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A comparative study of the quality of wheat grain stored in straw-clay, concrete block and ferrocement bins

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Key words: Storage bins, wheat quality, storage period, moisture.

Abstract

A considerable quantum of grains is lost during storage due to several defects in the storage structures. Considering the problem with regard to wheat losses during storage, the present study was conducted. Fungal incidence was increased throughout the storage period. A decreasing trend was noted in 1000 grain weight, germination capacity, fat content and protein content throughout the storage duration. The highest grain moisture content and fungal incidence was found in ferrocement bin followed by concrete block bin and then straw-clay bin. The highest rate of decrease of 1000 grain weight, germination capacity, fat content and protein content of wheat was detected from grain stored in ferrocement bin followed by concrete block bin and then straw-clay bin. However, grain moisture contents at loading (11 and 15%) showed very little or no effect on the quality characteristics of wheat grain. The storage bins have proven to be a promising solution to reduce storage losses and preserve quality of wheat grain. Results further revealed that straw-clay bin is suitable for retaining better values for maximum numbers of all the quality parameters studied during this research followed by concrete block bin and ferrocement bin.

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Introduction

Wheat is the cheapest and main source of energy and protein for the people of Pakistan. It is grown on an area of about 8693 thousand hectares and the whole wheat production of the country is about 24.2 million tons with an average yield of 2787 kg ha^{-1}, that contributes 10.1% to the value addition and 2.2% to GDP (GOP, 2013).

Wheat is produced in huge quantity and stored for off-season consumptions and for export to other countries to earn foreign exchange. Therefore storage of grain is necessary so that grains supply could be maintained on a regular basis from one harvest season to the next harvest season to meet the food and seed requirements. A major amount of grain produced is stored at the farm for own consumption and/or for seed purpose. Farmers in developing countries still rely on traditional storage methods. Traditional storage structures expose grain to rodents and insect attack, and provide favourable climatic conditions for their proliferation, as well as for that of microorganisms, thus leading to substantial post-harvest losses (Ngamo *et al.*, 2007). Deterioration of grains during storage results from the interactions among the physical, chemical and biological factors existing in the system. The most important factors that affect quality of stored grain are temperature, moisture, seed characteristics, micro-organisms, insects, climate and storage structures (Govender *et al.*, 2007).

Moisture level when exceeds from the standard level may leads to the insects and certain species of fungi to grow faster. Abba and Lovato (1999) suggested that grain should be stored at 20 ^{o}C with 40 to 50% relative humidity and 11.5% moisture content. Reduction in the amount of carbohydrate, protein, vitamins and fat in stored grain can occur as a result of infestations by insect, mould and rodents where inadequate grain storage technologies apply (Kung'u *et al.*, 2003; Lamboni and Hell, 2009). Fungal infestation results in reduction of grain quality such as change in colour, taste, smell, nutritional value, germination ability and leads to the production of different metabolites which are toxic in nature (White and Jayas, 1993). Similarly, Ravalo *et al.* (1980) reported that the seeds with 8.6% initial moisture content in sealed bags at 12 ^{o}C had least loss in viability and 85% germination after 11 months storage period.

Many farmers sell off their grain immediately after harvest to avoid damage by storage pests and consequently receive low prices (Proctor, 1994). Good storage practices have therefore become most important aspect for food security and rural livelihoods, since they ensure a continuous stable supply of food and better farm incomes (Tefera *et al.*, 2011). The present study is therefore aimed at the establishment of suitable storage technology which will help to minimize post-harvest losses of agricultural produce in Sindh province Pakistan. This will implies maximum possible net benefit to the farmers of rural areas by minimizing the cost and providing great protection to their cereal crops for longer periods of time.

