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QUALITY CHANGE OF WHEAT GRAIN DURING STORAGE IN A FERROCEMENT BIN

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ABSTRACT

Wheat is a seasonal agricultural commodity which produces once in year. The demand of wheat remains high throughout the year because it is considered as staple food in developing countries including Pakistan which necessitates the proper storage and maintenance systems to obtain quality grains. Grain stored for one year in ferrocement bin retained better germination percentage, starch content and falling number than grain stored in room type store. Ferrocement bin protected stored wheat from deterioration caused by fungi, aflatoxin, and insects while wheat stored in conventional room type store suffered severe damages. Ferrocement bin showed lower grain moisture and grain weight loss throughout the storage period than room type store. The quality of wheat in traditional room type storage system was low and this storage system was inadequate for protecting stored wheat from deterioration. Therefore ferrocement bin has proven to be a promising solution for storage of good quality grain.

Keywords: wheat storage, aflatoxin, seed germination, starch, weight loss.

INTRODUCTION

Wheat (Triticum aestivum L.) is the principle grain harvest and staple sustenance of Pakistan. It possesses a focal position in agriculture and economy (Shuaib *et al*., 2007). In Pakistan wheat was become on a range of around 8693 thousand hectares which produced 24.2 million tonnes of grains (GOP, 2013). The demands for wheat products are more consistently spread throughout the year. In this condition, there is need to meet average demand by storing surplus supply during the harvesting period for gradual discharge to the market during off-season periods.

Grain storage structures being used by majority of farmers in Sindh province are traditional ones that cannot save the stored grains from losses and are inadequate to meet the needs of food protection in terms of quality and quantity. Inadequate storage systems have found to be the main issue in developing countries, which often leads to huge losses of cereal grains (Birewar, 1990; Ngamo *et al*., 2007). The conservation of grain quality now a day is the real concern all through the world. Deterioration of grain quality may begin in fields before harvesting, which further aggravates during improper storage (Kent and Evers, 1993). High quality grain is that which is rich in nutrients and free from pathogens and physical and chemical contaminants (Weinberg *et al*., 2008). A few studies have shown that a significant part of the grain quality deterioration have been connected with insufficient storage systems and climatic conditions for example, high moisture content, dampness and temperatures (Ahmad *et al*., 1998; Williams, 2004; Gourama and Bullerman, 1995). Fluctuations in temperature, humidity and prolonged storage results in considerable nutrients loss (Shah *et al*., 2002; South *et al*., 1991; Naoufal *et al*., 2012).

Insect infestation in grain during storage (Linda and Obermeyer, 2006; Neethirajan *et al*., 2007), waste items created by rodents (Drummond, 2001) and the fungal attack in the stored grain are identified to lead to serious deterioration of grain (Ramaswamy *et al*., 2009; Oladele and Osipitan, 2011), which can further prompt sick wellbeing of the customers (Bennett and Klich, 2003; Mathew *et al*., 2010). Chemical investigation of insects damaged grains has indicated substantial deterioration of nutrients like starches, vitamins and minerals (Daniel *et al*., 1977; Sharma *et al*., 1979), which may prompts undesirable tastes and off-smells making the products inadmissible and in addition unfit for utilization (Hansel *et al*., 2004). Fungal infestation brings about decrease of grain quality, for example, changes in shade, taste, smell, nourishing worth, germination capacity and prompts the generation of distinctive metabolites which are poisonous in nature (Dutta and Roy, 1987; White and Jayas, 1993). Aflatoxins are the group of mycotoxins, these auxiliary metabolites are delivered by toxigenic fungi type for example, *Aspergillus flavus* and *A. parasiticus* (Iqbal *et al*., 2010) that contaminate different types of nourishment and feed commodities, particularly in hot and humid regions of the world (Murphy *et al*., 2006; Iram *et al*., 2014; Udoh *et al*., 2000).

