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Impact of concrete block bin on wheat storage losses and food security

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Abstract

Farmers in Pakistan face many storage problems leading to huge losses in the stored wheat. It is therefore, utmost important to protect our food reserves and prevent losses caused by pest's infestation and improper storage management. Wheat grain stored in concrete block bins for 12 months retained germination capacity, weight of 1000 grain and fat/lipid content significantly better than grain stored in traditional bamboo/straw bins. Concrete block bins prevented major damage caused by insects, while grain stored in bamboo/straw bins suffered severe losses. Concrete block bins maintain low temperature and moisture conditions for extended periods of time better than traditional bamboo/straw bins. Thus, concrete block bins have shown potential to positively impact the economy of wheat farmers in tropical climate like Pakistan. Concrete block bins have proven to be a promising solution to reduce deterioration of wheat grain and retain high quality of grain for extended period of time.

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Introduction

Wheat is the biggest grain harvest and the staple sustenance of Pakistan contributes 2.2% to the GDP (GOP, 2013). It involves a focal position in agriculture and economy (Shuaib *et al.*, 2007). In Pakistan, wheat is grown on a range of around 8693 thousand hectares with entire wheat production of the nation is around 24.2 million tons with a normal yield of 2787 kg for every hectare land (GOP, 2013). 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. Farmers in Pakistan face many storage problems leading to huge losses in the stored wheat. It is therefore, utmost importance to protect our food reserves and prevent losses caused by pest infestation and improper storage management.

Inadequate storage methods have found to be the central problem in developing countries, which often leads to enormous losses of agricultural produce (Birewar, 1990). Traditional grain storage methods in developing countries cannot assure the protection against major storage pests and are associated with different types of defects which occur mainly on the roof, wall and foundation of the structures. Most of these structures are not moisture proof, rodent proof and are not airtight (Ngamo *et al.*, 2007). The lack of proper storage structures for grain stockpiling and unlucky deficiency of storage management innovations often compels the farmers to sell their commodities quickly after harvest to evade deterioration. Hence, agriculturists get low market costs for any abundance grain produce (Proctor, 1994). Safe storage of grains at the farm-level is very important, as it directly related with poverty alleviation, food security, income generation and prosperity of the farmers**.** It is, hence, essential that proper and ease storage innovations are promptly exhibited to farmers to securely store and keep up the quality of their produce (Tefera *et al.*, 2011; Thamaga-Chitja *et al.*, 2004).

The present study is in this manner aimed for the establishment of suitable storage structures which will help to minimize post-harvest misfortunes of agricultural goods in the Sindh region of Pakistan. This will intimates most extreme conceivable net profit to the farmers by minimizing the expense and giving incredible insurance to their cereal products for more storage periods of time. The objective of the present study is to evaluate the performance of the concrete block bins versus the traditionally used bamboo/straw bins on wheat grain quality over a storage period of 12 months.

Materials and methods

Experimental design

The present study was carried out from first July 2013 to first July 2014 at the Latif homestead of Sindh Agriculture University, Tandojam, Pakistan (Fig. 4). The factorial analysis was utilized for this study. The fixed elements were kind of structures (concrete block bin and bamboo/straw bin) and time of storage (3, 6, 9 and 12 months). Every treatment arrangement had three replications (random factor).

Storage structures

Concrete block bin: A grain storage bin with a capacity of 2500 kg was constructed from hollow concrete blocks using cement-sand mortar as binding material (Fig. 1 & 2). Hollow concrete blocks are alternates for ordinary bricks and stones in building development. They are lighter than bricks, easier to place furthermore confer economics in foundation cost and utilization of cement. In contrast to burnt clay bricks, they offer the points of interest of uniform quality, thermal insulation, lower labour involvement, faster speed of construction and longer durability. The foundation of the concrete block bin was made above ground level in order to give satisfactory protection of stored wheat from moisture or surface water and to provide an easy collection of grain from the outlet. The foundation of the bin was then filled with well compacted sand or coarse aggregates to provide a base for floor. A floor made of a layer of bitumen between two layers of cement concrete was constructed to prevent from rodents and moisture absorption from the ground.