Materials and methods

Experimental site

The study was conducted during 1st July 2013 to 1st July 2014 to investigate the effect of storage structures, storage periods and grain moisture contents at loading on deterioration of wheat at Latif farm of Sindh Agriculture University, Tandojam, Pakistan, located at 25^{o}25'40'' (N), 68^{o}31'40'' (E), 19.5 m above sea level in southern agro-ecological zone of Sindh province. According to the meteorological observatory of Drainage Research Centre Tandojam, the climate of Tandojam is hot and dry with average annual rainfall of 87.5 mm. The maximum average temperature in summer could go as higher as 39.5^{o}C that occurs in the month of May and minimum mean temperature of 10.1^{o}C occurs in January. The relative humidity is highest (83%) in the month of August whereas lowest (56 %) in the month of April.

Storage bins

Three different types of cylindrical storage structures (straw-clay, concrete block and ferrocement bins) were constructed from locally available materials for the experimental studies that met the typical storage capacity requirement of farmers in Sindh, Pakistan. Dimensions of three storage structures were identical, having 180 cm height and 160 cm in diameter (Fig. 1). Hollow concrete blocks were used in the construction of concrete block bin. Hollow concrete blocks are substitutes for conventional bricks and stones in building construction. They are lighter than bricks, easier to place, thermal insulate and also confer economics in foundation cost and consumption of cement. Ferrocement is the most versatile form of reinforced concrete. It is made up of sand mortar, cement and closely spaced light reinforcing rods or wire mesh. It does not require any skilled labour and can easily be handled. The most important feature of reinforcing is that it can easily be assembled in any desirable shape and the mortar can be applied in layers to its both sides. The material is very dense, but structures made from it are light in weight. It is also rot and vermin-proof, impervious to worms and borers, and watertight. In the construction of straw-clay bin, rice straw and clay were selected as building materials because they are cheap and locally available at farms. Individually the clay has a very low tensile strength; however it can be increased when straw and clay are combined together.

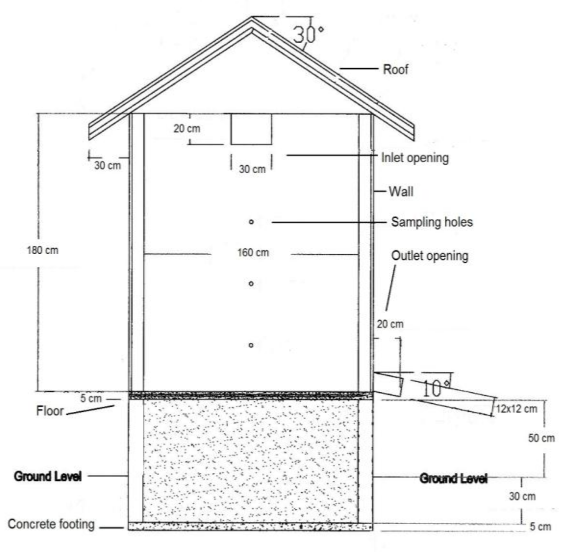

Fig. 1. Vertical section of an experimental cylindrical storage bin.

The foundation of bins was made above ground level to give adequate protection of stored wheat from moisture or surface water and to provide easy collection of grain from outlet. A damp proof course layer of bitumen and polythene sheet between two layers of cement concrete was provided as floor of each bin to protect the grain from moisture uptake from ground. Grain inlet and outlet facilities were provided at the top and bottom of the structure wall, respectively. The top portion of the bins was constructed with conical roof at 30° slopes and over hanged from the wall to protect the structures from direct sun-light by keeping it in shade and the walls from rain destruction. The roof of the bins was covered with heat insulated materials such as thatch or straw layer and asbestos sheets which protect the stored grain from excessive heating over daytime and cooling during the night to prevent moisture migration and condensation of moisture (Fig. 1).

Experimental design

A factorial experimental design was used for this study. The fixed factors were structure type (straw-clay, concrete block and ferrocement bins), grain moisture content at loading (11 and 15%) and storage period (0, 3, 6, 9 and 12 months). Each treatment combination had three replications (random factor).