In Sindh province of Pakistan, practically no work has been done so far to improve grain storage methods as well as to develop grain storage structures particularly at farmer level. Absence of suitable storage structures is one of the main problems at the farm which results in substantial losses of food grain. Thus, the objective of the present experiment is to assess the performance of the ferrocement bins versus the traditionally used room type store on wheat grain quality.

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MATERIALS AND METHODS

Experimental area

The research was conducted for one year from July 2013 to July 2014 at Sindh Agriculture University Tandojam, Pakistan (Figure-4). The climate of the study area is hot and dry with 90 mm mean annual rainfall. The maximum temperature of 41 °C is occur in May while minimum (10 °C) in the month of January. The highest relative humidity of 81% found in August whereas lowest (55%) in April.

Grain storage systems

Ferrocement bin: A cylindrical ferrocement bin of 2500 kg grain storage capacity was made from cement mortar, closely spaced light reinforcing rods, and wire mesh (Figures 1 and 2). The most essential peculiarity of reinforcing is that it can easily be assembled in any required shape and the mortar can be used in layers to its both sides. The material is extremely thick, however structures produced using it are light in weight. It is also rot and vermin-proof, impenetrable to worms and borers, and watertight. Foundation of a ferrocement bin was fabricated from burnt clay bricks with cement mortar above the ground to give safety of grain from rain water. The foundation was filled with sand and a damp proof stratum of bitumen and polythene sheet between two layers of cement concrete made over the sand to protect the grain from moisture uptake. Cylindrical wall and conical roof of the bin were fabricated from skeleton of mild steel bars and chicken wire mesh. The skeleton was plastered with cement mortar and kept moist for 28 days to facilitate hardening of cement and to avoid development of cracks. The roof of the bin was covered with straw layers over hanged from the wall to prevent the grain from heating, moisture migration and moisture condensation. Grain inlet, outlet and three grain monitoring channels were also provided to the bin.

Room type store: This structure is typically made of burnt clay blocks laid with cement mortar. It might be made out of various rooms close from all sides and of variable measurements. It has walls, floor, top, windows, entryways and ventilators. The sacks are stacked on the floor or on dunnage with space to course air around the sacks (Figure-3).

Procurement of wheat grain

The freshly gathered wheat grain sample was acquired from Latif farm of Sindh Agriculture University Tandojam and the initial data of grain quality parameters (moisture, aflatoxin, germination, starch and falling number) was calculated. The grain sample was then loaded in selected storage systems.

Collection of sample

Grain samples were taken from different positions of storage systems with the help of sampler at three months interval for one year and then mixed completely to get a composite sample. The composite sample was then used for determination of quality parameters at laboratory of Pakistan Council of Scientific and Industrial Research, Hyderabad. Further, temperature (°C) and relative humidity (%) conditions of the experimental site were observed monthly for one year by psychrometer.

Quality observation

The moisture (%) of each grain sample was observed according to AACC (2000) method No. 44-15A. Each grain sample was analyzed for aflatoxin content (µg/kg) by high performance liquid chromatography (HPLC) method according to the procedure explained by Giray *et al*. (2007) with slight changes. In order to determine seed germination (%), a hundred grains were randomly picked from each sample in three replications and kept in petri dishes lined with filter paper and soaked with water. The petri dishes were set at 25 °C in an incubator for 7 days to permit them develop (ISTA, 1996). Grain starch (%) was determined by Gluco-amylase method (Buriro *et al*., 2012). Falling number (second) was recorded in triplicate by placing 7g of wheat grain sample (collected from each storage) in tubes structure and added with 25 ml of distilled water according to procedure described in AACC (2000) method No 56-81B. In order to calculate the weight loss (%) due to insect infestation, insect infested grains were separated from a grain sample of 50 g of wheat. Number and weight of insect damaged grains and undamaged grains were noted and weight loss due to insect infestation was determined by the following formula (Harris and Blad, 1978):

$$\text{Weight loss (\%)} = \left(\frac{M_u N_d - M_d N_u}{M_u N_u + M_u N_d}\right) \times 100$$

Where,
M_u = weight of undamaged grains, M_d = weight of damaged grains, N_u = number of undamaged grains, N_d = number of damaged grains

Data analysis

The data was analysed through analysis of variance by 2-factorial design model (2 storage system × 4 storage duration) for studying the effect of these two independent factors on the different dependent variables (moisture, germination, aflatoxin, weight loss, starch, and falling number). The comparison of means was performed by LSD (least significant difference) at probability level of 5%.