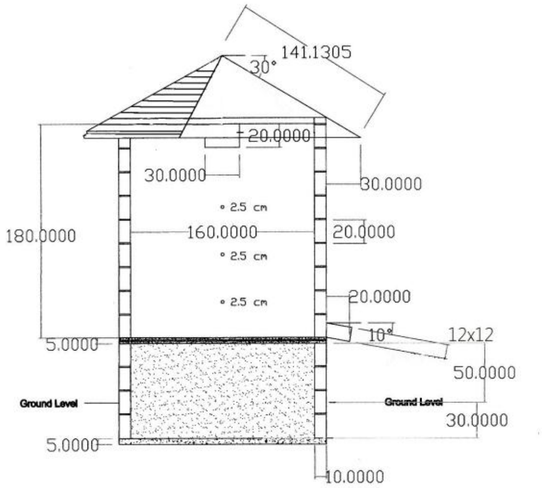

Fig. 1. Schematic diagram of the concrete block grain storage bin.

Fig. 2. Three dimensional view of the concrete block grain storage bin.

Three openings were made on top, middle and bottom of the wall using PVC pipes for monitoring of stored grain and covered them to prevent stored grain from insect and atmospheric effect. Grain channel and outlet facilities were given at the top and lowest of the structure divider, separately. The upper portion of the structure was constructed with conical roof using wooden rafters and purlins supported over wooden wall plate and made over hanged to keep the structure in shade and protect the wall from rain. Asbestos sheets were used as roof covering material and fixed over purlins by nailing. Asbestos sheets ensure the content from extreme heat over daytime and cooling during the night to forestall moisture relocation and condensation of moisture.

Bamboo/straw bin: This structure is made of date palm leaves or woven straw tangle and wooden/ bamboo log of variable sizes and shapes. The base on which the structure is built is made up of blocks or stones 2-3 feet over the ground level. Straw tangles and covering are settled on the wooden skeleton utilizing ropes. The highest point (top) of the structure is secured with straw tangle and covering and eventually these structures are coated with mud to make them airtight. Grain is filled in bulk through an entryway provided at the top of wall of the structure and the same opening is utilized as an outlet for grain (Fig. 3).

Fig. 3. Wheat grain stored in bamboo/straw bin.

Wheat grain

The freshly reaped wheat grain was gotten from the Research Institute of Sindh Agriculture University

Tandojam, Pakistan. The wheat grain specimen was cleaned manually to remove foreign matter, for example, stones, straw, dirt and debris. The parameters such as grain moisture, weight of 1000 grain, insect infestation, seed germination capacity and grain fat/lipid content were evaluated upon arrival of the grain. These initial values of the data were used as the baseline reference. All the structures were then completely filled with wheat grain.

Samples collection and analysis

Grain sampling was done from top, base and center of every storage structure at every 3 months (3, 6, 9 and 12 months) by using a sampling probe. The grain samples were then altogether mixed in order to get a composite specimen. The analysis of quality parameters of the collected specimen were completed in the research center of the Pakistan Council of Scientific and Industrial Research (PCSIR), Hyderabad Sindh. Ambient temperature and relative humidity of the experimental site were noted monthly throughout the experiment using dry-wet bulb thermometers.

Determination of quality assessment characteristics

In order to monitor grain temperature three thermometer probes were inserted at three different positions for about 15 minutes inside each storage structure. Moisture content of grains was determined through the procedure of AACC (2000) method No. 44-15A. Germination capacity was determined from one hundred randomly selected wheat seeds from every storage bin and set aside in petri dishes furrowed with filter paper and moistened with 4ml of distilled water in three duplicates. The petri dishes containing wheat seeds were then incubated at 25^{o}C temperature for five to seven days to give them a chance to germinate (ISTA, 1996). Insect damage was assessed by the counting method as described by Wambugu *et al.* (2009). From each storage structure about two hundred wheat grains were randomly collected and visually observed for number of insect damaged and undamaged grains by the presence of hole in each grain. Weight of 1000-grain was calculated from randomly selected 1000 grain from each storage structure and weighed on digital balance. The fat/lipid content of each one grain specimen was assessed by running dry specimens through a Soxhlet device for 2-3 hours utilizing petroleum ether as a solvent as indicated by the methodology depicted in AACC (2000) method No.30-10.

Statistical analysis

Analysis of variance was done using two-factor factorial model considering type of storage (concrete block bin and bamboo/straw bin) and storage duration (3, 6, 9 and 12 months) as fixed effect factors and replications as random effect factors. Comparison of means was done using least significant difference (LSD) at 0.05.

