and African countries. It is primarily used as livestock feed and as industrial use in USA and other develop developed countries. Sorghum is often referred to as “coarse grain”. However, it is now changing its role to commercial/ semi commercial crop from a traditional substance crop.

The global production and international trade are increasing the demand for sorghum for feed purpose is the main driving force. It has also been used in the production of alcohol. The whole plant is used for hay or silage and forage. The sweet stalked sorghum is emerging as a potential raw material to industries producing ethanol, jiggery and papermaking. Sorghum can grow in a wide range of elevations from lowlands to highlands in the country under adverse soil, climatic and poor management conditions and can supply food in drought prone areas (Brhane, 1980, 1981a, 1981b, 1982; Hepperly, Filiciano &, 1982) [7, 8, 9, 10]. Sorghum crop is the main food crop in Hararghe, eastern Ethiopia, next to maize. It covers 87000 ha (48% of cultivated temporary crops) in East Hararghe and 65000 ha (42% of cultivated temporary crops) in West Hararghe with a total annual grain production of 223000 t in the region (CSA, 2000) [14]. In Hararghe, sorghum is mainly intercropped with maize and often intercropped with haricot beans (*Phaseolus vulgaris* L.) groundnut (*Arachis hypogea* L.) and chat (*Catha edulis*). According to Brhane & Belaynesh, (1981) [10]; Belaynesh (1982) [3, 10] report the sole sorghum flour or mixed with other cereal flour is used for making injera (local circular-pancake that serves for preparing lafiso in Hararghe), porridge, and leavened bread (Brhane & Belaynesh, 1981; Belaynesh, 1982) [9, 10] while the whole grain may be cooked or boiled with other cereal and/or legume grain and expended.

It is not documented how long a farmer can keep his grain within the underground pit without deterioration. The patterns of granary temperature, relative humidity, grain moisture contents, and association of micro flora with sorghum grain stored in underground pits under different agroecological conditions are not documented. The changes in grain bulk density, grain weight loss, seed germination, and chemical components of sorghum grain stored over time aren't estimated. Information is meager on source of grain contamination by storage fungi prior to grain storage. It is not certain where and when the storage fungi commence grain contamination and flourish later during storage. The effects of lining methods of underground pits on pit environment, mycoflora development, grain quality and storability aren't recognized. A thorough comparative investigation of aboveground bin and underground pit storage has not been conducted to seem into their impacts on grain quality and storability. The availability of such information would qualify us to forecast the permissible safe storage times (Sinicio, Muir & Jayas, 1997) [31].

Today, quite ever, safe grain storage and prevention of post-harvest losses by farmers has become more a necessity than a rule to beat shortage of grain and to tackle starvation and hunger in Ethiopia. This is crucial to ensure food security and to feed the ever-increasing population (currently over 72 million increasing at a rate of 3%) of the country where more than 85% of the broad mass of the population earns its livelihood directly or indirectly from agriculture. Minimizing the postharvest grain losses thanks to destructive agents like storage fungi needs due attention by researchers, grain managers, farming community and consumers. Improved storage methods and/or modified underground pits is unquestionable and timely needed for maintenance of the grain nutritive and other inherent qualities. This grain storage study provides data on the underground pit storage environment, source of inoculums for contamination, extent of sorghum grain damage expected, storability of grain in safe conditions, most affected grain parameters resulting from poor storage, changes in chemical components over time, and mycoflora associated with the grain. This paper would give hints to grain managers with regard to the necessity for designing storage structures that maintain low temperatures and grain moisture contents at levels safe for reasonably long grain storage.

Objective

To review the Impact of Grain Storage Method on Sorghum Grain Quality

Literature Review

Grain Storage and storage structures

Storage Structures

According to accessible materials, economical aspects and storage capacity etc. storage structure classified into:

- Indoor and outdoor storage structures
- Above-ground and under-ground
- Rooms/bins/pots constructed with mud
- Wood or Bamboo storage structures
- Metallic drums, bins or containers
- Structures formed with straw of paddy and wheat, etc.