RESULTS

Changes in ambient temperature and relative humidity

Ambient temperature and relative humidity of the study site decreased gradually from the start of storage until January, 2014 and then increased continuously throughout the storage experiment. The ambient temperature remained over 35 °C for more than 6 months in the summer season. The mean ambient temperature and

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relative humidity remained around 34.17 °C and 70%, respectively throughout the study duration (Table-1).

Initial data of grain quality parameters

The mean values of moisture content, germination, aflatoxin level, starch content and falling number of newly harvested dried wheat grain were 13.8%, 93%, 2 µg/ kg, 65.6% and 306 seconds, respectively.

Influence of grain storage system alone

Grain storage systems had significant influence on grain moisture content, aflatoxin level, germination percentage, weight loss, starch content and falling number (Table-2). The results of the experiment exhibited significantly greater germination percent (83%), starch content (65.16%) and falling number (296.7 seconds) in grains stored in ferrocement bin than in room type store. However, aflatoxin level (8.975 µg/ kg), weight loss (2.025%) and moisture content (13.93%) were significantly greater when grain stored in room type store than in ferrocement bin.

Influence of storage duration alone

Grain storage duration had also a significant influence on all the grain quality parameters (Table-2). The starch content, falling number and germination percentage of wheat grain decreased with respect to the storage duration and the least values of 62.68%, 284 seconds and 65.5%, respectively were recorded at the end of experiment (one year). Whereas, aflatoxin level and weight loss of stored wheat were increased with the progress of storage duration and the maximum values of 9.55 µg/ kg and 2.45%, respectively were observed at the 12th month of storage duration. Grain moisture content varied with the relative humidity during whole study period and decreased from 13.8 to 12.95% during first six month storage then continuously increased during the remaining storage period to maximum value of 13.55%.

Interactive influence of storage duration × storage system

Interaction of storage duration × storage system showed a significant effect on all the selected quality assessment parameters (Table-3). At first 3 months of storage duration maximum germination percentage (90%), starch content (65.53%) and falling number (304 seconds) were recorded in grains stored in ferrocement bin. However, the lowest germination percentage (56%), starch content (60.68%) and falling number (280 seconds) of wheat were noted during storage in room type store at 12th month of storage time. The aflatoxin level (12.4 µg/ kg), weight loss (3.69%) and moisture content (14.53%) of grain stored in room type store at 12th month of storage were maximum while the least values of aflatoxin (2.1 µg/ kg), weight loss (0.34%) and moisture content (13.6%) were observed in grains stored in ferrocement bin at 3 months of storage.

Table-1. Ambient temperature and relative humidity of the experimental site.

Storage duration	Ambient temperature ^{0}C	Relative humidity %
1 July, 2013	37.70	77
1 August, 2013	36.42	76
1 September, 2013	36.53	76
1 October, 2013	35.35	75
1 November, 2013	32.61	66
1 December, 2013	25.72	64
1 January, 2014	24.53	63
1 February, 2014	27.62	66
1 March, 2014	34.41	65
1 April, 2014	37.63	67
1 May, 2014	41.42	68
1 June, 2014	37.74	71
1 July, 2014	36.62	73
Average	34.17	70

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Table-2. Means of wheat quality parameters determined in the experimental study based on storage system and storage duration.