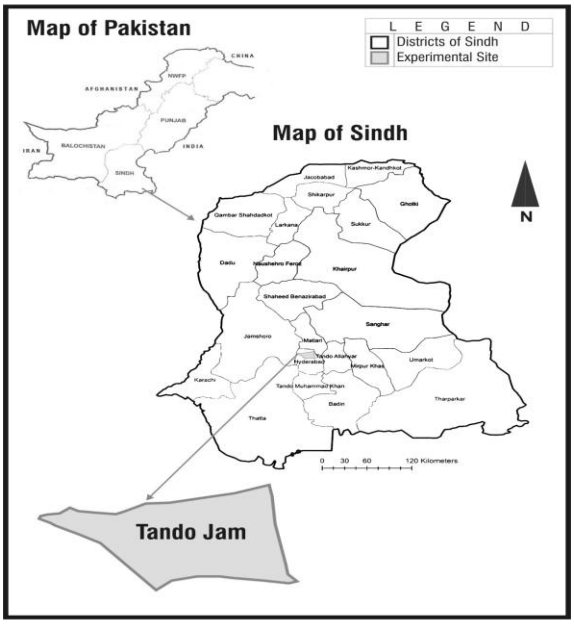

Fig. 4. Map of Pakistan and study area.

Results

Baseline data of wheat grain upon arrival

The wheat grain used in the experiment was very healthy. The initial seed germination rate was high (97% average), and showed no evidence of insect damage (no holes, no insects present). The grain was dry (average 14.7% moisture), the average 1000 grain weight was 44.3g and the average grain fat content was 2.97%.

Effect of storage structures

The results for grain temperature, grain moisture, weight of 1000-grain, insect infestation, seed germination capacity and grain fat content in different types of storage structures showed significant differences (Table 1). The comparison of storage structures indicated that on average weight of 1000-grain (43.86g), seed germination capacity (85.25%) and grain fat content (2.655%) were significantly higher in grain samples taken from the concrete block bin than in a bamboo/straw bin. The grain temperature (34.26 °C), grain moisture (13.90%) and insect infestation (13.25%) were significantly higher in the bamboo/straw bin than in the concrete block bin.

Table 1. Means of quality parameters evaluated in the wheat storage experiment based on storage type and storage period.

Treatments	Parameters					
	Grain temperature (°C)	Grain moisture (%)	Insect infestation (%)	1000 grain weight (g)	Germination capacity (%)	Fat or lipid (%)
Storage type						
Concrete block bin	32.79b	12.98b	5.500b	43.86a	85.25a	2.655a
Bamboo/straw bin	34.26a	13.90a	13.25a	41.34b	79.50b	2.545b
LSD (0.05)	0.0112	0.0091	0.7307	0.0099	0.6619	0.0065
Storage period						
3 months	34.83c	14.18a	3.000d	43.44a	92.00a	2.920a
6 months	24.25d	12.90d	6.500c	43.11b	88.00b	2.800b
9 months	39.14a	13.13c	12.00b	42.33c	80.50c	2.595c
12 months	35.90b	13.55b	16.00a	41.51d	69.00d	2.085d
LSD (0.05)	0.0159	0.0128	1.0334	0.0139	0.9361	0.0092

Means followed by the same letter in each column are not different significantly according to least significant difference (LSD) at 5% probability level.

Effect of storage period

Grain storage period had a significant effect on grain temperature, grain moisture, weight of 1000-grain, insect infestation, seed germination capacity and grain fat content (Table 1). The seed germination capacity, weight of 1000-grain and grain fat content decreased with the passage of time and significantly lowest values of 69%, 41.51g and 2.085%, respectively were observed at 12 months of storage. An increasing pattern in insect infestation was recorded during the whole storage duration and the maximum value of insect infestation (16%) was recorded at 12 months of storage. Grain temperature followed the trend of the ambient temperature throughout the storage duration and significantly highest grain temperature (39.14 °C) was detected at 9 months of storage. Grain moisture content decreased to the low value of 12.9% during the first 6 months of storage and then continued to rise till 12 months of storage (13.55%).

Interactive effect of storage type and storage period

The interactive effect of storage type and storage period showed significant effect on grain temperature, grain moisture, weight of 1000-grain, insect infestation, seed germination capacity and grain fat content (Table 2). Weight of 1000-grain (42.22g), seed germination capacity (93%) and grain fat content (2.94%) were significantly higher in grain samples taken from a concrete block bin at 3 months of storage while the lowest values of 39.52g, 61% and 1.85%, respectively were observed in bamboo/straw bin at 12 months of storage. The insect infestation was significantly higher in grains stored in a bamboo/straw bin at 12 months (23%) and significantly lowest in the concrete block bin at 3 months of storage (2%). The minimum grain moisture content (12.28%) was detected from the grain stored in a concrete block bin at 6 months of storage. The grain temperature was significantly greater in a bamboo/straw bin at 9 months of storage (39.96 oC) and significantly lowers in a concrete block bin at 6 months of storage (23.37 °C).