The objective of storage is to preserve the value of the grain for its intended future use. This means either retaining as high a proportion of viable seeds for planting at the next harvest or preserving as much as possible of the food value of the grain for long period. Several factors lead to the loss of both viability and nutrients, but globally the main causes of loss are the depredations of pests (insects, birds and rodents) and mould damage. Germination of the grain (sprouting) also results in losses, but on a smaller scale. Consumer and processor stored the grain for future consumption. It is also stored by commercial traders for resale, usually on the home market but occasionally for export. (Belaynesh, *et al*, 1982) [3, 10].

Moisture within the grain and therefore the temperature of storage are the foremost important physical factors that contribute to losses. In Africa there are traditional storage structures as many publications' reports (FAO, 1994; Adejumo and Raji, 2007). These storage facilities are made of local materials (plant materials and soil) and constructed by the villagers themselves. Some structures are used for temporary storage (mostly planned for the drying of the crop), whereas others are for long-term storage (FAO, 1994). Temporary storage methods are gathered into aerial storage (maize cobs or sorghum and millet panicles are sometimes tied in bundles, which are then deferred from tree branches, posts, or tight lines on or inside the house), storage on rock bottom, or on drying floors and open timber platforms. Long-term storage methods include (i) storage baskets (cribs or thatched rhombus) made entirely of plant materials, (ii) calabashes, gourds, earthenware pots, etc., (iii) jars, (iv) solid wall bins (mud rhombus), and (v) underground storage.

Effect of Storage on Quality of Sorghum Grain

During storage, grain is subjected to qualitative and quantitative losses due to several agents including insects, fungi, rodents and mites. Sorghum grains shall be saved and suitable for human consumption. It shall be free from abnormal flavors, odor, and living insects. Sorghum grains shall be free from filth (impurities of animal origin, including dead insects) in amounts which may represent a hazard to human health. Lower moisture should be required for certain destination in relation to the climate, duration of transport and storage. Governments accepting the standard are requested to indicate and justify the requirements in force in their country.

As moisture content of the seeds is one the most important factors determining seed longevity during storage (Qaisrani, 2000), conditions which maintain seeds moisture content close to that of the newly harvested seed provide better storage. The results of this study indicated that the different types of silos provided these conditions. It also suggested that as far as moisture content and terminality are concerned, a conventional silo is good as the more expensive modern silo kept under controlled conditions. In the storage facilities, which provide little protection for stored seeds from exchange of moisture with the surrounding air, namely the corrugated Iron warehouse and the underground pits seeds recorded the highest moisture content in this study. This is supported by Lemmessa *et al*. (2000) for results also revealed that a brick wall warehouse is the better facility for storing sorghum seed than a corrugated Iron warehouse in terms of moisture content and viability. This is may, possibly, be related to better insulation offered by the brick wall warehouse both in terms of climatic factors and seed infection. However, as seeds in the brick wall warehouse were not completely sequestered their moisture content sustained to increase during the second year of storage. On the other hand, the moisture of seeds stored in the corrugated Iron warehouse seemed to have reached equilibrium with that of surrounding air in the first year and hence no increase was observed in the second year of storage, which may again reflect the poor insulation provided by this type of storage.

Different levels of relative humidity for normal development required for deteriorative organisms which affecting stored cereals. The level for bacteria is generally above 90%, for storage moulds above 70%, for storage mites above 60%, and for storage insects in the range 30-50%. Relative humidity and moisture are dependent on temperature. The maximum moisture level for save storage of grain, sorghum is 130 g/kg for one year and 100-110g/kg for five years (Hall, 1980). The maximum storage of sorghum at 27 ^{0}C is 135g/kg according to Muckle and Strrling (1971), but this figure varies considerably between varieties. In sorghum an inter granular relative humidity of 70% of equilibrium with moisture content level of 138 g/kg (Hall, 1980).