Independent variables	Dependent variables					
	Grain moisture (%)	**Aflatoxin** (µg/kg)	**Weight loss** (%)	**Seed germination** (%)	**Starch** (%)	**Falling number** (second)
Storage system						
Ferrocement bin	12.75b	3.900b	0.740b	83.0a	65.16a	296.7a
Room type store	13.93a	8.975a	2.025a	76.0b	63.32b	292.5b
LSD (0.05)	0.0073	0.0468	0.00452	0.4532	0.00453	0.4053
Storage duration						
3 months	13.69a	3.400d	0.44d	89.5a	65.39a	302.5a
6 months	12.95d	5.550c	0.90c	85.5b	65.0b	298.5b
9 months	13.15c	7.250b	1.74b	77.5c	63.89c	293.5c
12 months	13.55b	9.550a	2.45a	65.5d	62.68d	284.0d
LSD (0.05)	0.0103	0.0662	0.00641	0.6409	0.0064	0.5732

Means followed by the different letter in each column are significantly different according to (LSD) least significant difference at probability level of 0.05

Table-3. Moisture, Aflatoxin, weight loss, seed germination, starch and falling number of wheat grain under interactive effect of storage system and storage duration.

Storage system	**Storage duration**	**Grain moisture** (%)	**Aflatoxin** (µg/kg)	**Weight loss** (%)	**Seed germination** (%)	**Starch (%)**	**Falling number** (second)
Ferrocement bin	3 month	13.60d	2.10h	0.34h	90.0a	65.53a	304.0a
	6 month	12.35h	2.80g	0.57f	85.0d	65.33b	300.0c
	9 month	12.47g	4.00f	0.84e	82.0e	65.10d	295.0e
	12 month	12.57f	6.70d	1.21d	75.0f	64.67e	288.0g
Room type store	3 month	13.78c	4.70e	0.54g	89.0b	65.25c	301.0b
	6 month	13.56e	8.30c	1.23c	86.0c	64.67e	297.0d
	9 month	13.83b	10.5b	2.64b	73.0g	62.68f	292.0f
	12 month	14.53a	12.4a	3.69a	56.0h	60.68g	280.0h
LSD at 5%		0.0146	0.0936	0.0090	0.9063	0.0091	0.8107

Means followed by the different letter in each column are significantly different according to (LSD) least significant difference at probability level of 0.05

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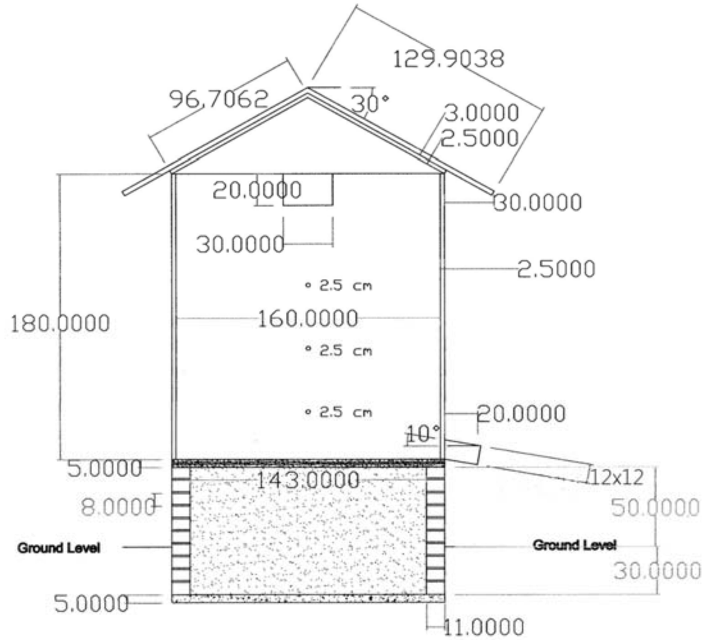

Figure-1. Two dimensional view of the ferrocement bin.