Preparation of the wheat samples

The freshly harvested wheat grain was obtained from the Research Institute of Sindh Agriculture University Tandojam, Pakistan. The wheat grain sample was cleaned manually and foreign matter such as stones, straw and dirt was removed. Wheat sample was received at 17% moisture content (wet basis) and divided into two portions that were adjusted to approximately 11% and 15% moisture content (wet basis) by sun drying. All the constructed structures were completely filled with wheat grain at both moisture levels.

Samples collection and analysis

Grain sampling was carried out from top, bottom and middle of each storage structure at the interval of three months by using sampling probe throughout the storage period (12 months). The grain samples were thoroughly mixed in order to get a composite sample. The analysis of the collected samples was carried out at the laboratory of Pakistan Council of Scientific and Industrial Research (PCSIR), Hyderabad Sindh for the quality parameters of grain. The reading for each parameter was taken three times to get the average value.

Quality assessment parameters

Moisture content (%): The moisture content was determined in each grain sample by drying 3g sample in an air forced draft oven at a temperature of 105± 5 °C till to constant weight. The procedure of AACC (2000) method No. 44-15A was followed for the estimation of moisture content in each sample. The moisture content of the grain sample was determined on weight basis with the help of following formula:

$$\text{Moisture Content} = \left(\frac{\text{weight of sample} - \text{weight of dried sample}}{\text{weight of sample}}\right) x100$$

Fungi or mould (%): The analysis for molds in the stored wheat was done by seed plating method. The percentage of seeds infected was determined by shaking about 100 kernels for 1 min in 2% sodium hypochlorite (NaOCl) solution, rinsing twice with sterile distilled water, and plating on malt agar (MSAT) containing 6% sodium chloride plus Tergitol (Stroshine *et al.*, 1984). After incubation for 5–7 days at room temperature (25–27 °C), the molds growing in each kernel were identified and the percentage of mold infection was recorded.

Thousand grain weight (g): The 1000 grain weight is a useful tool used for assessment of the potential milling yield i.e. flour yield. The kernel size contributes directly towards the improvement of grain yield as well as milling yield. One thousand grains from each storage structure were randomly collected, weighed on digital balance and recorded.

Seed germination capacity (%): Standard procedures of ISTA (1996) were applied to conduct this test. One hundred wheat seeds were randomly collected from each storage structure and kept in petri dishes lined with filter paper and moistened with 4ml of distilled water in three replicates. The petri dishes containing wheat seeds were then incubated at 25°C temperature for five to seven days to let them germinate. The germinated seeds were visually counted on the basis of their appearance of radicle, whereas percentage germination was calculated as given bellow:

$$\text{Germination (\%)} = \left(\frac{\text{No. of germinated seed}}{\text{Total no. of seeds}}\right) \times 100$$

Protein content (%): Protein content is most important key factor in evaluating the quality of wheat flour and it also determines the suitability of wheat for different types of products. The nitrogen content in each grain sample was estimated by using Kjeldahl's method according to the procedure described in AACC (2000) method No. 46-10. The protein percentage was calculated by multiplying nitrogen percent with a factor 5.7.

% protein = % N x 5.7

Fat content (%): The fat content is not only a good source of energy but also plays significant role in controlling the quality and shelf life of wheat flour. The crude fat content in each grain sample was estimated by running dried samples through Soxhlet apparatus for 2-3 hours using petroleum ether as a solvent according to the procedure described in AACC (2000) method No.30-10.

Statistical analysis

The effect of grain moisture content at loading, storage structure and storage period on the quality characteristics of wheat grain was analyzed from analysis of variance using three-factor factorial model to find out levels of significance among various treatments and their interactions. Significance of results were accepted at 5% and least significant difference (LSD) test was obtained by following the procedures of Steel and Torrie (1980).

Results

Effect of storage structures on quality of wheat grain

The results for grain moisture, 1000 grain weight, fungi, germination capacity, fat content and protein content in different storage structures across storage time and initial grain moisture showed significant differences (Table 1). Among the storage structures, ferrocement bin had maximum grain moisture (12.76%) and mould infestation (7.3%) while the minimum (12.67%) grain moisture and mould infestation (4.5%) were noted in straw-clay bin. Grain stored in straw-clay bin had higher 1000 grain weight (44.03g), germination capacity (89.50%), fat content (2.777%) and protein content (12.25%) as compared to concrete block and ferrocement bins.