Table 2. Temperature, moisture, insect infestation, 1000 grain weight, germination capacity and fat content of wheat grain under interactive effect of storage type and storage time.

Storage type	Storage period	Grain temperature (°C)	Grain moisture (%)	Insect infestation (%)	1000 grain weight (g)	Germination capacity (%)	Fat/ lipid (%)
Concrete block bin	3 month	34.23f	14.60a	2.000f	44.22a	93.00a	2.940a
	6 month	23.37h	12.28h	4.000e	43.95b	88.00c	2.820c
	9 month	38.33b	12.45g	7.000d	43.77c	83.00d	2.540f
	12 month	35.26e	12.59f	9.000c	43.51d	77.00e	2.320g
Bamboo/ straw bin	3 month	35.43d	13.76d	4.000e	42.67e	91.00b	2.900b
	6 month	25.13g	13.52e	9.000c	42.28f	88.00c	2.780d
	9 month	39.96a	13.81c	17.00b	40.90g	78.00e	2.650e
	12 month	36.54c	14.51b	23.00a	39.52h	61.00f	1.850h
LSD at 5%		0.0224	0.0181	1.4614	0.0197	1.3238	0.0130

Means followed by the same letter in each column are not different significantly according to least significant difference (LSD) at 5% probability level.

Fluctuation in ambient temperature and relative humidity of the study area

The ambient temperature was recorded in range from 23.60 to 40.30 °C with a mean value of 33.62 °C, whereas the relative humidity was ranging from 62 to 76 % with an average value of 69 % throughout the storage period. A decreasing trend was observed in ambient temperature from July, 2013 to January, 2014 reached to a minimum level of 23.60 °C and then increased gradually to a maximum value of 40.30 °C in May, 2014. While, relative humidity also decreased from July, 2013 to January, 2014 to get a minimum value of 62 % and then increased during rest of the period to a maximum value of 72 % in July, 2014 (Table 3).

Table 3. Relative humidity and ambient temperature of the study area.

Storage period	Ambient temperature °C	Relative humidity %
1 July, 2013	36.62	76
1 August, 2013	35.30	75
1 September, 2013	35.61	75
1 October, 2013	34.46	74
1 November, 2013	31.50	65
1 December, 2013	24.80	63
1 January, 2014	23.60	62
1 February, 2014	28.80	65
1 March, 2014	33.30	66
1 April, 2014	38.50	66
1 May, 2014	40.30	68
1 June, 2014	38.82	70
1 July, 2014	35.51	72
Mean	33.62	69

Discussion

Relative humidity and ambient temperature of the study area were in a range between 62 and 76 % and 23.6 and 40.3 oC, respectively. Storage bins environment depends upon the environmental conditions outside the bin. The temperature and humidity percentage of surrounding had a maximum influence on the quality of grains (Alabadan and Oyewo, 2005). Higher relative humidity and ambient temperature provide the favorable conditions for the production of insect, mould and other micro-organisms which deteriorate the grain quality during storage. The optimum temperature for the growth of insects and fungi inside the stored grains ranged between 25 and 33 °C (Fields and Muir, 1996). Abba and Lovato (1999) recommended that grains must be kept at 20 °C temperature, 40 to 50% relative humidity and 11.5% moisture content.

The results of the present study indicated that storage type, storage period and their interaction showed a significant effect on the grain temperature. The temperature of grain stored in bamboo/straw and concrete block bins followed the pattern of the ambient temperature. However, the temperature of grain stored in traditional bamboo/straw bin was higher than in the concrete block bin and the surrounding ambient temperature during the whole storage period. The maximum grain temperature in a bamboo/straw bin can be attributed to release of heat by high respiration rate of grain, insects and fungi.

Temperature of grain stored in the concrete block bin was less than the ambient temperature this might be due to low thermal conductivity of the materials used in the construction of the concrete block bin. This extends the storage period and maintains the quality of wheat. The results of the present study are in line with Sawant *et al.* (2012) who reported that after the 5th month of storage up to 12th month, the temperature of the grains was observed increased from the ambient temperature. The reason behind the increase of temperature of the grains was due to insect invasion inside the storage structure. The results are also in agreement with Bosnia *et al.* (1997) who found that the highest grain temperature was observed in a metal bin as compared to bamboo and wooden bins during storage of rough rice. Alabadan and Oyewo, (2005) also observed that the grain temperature in the metal silo was generally higher than those within the wooden silo and the ambient during storage of maize.