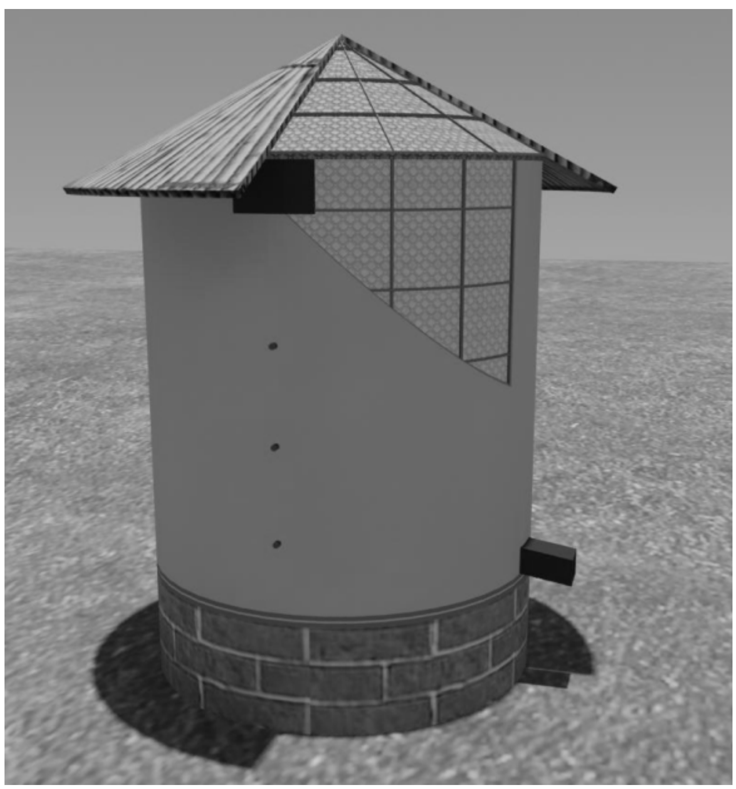

Figure-2. Three dimensional view of the ferrocement bin.

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Figure-3. Wheat grain stored in room type store.

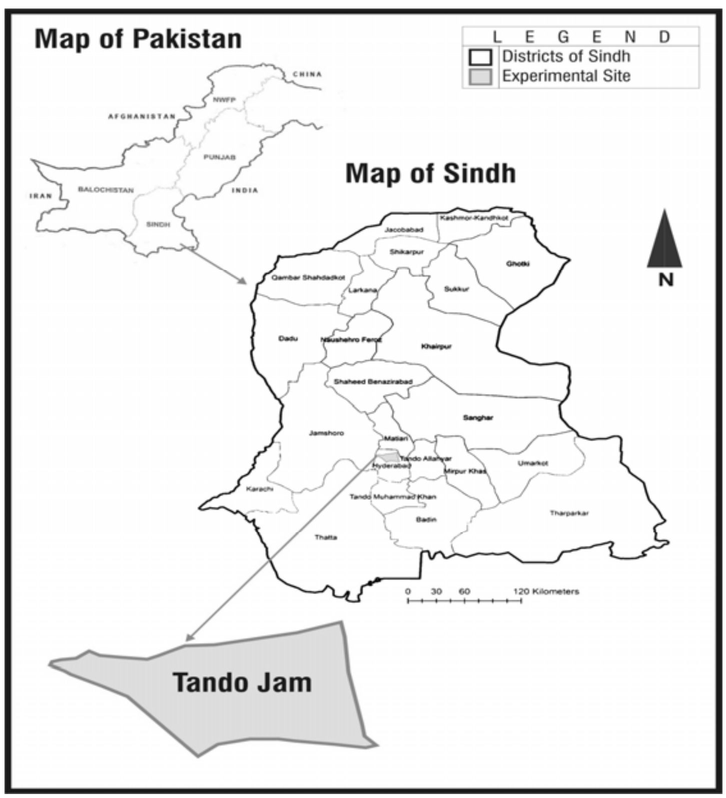

Figure-4. Map of Pakistan and experimental site.