Table 1. Means of quality parameters evaluated in the wheat storage experiment based on storage type, Initial grain moisture content and storage period.

Treatments	Parameters					
	Grain moisture (%)	1000 grain weight (g)	Fungi/ mold (%)	Germination capacity (%)	Fat or lipid (%)	Protein (%)
Storage type						
Straw-clay bin	12.67 c	44.03 a	4.500 c	89.50 a	2.777 a	12.25 a
Concrete block bin	12.73 b	43.96 b	6.000 b	87.06 b	2.730 b	12.19 b
Ferrocement bin	12.76 a	43.89 c	7.300 a	85.50 c	2.657 c	12.11 c
LSD (0.05)	0.0055	0.0054	0.4738	0.5518	0.0054	0.0049
Initial grain moisture content						
15%	13.38 a	43.96	6.066	87.24	2.720	12.18
11%	12.07 b	43.96	5.800	87.46	2.723	12.19
LSD (0.05)	0.0045	NS	NS	NS	NS	NS
Storage period						
Initial	13.00 b	44.37 a	2.333 e	95.11 a	3.033 a	12.46 a
3 months	13.33 a	44.23 b	3.167 d	91.83 b	2.922 b	12.41 b
6 months	12.27 e	43.98 c	5.500 c	88.17 c	2.798 c	12.35 c
9 months	12.44 d	43.77 d	7.833 b	83.83 d	2.542 d	12.09 d
12 months	12.59 c	43.48 e	10.83 a	77.83 e	2.315 e	11.65 e
LSD (0.05)	0.0072	0.0070	0.6116	0.7124	0.0069	0.0064

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 initial grain moisture on quality of stored wheat

Wheat grain stored with two moisture levels (15% and 11%) at loading displayed non-significant differences for 1000 grain weight, fungi, germination capacity, fat content and protein content across storage time and structure type (Table 1). However, values of 1000 grain weight (43.96 g), germination capacity (87.46 %), fat content (2.723%) and protein content (12.19%) were slightly greater when grain was stored at 11% moisture content compared to 15% grain moisture. The fungi or mold growth had slightly higher value of 6.066% when grain stored at higher initial moisture (15%) as compared to lower (11%) grain moisture at loading. Grain moisture (15% and 11%) at loading had significant effect on grain moisture content and the highest value (13.38%) was observed from grain stored at 15% initial grain moisture while the lowest value of 12.07% was found at 11% initial moisture level.

Effect of storage time on quality of wheat grain

Grain storage time had significant effect on grain moisture, 1000 grain weight, fungi, germination capacity, fat content and protein content across storage structures and grain moisture at loading (Table 1). Moisture content of wheat grain increased to highest value from 13 to 13.33% at 3 month of storage which decreased to lowest value of 12.27% after storage period of 6 month and then continued to increase till 12 month storage period i.e. up to 12.59%. Decrease in germination capacity, 1000 grain weight, fat content and protein content was noted during throughout storage time and gets the lowest values of 77.83%, 43.48g, 2.315% and 11.65%, respectively at 12 month of storage. An increasing pattern in fungi was found during whole storage experiment and the maximum fungal infestation (10.83%) was found at 12 month storage period.

Interactive effect of storage type, storage time and initial grain moisture on wheat quality

Interactive effect of grain moisture at loading x storage type resulted non-significant differences for 1000 grain weight, fungi, germination capacity, fat content and protein content (Table 2). The values of 1000 grain weight, fungi, germination capacity, fat content and protein content were recorded between 43.89 - 44.03g, 4.4 - 7.6%, 85.4 - 89.6%, 2.657 - 2.78% and 12.11 - 12.25% respectively when grains stored in all the structures at both (11% and 15%) moisture content at loading. However, grain moisture content under the interactive effect of initial grain moisture x storage type showed significant differences and the highest grain moisture content (13.41%) was recorded when grain was stored in ferrocement bin at 15% initial grain moisture while the lowest grain moisture content (12.01%) was established from grain stored in straw-clay bin at 11% initial grain moisture.