Grain stored in traditional bamboo/straw bin had significantly higher moisture content as compared to concrete block bin throughout the storage period. The main reason behind the increase of moisture content was higher respiration rate of grains, insects and fungi. Water is one of the finished results of respiration which includes in the moisture content inside the grain storage bins (Sanches *et al.*, 1997). Different scientists have stated that the metabolic products of fungi and insects inside the infested grain raised the moisture content (Jood *et al.*, 1996; Mills, 1983; Panth and Susheela, 1977; Sinha, 1984; Stephen and Olajuyigbe, 2006). The rise in moisture content of grain might be because of variation in relative humidity and ambient temperature during storage. Grains absorb and release the moisture with respect to the moisture present in its surrounding. As greater the humidity present in the surrounding, more will be the absorption of moisture percentage by the wheat grains will happen (GC, 2006; Hossain *et al.*, 2011; Hruskova and Machova, 2002; Ogendo *et al.*, 2004).
There was no insect damage observed on the wheat grain before storage. Insect infestation increased throughout the storage period and the highest rate of increase of insect infestation was noted in grain samples taken from traditional bamboo/straw bin than the concrete block bin. The highest percentage of insects in the bamboo/straw bin can be attributed to high temperature and moisture conditions in this structure, which favors the growth of the insects. The conditions including high temperature and raised humidity levels are responsible for growth and development of insects inside the stored grains (Murdolelono and Hosang, 2009; Weinberg *et al.*, 2008). Ilelejia *et al.* (2007) stated the optimum temperature for the growth of insects inside the stored grains was ranged between 25 and 33 °C. Increase in insect infestation might also be due to non-existence of hygienic conditions (Bekele *et al.*, 1997; Danho *et al.*, 2003). The residues of old grains left inside the storage structures always become the major cause of contamination of newly loaded grains. It is the common practice of farmers to keep the old grains along with newly harvested grains, through which the insects of old grains reach to the new grains and results in grain infestation.

A decrease in weight of 1000-grain was recorded throughout the storage period. The low weight of 1000-grain was observed in grain samples from the bamboo/straw bin than from the concrete block bin. The low weight of 1000-grain in this bin may be because of high insect and fungal invasion. The results of the current study are in agreement with the previous discoveries of Basunia *et al.* (1997) who perceived that due to high insect intrusion the most minimal 1000-grain weight was recorded in the top layer of bamboo structure. Vales *et al.* (2014) additionally stated that insect contamination of pigeon pea seed pointedly decreased 100-grain weight and the most reduced 100-grain weight was seen at storage period of 8 months. Saravanan *et al.* (2001) observed a decrease in 100-grain weight of sorghum principally because of mould infection throughout one year storage.
Germination capacity of wheat grain decreased continuously with the storage time and the rate of

decrease was higher in grain samples taken from a bamboo/straw bin than from the concrete block bin. The highest deterioration of seed germination capacity in this bin can be attributed to higher moisture and temperature conditions. Previous studies have found that high storage moisture content and high storage temperature are some factors that negatively correlate with loss of seed viability (Guberac *et al.*, 2003; Moreno *et al.*, 1988; Rani *et al.*, 2013). The deterioration in seed germination capacity could also be due to destruction of seed embryos by insects and fungi as reported by many researchers (Charjan and Tarar, 1998; Imura and Sinha, 1984).

Fat content of grain decreased throughout the storage period and the higher rate of decrease of fat content was observed in grain samples taken from the bamboo/straw bin in contrast to concrete block bin. The high fat content deterioration rate of the wheat in this bin can be due to higher insect and fungal infestation. Samuels and Modgil (1999) found a maximum reduction in fat content of wheat stored in jute bags as compare to polythene sacks and metal canisters because of high insect infestation. Invasion levels of 75% in wheat, maize, and sorghum grains created by insects brought about remarkable reductions in fat content (Jood *et al.*, 1996; Jood and Kapoor, 1993). Rehman *et al.* (2011) have noted a reduction in the fat content of wheat grain during storage due to the growth of fungi in contrast to the freshly reaped grain.

Conclusion

Storing wheat in the concrete block bin offer a safe storage option for farmers in the tropical climate like Pakistan and enabling them to preserve their own high quality seed (good germination capacity, low insect infestation, and high grain weight and fat/lipid content) and to store grain for extended periods of time in order to obtain higher market prices.

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