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DISCUSSIONS

Stored grains are hygroscopic and pickup moisture under humid conditions. Therefore environment of storage structures depends upon the environmental conditions outside the structure. The variation in environmental conditions has direct impact on the biological, chemical and physical conditions of the grain within the storage bin (Fleurat, 2004; Alabadan and Oyewo, 2005). Relative humidity and ambient temperature conditions of the study area ranged from 24.53 to 41.42 °C and 63 to 77%, respectively. This high humidity and temperature condition was suitable for insects and fungal growth which deteriorate stored grain quality. The insects that grow inside the stored grains are actually thermophillic in nature hence they survive even in higher temperature. Insects start to develop when the temperature of grain reach at 18 °C and continue to rise in quantity even at 25 to 35 °C (Ilelejia *et al*., 2007; Fields, 1992). For the safe and acceptable storage of grain it is essential to store the grains below the levels of insect’s optimum moisture and temperature.

Moisture content of wheat samples taken from traditional room type store was higher than in samples from ferrocement bin during the whole storage time (one year). The high moisture content of grain in room type store might be because of higher respiration of insects, fungi, and wheat grain. Moisture is one of the finished results of respiration process which increase moisture of the stored grain (Sanches- Marines *et al*., 1997). Various studies have reported that moisture content of stored grain rise with rise in insect and fungal contamination (Girish *et al*., 1975; Sinha, 1984; Mills, 1983). High grain moisture can also be due to variation in relative humidity and temperature conditions of the surrounding air. Hruskova and Machova (2002) observed an increase in moisture of grain under high humidity conditions of the surrounding. Hossain *et al*. (2011) also found a continuous increase in grain moisture content of different storage structures (sealed container, polythene bag and gunny bag) with interval of time and the grains stored in gunny bags was noticed with highest moisture content as compared with other structures. It might be due to high permeability of gunny bags which allows the moisture to come in contact with stored grain thereby increasing moisture. GC (2006) also reported that maize grains stored in metal bins had lower moisture percentage as compared with jute bags.

Aflatoxins are toxic secondary metabolites produced by fungal genera such as *Aspergillus flavus* and *Aspergillus parasiticus*. Their presence in nourishment is of incredible concern in view of their unsafe consequences for human and creature wellbeing (Toteja *et al*., 2006). The aflatoxin level wheat grain before storage was 2 µg/ kg which gradually increased throughout the storage duration and the maximum rise in aflatoxin level was found in grain samples collected from room type store as compare to ferrocement bin. The higher rate of increase of aflatoxin level in the room type store could be due to high moisture and temperature. Aflatoxins produce quickly within the temperature from 20 to 44 °C (Farrel and Hodges, 2004), which is near the temperature found in these storage systems. This may have quickened the improvement of a few types of *Aspergillus* and *Penicillium*, which have a tendency to create aflatoxins. Cereal grains stored at relative humidity between 75 and 85% are susceptible to fungal infestation within the common storage duration (Hell, 2000). Ranjan *et al*. (1992) found high aflatoxin level in the grain samples collected from gunny bags and this may be ascribed to the accessibility of dampness because of the permeable nature of these bags as compared to other structures. Kayaa and Warren (2005) have also stated that grain stored in woven polypropylene bags for 6 to 7 months had aflatoxin above the safe limit which is an indication that the grains were not suitable for the export and local markets.

An increasing trend in weight loss of grain was recorded during the whole storage duration and the maximum increase in grain weight loss was noted in samples from room type store than from ferrocement bin. The highest weight loss of wheat samples collected from room type store can be attributed to higher insect infestation. The results of the present study regarding grain weight loss are in agreement with the previous works of other researchers Khattak *et al*. (2000), Khan and Kulachi (2002), Sayed *et al*. (2006) who observed positive association between the insect infestation level and weight loss of stored grains. Eticha and Tadesse (1999) conducted research in Ethiopia on the stored sorghum in traditional structures and found about 38.7% sorghum grain damage and 15% grains weight loss. Singh and Jackai (1985) also noted 30% weight loss and about 70% damaged seeds of cowpeas stored for six months on farm storage structures which are unfit for human consumption.