Table 2. Moisture content, 1000 grain weight, fungi, germination capacity, fat content and protein content of wheat grain under interactive effect of initial moisture and storage type.

Initial moisture	Storage type	Grain moisture (%)	1000 grain weight (g)	Fungi/ mold (%)	Germination capacity (%)	Fat/ lipid (%)	Protein (%)
15%	Straw-clay bin	13.32 c	44.03	4.600	89.40	2.774	12.25
	Concrete block bin	13.38 b	43.96	6.000	86.93	2.730	12.19
	Ferrocement bin	13.41 a	43.89	7.600	85.40	2.657	12.11
11%	Straw-clay bin	12.01 f	44.02	4.400	89.60	2.780	12.25
	Concrete block bin	12.08 e	43.96	6.000	87.20	2.731	12.19
	Ferrocement bin	12.12 d	43.90	7.000	85.60	2.658	12.12
LSD at 5%		0.00784	NS	NS	NS	NS	NS

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

Interactive effect of storage structures x storage periods had significant effect on grain moisture, 1000 grain weight, fungi, germination capacity, fat content and protein content (Table 3). The highest grain moisture content (13.44%) and fungal infestation (12.5%) was recorded in grain samples taken from ferrocement bin at 3 and 12 month of storage, respectively. The minimum 1000 grain weight (43.37g), seed germination (75.5%), fat content (2.225%) and protein content (11.51%) was observed from ferrocement bin at 12 month of storage as compare to concrete block and straw-clay bins.

Table 3. Moisture content, 1000 grain weight, fungi, germination capacity, fat content and protein content of wheat grain under interactive effect of Initial grain moisture content and storage time.

Storage type	Storage period	Grain moisture (%)	1000 grain weight (g)	Fungi or mold (%)	Germination (%)	Fat or lipid (%)	Protein (%)
Straw-clay bin	Initial	13.00 d	44.37 a	2.000 i	95.00 ab	3.032 a	12.46 a
	3 month	13.18 c	44.26 b	2.000 i	94.00 b	2.955 b	12.45 b
	6 month	12.18 l	44.10 e	3.500 gh	91.50 c	2.855 e	12.38 d
	9 month	12.42 i	43.86 h	6.000 f	86.00 f	2.645 h	12.19 g
	12 month	12.57 f	43.56 k	9.000 cd	81.00 h	2.400 k	11.78 j
Concrete block bin	Initial	13.00 d	44.36 a	2.000 i	95.33 a	3.033 a	12.46 a
	3 month	13.36 b	44.22 c	3.000 hi	91.50 c	2.940 c	12.40 c

Storage type	Storage period	Grain moisture (%)	1000 grain weight (g)	Fungi or mold (%)	Germination (%)	Fat or lipid (%)	Protein (%)
	6 month	12.27 k	43.95 f	6.000 f	88.00 e	2.820 f	12.35 e
	9 month	12.44 h	43.77 i	8.000 de	83.50 g	2.540 i	12.13 h
	12 month	12.59 e	43.51 l	11.00 b	77.00 i	2.320 l	11.64 k
Ferrocement bin	Initial	13.00 d	44.37 a	3.000 hi	95.00 ab	3.033 a	12.46 a
	3 month	13.44 a	44.20 d	4.500 g	90.00 d	2.870 d	12.38 d
	6 month	12.34 j	43.88 g	7.000 ef	85.00 f	2.720 g	12.30 f
	9 month	12.46 g	43.66 j	9.500 c	82.00 h	2.440 j	11.93 i
	12 month	12.59 e	43.37 m	12.50 a	75.50 j	2.225 m	11.51 l
LSD at 5%		0.0124	0.0121	1.0594	1.2339	0.0120	0.0110