Grain quality in storage is highly affected by high temperature and moisture. Each can cause malting quality baking quality, rapid decline in germination, color, oil composition, and many other quality characteristics. Sorghum grains shall be free from heavy metals in amounts, which may represent a hazard to human health. Spraying with insecticides or fumigating minimizes insect problems but leaves chemical residues, and their concentration affect acceptability of the grain to markets.

Storage Methods and Sorghum Grain Quality

Traditional storage method

The traditional underground pit environment is unsuitable for safe grain storage. Moisture soil into the grain elevates the grain moisture content and enhances respiration by insect pests and microorganisms. This condition more boost the granary temperature, relative humidity and grain moisture making suitable conditions for storage fungi leading to grain spoilage. Severely molded grain loses its bulk density, grain weight, percentage germination and other inherent qualities. Modification of the underground pit by lining with plastic or replacing with an improved aboveground bin can avert bio deterioration and improve grain quality and storability. Such a storage structure would maintain grain moisture and temperature at lower levels that do not favour development of spoilage organisms (Chitio *et al.,* 2002)

Modern storage method

Poor storage conditions resulted in significant decreases in the seed weight compared to newly harvested seed and modern storage facilities. Loss in seed weight is associated with seed deterioration and results from the degradation of storage compounds and the leaching of inorganic and organic compounds (Abdul-Baki and Anderson, 1972), or farm seed infection with pathogens or insect (Sarvanan *et al*., 2001; Chitio *et al.,* 2002). The two most prevalent types of sorghum seeds storage in sorghum-growing areas of Sudan are the corrugated iron warehouses and underground pits. These Seeds from the modern storage facilities are subjected to purification such as sieving and blowing hence their very low percentage of other seed and inert matter. On the other hand, seeds from traditional storage facilities contain a large proportional of inert matter and other seeds sometimes reaching as high as 30%. This would mean that sometimes 30% of the material planted by farmers is not really sorghum seed that may represent a financial loss in terms of the material planted and the consequent loss in plant population. Storing the seeds under controlled conditions in the modern silo maintained seed viability, germ inability, and field emergency at the same level a newly harvested seed.

Effect of Storage Time and Agro-ecological Zones on Sorghum Quality

Storage time

Storage period influenced the contents of all chemical components analyzed. The organic matter and soluble carbohydrate contents of sample from the soil pits were significantly different from samples taken from the above ground bins and the other non-soil pits. The organic matter decreased from 97.8 to 91.6% in grain samples from the soil pit while the soluble carbohydrate decreased from 2.4 to 0.97%in 17 months. Prolonging the storage period under these conditions led to further decrease in the fat content. The maintenance of fat level in the underground pit probably reflects the early death of embryos. One of the physiological manifestations of seed deterioration is increase in the percentage of abnormal seeding and may also result from mechanical damage or infection by microorganisms during storage. As such storage conditions, which encourage seed deterioration, are expected to show a higher percentage of abnormal seedlings in the germination test. This was clearly indicated by the results of this study where significantly higher percentage of abnormal seedlings was recorded for the water house storage facilities compared to silo storage; with longer storage and hence further deterioration, the % of abnormal seedlings significantly increased. (Bullerman, 1979) [11].

Agro-ecological zones

Countries in the sub-Sahara domain including Ethiopia frequently suffer from disturbances of the regular patterns of rainfall due to climatic changes that negatively affects crop production in the field. Besides the use of poor storage methods often results in post-harvest grain losses and aggravates the grain shortage situation, thus leading to difficulties in feeding the ever-increasing human population. The environmental condition during grain maturation greatly affects the appearance of the grain because the sorghum head is exposed to insects, moulds and moisture. The grain quality negatively affected by an environment that is humid during post maturation. Moulds discolor the grain, break down the endosperm significantly affect the grain qualities. Sorghum mould and weather damage are the most important to limitations to sorghum improvement worldwide. (Brhane *et al*., 1982) [9]

Grain Storage Strategy

Control of grain moisture is the first step toward successful storage. As Maier *et al*. (1997) [19] reported integrated pest management strategy these includes bin loading, aeration, sanitation, and monitoring strategies proven to reduce storage problems. This approach involves a combination of sequential steps from pre harvest through post-harvest that are designed to control grain storage pests and the economic losses associated with their activity.