A decline in grain germination percentage was noted throughout the storage duration and the least values of germination percentage were recorded in grain samples collected from room type store than samples from ferrocement bin. The lowest grain germination percentage in room type store can be due to high temperature and moisture. High grain moisture and temperature negatively correlate with grain germination percentage as observed by many researchers (Owolade *et al*., 2011; Moreno *et al*., 1988; Rani *et al*., 2013). Deterioration of grain germination percentage might also be due to the attack of insects and fungi. The presence of insects and fungi negatively affect the germination percentage of grain during storage as indicated by previous studies (Imura and Sinha, 1984; White and Jayas, 1991; Lemessa *et al*., 2000). Fekadu *et al*. (2000) recorded lowest percentage germination of sorghum during storage in traditional pits can be due to the damage of the embryo of grain by fungi and insects. The earlier work of Charjan and Tarr (1998) illustrated that storage of grain in polyethylene sacks protected germination capacity and decreased attack by storage fungi compared with jute sacks.

Starch is a major component of most of the cereals and is responsible in providing major amount of nutrients and vast amount of energy in the human food. The results indicated that starch content of grain decreased throughout the storage duration. The maximum decrease of starch content was observed in samples taken from room type store as compare to ferrocement bin. The higher rate of decrease of starch content in room type store could be due to higher moisture and temperature conditions. The findings of Strelec *et al*. (2010) showed a significant decrease in starch content of wheat stored at elevated temperatures (40 and 25 °C) and relative humidity of 45% during one year of storage. However highest decrease in starch content was observed for wheat grain kept at higher temperature. The reduced starch was consistent with other reports (Rehman *et al*., 2002; Simic *et al*., 2007) where starch was reduced when exposed to high temperatures (25 °C) for 6 months of storage. The reduction in starch percentage of grain could also be due to the improved growth of insects and fungi. It has been reported that 75% level of insect infestation in wheat, maize, and sorghum seeds resulted in considerable decline in starch percentage (Jood and Kapoor, 1993; Jood *et al*., 1996). It was noted a significant decrease in carbohydrate/starch percentage of wheat grains (Hameed *et al*., 1984) and cowpea grains (Bamaiyi *et al*., 2006) due to attack of insects. Previous studies have reported a decrease in starch content of cereal grains due to the consumption of carbohydrates as a source of energy for growth of fungi during storage (Magan, 1993; Bhattacharya and Raha, 2002; Rehman *et al*., 2011).

The falling number is a marker of α-amylase action in wheat flour. The results of the present study showed a decreasing pattern in falling number of wheat grain with the progress of storage duration and the highest rate of decrease of falling number was observed in grains stored in room type store as compare to ferrocement bin. The higher rate of decrease of falling number in this store can be credited to the pre-germination process that may have happened because of expanded moisture percentage of the wheat. High dampness conditions cause germination of the wheat seeds. For germination to happen energy is essential and this energy is gotten from simple sugars. Thus, the alpha amylases quickly hydrolyse the starch in the endosperm of the wheat grain, forming sections of glucose sub-units called maltodextrins. The maltodextrins are then hydrolysed by maltase into glucose. Kruger and Tipples (1980) reported that pre-harvest sprouting of grain or sprouting during grain storage at high temperature and moistness builds the level of α- amylase enzyme. The raise in alpha-amylase activity has a very drastic effect on the dough and bread making process. The flour with high α-amylase activity produces a sticky bread crumb together with a low volume, which are detrimental for bread making quality (Every *et al*., 2002). The findings of Warchalewski *et al*. (1985) showed a decreased in falling number of wheat from initial value of 360 seconds to 307 seconds after 4 years storage in closed structure at temperature of 20 °C and 74% relative humidity.

CONCLUSIONS

The deterioration of wheat grain stored in ferrocement bin was least as compared to room type storage system and the quality of wheat was superior throughout the storage period. Use of ferrocement bin can reduce grain deterioration due to changes in grain quality as a result of insect infestation and growth of fungi. By preventing storage losses, the ferrocement bin also becomes an essential technology for enhancing food security.

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