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

1000 grain weight, fungi, germination capacity, fat content and protein content under the interactive effect of storage time x initial grain moisture showed non-significant differences among the treatments (Table 4). The values were ranged from 44.37-43.48g, 2.33-11%, 95.22-77.66%, 3.03-2.31% and 12.46-11.64% of 1000 grain weight, fungi, germination capacity, fat content and protein content, respectively, from initial to 12 month of storage at both initial moisture level (11 and 15%). However, grain moisture content showed significant differences under the interactive effect of storage time x initial grain moisture and the highest moisture content (14.58%) was determined from the grain stored with 15% initial grain moisture at 3 month while the lower grain moisture content (12.08%) was exhibited with 11% initial grain moisture at the same time.

Table 4. Moisture, 1000 grain weight, fungi, germination, fat content and protein content of wheat grain under interactive effect of storage structure and storage time.

Initial moisture	Storage structure	Grain moisture (%)	1000 grain weight (g)	Fungi or mold (%)	Germination capacity (%)	Fat or lipid (%)	Protein (%)
15%	Initial	15.00 a	44.37	2.333	95.22	3.033	12.46
	3 month	14.58 b	44.22	3.333	91.66	2.920	12.41
	6 month	12.26 e	43.97	5.667	88.00	2.796	12.34
	9 month	12.44 d	43.76	8.000	83.66	2.540	12.08
	12 month	12.58 c	43.48	11.00	77.66	2.313	11.64
11%	Initial	11.00 g	44.36	2.333	95.00	3.032	12.46
	3 month	12.08 f	44.23	3.000	92.00	2.923	12.41
	6 month	12.26 e	43.98	5.333	88.33	2.800	12.34
	9 month	12.44 d	43.76	7.667	84.00	2.543	12.09
	12 month	12.58 c	43.48	10.66	78.00	2.316	11.64
LSD at 5%		0.0101	NS	NS	NS	NS	NS

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

Discussion

The moisture content of wheat grain indicated a decreasing trend for the first six months of storage but after 6th month onwards up to the 12th month it increased. Among the storage structures, ferrocement bin had maximum increase in grain moisture content as compare to concrete block and straw-clay bins. The higher values of grain moisture content were observed from the stored wheat in all structures at 15% initial grain moisture than at 11% initial grain moisture (Table 1). This increase in moisture may be due to respiration of fungi and insects in stored grain. Water is one of the end products of respiration (metabolism of microbes) which add in the moisture content inside the storage structure (Sanches-Marines *et al.*, 1997). Different scientists have stated that grain moisture content increase with the increase in level of insects and fungi invasion inside the grains (Jood *et al.*, 1996; Panth and Susheela, 1977; Stephen and Olajuyigbe, 2006). The increase in grain moisture content can also be due to variation in relative humidity. As higher the humidity present in the surrounding, greater will be the absorbance of moisture content by the wheat grains will occur (Hossain *et al.,* 2011; Hruskova and Machova, 2002).

A decrease in 1000 grain weight was recorded throughout the storage period. Grain stored in straw-clay bin had the highest 1000 grain weight followed by concrete block bin and ferrocement bin (Table 1). The loss in 1000 grain weight might be due to insect and fungal infestation. The results of the present study are in consistent with the earlier findings of Basunia *et al.* (1997) who observed that due to high insect invasion the lowest 1000 grain weight was recorded in the top layer of bamboo structure. Vales *et al.* (2014) also reported that insect infestation of pigeon pea seed significantly reduced 100 seed weight and the lowest 100 seed weight was observed after 8 months storage. Whereas, Saravanan *et al.* (2001) have reported that reduction in 100 grain weight of sorghum was due to mould contamination in one year stored grains.