Sanitation

Sanitation involves the thorough cleanout of all equipment that will harvest, transport, or handle grain as it moves from the field to the final storage unit and ultimately to the point of sale. Combines, grain carts, trucks, pits, hoppers, conveyors, dryers, and storage bins should all be thoroughly cleaned to protect the new crop from contamination with mold or insect infested grain from other crops. Dust masks or similar personal protection equipment (PPE) should always be worn when cleaning equipment to protect lungs and breathing passageways from exposure to dust and mold spores. The area around storage bins should be mowed or sprayed with a herbicide to remove tall grass or weeds that can harbor insects and rodents. Spilled grain around pit hoppers, bin doors, and all other areas should be removed immediately after harvest to eliminate ready access of this food supply (Maier *et al*., 1997) [19].

Bin loading

Clean grain will always store better than grain with fines, trash, and weed/foreign material. If cleaning is not feasible, fill bins with grain spreaders so that fines and trash will not be concentrated in a central core in the middle of the bin. If a spreader is not used, remove the center core of grain after filling the bin, and place this material in a separate bin that will be unloaded first for sale or feeding. Do not store milo in the center peak of a bin for extended periods. This area offers more resistance to airflow, which renders it susceptible to rapid heating and spoilage.

Aeration

To facilitate aeration management the small fans should be operated continuously until the cooling cycle has moved completely through the grain mass. Ideally, operators should strive to select a 3- to 5-day period when average temperatures are predicted to be in the target range. Large fans should also be operated when outside conditions match the target range and can be run intermittently. Aerate milo once each month during the fall to maintain uniform temperatures in the bin that are within 10° to 15°F of the average monthly temperatures. Cool grain to between 35° and 40°F by December, and seal fans with plastic or a similar material to block wind-driven air currents through the grain that can lower grain temperatures below desired levels (Bothast, 1978) [5].

Monitoring

Monitoring grain sorghum for insect or mold activity is important during storage to be sure the crop remains in good condition. Considering that the crop value in a single storage bin can be worth tens of thousands of dollars and that spoiled grain can amount to a 5 to 10% loss, the recommendation that grain managers inspect stored grain on weekly or semimonthly intervals seems reasonable. Temperature cables can provide valuable information for isolated spots inside grain bins, especially where handheld grain/ temperature probes cannot collect samples or penetrate the grain bulk. It is important to realize that temperature sensors may not detect isolated warm areas or "hot spots" within 12 inches in any direction (Maier, 2002). Similarly, thorough manual inspections provide valuable information about the quality of stored grain near the surface but have severe limitations in deeper regions of the bin unless a vacuum probe (Seedburon, 2000) is used, which is expensive and cumbersome.

Summary and Conclusion

The aim of storage is to preserve the value of the grain for its intended future use. On-farm, village and city or central grain storage structure used depends on the level of storage. Some of them are for temporary storage such as aerial storage, storage on the ground, or on drying floors and open timber platforms and also for Long-term storage includes storage baskets, earthen ware pots, jars, solid wall bins (mud rhombus), and underground storage. The migration of moisture from the surrounding soil walls into the grain was the main cause for elevation of grain moisture. The storage fungi can produce mycotoxins such as aflatoxins on sorghum grains with high moisture contents. The reduction in grain weight, percentage seed germination, organic matter and soluble carbohydrate contents was associated with poor grain storage practices accompanied by insect infestations and storage fungal invasion. Poor storage structures increase the frequencies of storage fungi over time. Contamination of grain by storage fungi could occur during pre-harvest, at harvest, threshing, winnowing and transportation due to poor sanitary practices and could explode to damaging levels in the storage period. The grain is exposed to deleterious conditions due to the absence of any lining material in the underground pit and direct leakage of rainwater into the pit. Such kinds of grain would have low grain weight and poor nutritional value. There is also evidence that infestation by storage pests can aggravate the grain damage.

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