The grain samples had fungal incidence of 2.33% before storage which increased throughout the storage period and reached to 10.83% (Table 1). It may be due to the wheat was already infected by field fungi when it was stored. Field fungi invade the grain before harvest while the crop is still in the field and can affect the appearance quality and appearance of the wheat grain (Sweeney *et al.,* 2000). The higher rate of increase of fungal incidence was recorded from the grain stored in ferrocement bin followed by concrete block and straw-clay bins. The effect of different moisture contents while loading on grain quality revealed that the grains stored with 15% initial moisture percentage had slightly higher fungal content as compared with 11% moisture content (Table 1). Several studies have revealed that fungal infection in stored grain are associated with dramatic increases in grain moisture and temperatures resulting from unsafe storage of high moisture grain, leaks in a storage structure, and moisture migration and condensation (Malaker *et al.,* 2008; Miller, 1995). The results are further supported by the findings of Reed *et al.* (2007) who found 8 to 40% increase in mould count in maize seeds with 15- 18% moisture stored in un-insulated drums at 25 ^{o}C up to two months. According to these authors, higher moisture contents provide higher percentage of visible moulds in the grain surface. Naoufal *et al.* (2012) also observed increased in mycological contamination after 4 month of storage for the 2 wheat varieties but was lesser at ambient condition (16 to 39 °C) than at extreme temperature condition (45° C).

A decreasing trend was noted in seed germination with respect to the storage duration and the lowest values were observed at the end of the storage. The highest germination capacity was recorded in grain samples taken from straw-clay bin as compare to concrete block and ferrocement bins (Table 1). Seeds stored with 11% initial moisture retained slightly higher germination rate than at 15% initial moisture (Table 1). The loss of seed germination might be due to insects and fungi infestation. The presence of infestation negatively influences germination as observed by many authors (Dubale *et al.,* 2012; Maina *et al.*, 2006; Wambugu *et al.*, 2009). The results of the present study are also in consistency with Fekadu *et al.* (2000) who found lower seed germination rate of sorghum during storage in pits may be due to the destruction of the seed embryo by storage fungi and insects.

It was observed that fat and protein contents decreased throughout the storage period. Storage structures also showed the variation in fat and protein contents and it was declared that fat and protein contents in straw-clay bin were higher than in concrete block and ferrocement bins (Table 1). The loss in grain fat and protein contents might be due to the increased insect and fungal infestation of the wheat. In an experiment, infestation levels of 75% in wheat, maize, and sorghum grains caused by insects resulted in significant decreases in crude fat and protein contents (Jood *et al.*, 1996; Jood and Kapoor 1993). The results of the present study are also in agreement with the earlier findings of Samuels and Modgil (1999) who found a decrease in fat and protein contents of wheat stored in jute bags, polythene bags and metal bins due to insect infestation. The decrease was maximum in wheat, stored in jute bag and minimum in wheat stored in metal bin. The molds are known to consume both fat and protein contents for energy. Thus a reduction in fat and protein contents indicates that fat and protein are being consumed faster than other grain constituents. Rehman *et al.* (2011) have also found a decrease in the fats content of stored wheat grain due to growth of fungi as compared to the freshly harvested grain. Whereas, Saleemullah *et al.* (2006) found a decrease in fat content of both cereals and nuts inoculated with fungi. Bhattacharya and Raha (2002) noted a decrease in protein content of maize during 12 months storage under ambient conditions due to utilization of proteins as a source of energy for fungi growth and metabolism.

Conclusion

Storage types and storage periods had significant effects on quality characteristics of stored wheat. However, grain moisture contents at loading (11 and 15%) showed very little or no effect on the quality characteristics of wheat grains. The maximum value of grain moisture and fungal infestation was observed in ferrocement bin could be due to higher rate of respiration of grain and insects. The highest rate of decrease of 1000 grain weight, seed germination, fat content and protein content was detected in grain samples taken from ferrocement bin followed by concrete block bin and then straw-clay bin might be due to insect infestation, fungal incidence and respiration of the grain. Considering the changes in the quality parameters studied, it was suggested that these bins perform better for storing wheat grains at acceptable level in areas with higher temperature and humidity like that of Pakistan.

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