Traditional storage methods and their effect on quality characteristics of wheat grain in Sindh, Pakistan

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Abstract: The change in quality of wheat grains in terms of physical parameters (moisture, test weight, 1000 grain weight and insect damage), chemical parameters (protein, fat, ash and starch) and flour quality tests (falling number, water absorption, dough development time and dough stability) were observed during storage in conventional structures (earthen bin, metal bin, bulk covered and room store) for 12 months. The results showed that test-weight (66.8 kg/hl), 1000 grain weight (39.67 g), protein (8.9%), fat (1.82%), ash (1.62%), starch (61.64%), falling number (285 s), water absorption (62.54%), dough development time (4.7 min) and dough stability (7.47 min) were recorded highest in grain samples collected from earthen bin followed by metal bin, bulk covered and room type store. Grain moisture and insect-infestation were increased during the whole storage period. The maximum insect-infestation (27%) and moisture content (15.2%) were observed in grain samples taken from the room type store. Wheat grain stored in earthen bin showed better quality characteristics as compared to other storage methods. Hence, the adoption of earthen bin should be encouraged in the developing countries.

Keywords: storage, falling number, test weight, starch, wheat quality

Citation: Shakeel Hussain Chattha, Che Man Hasfalina, Muhammad Razif Mahadi, Benish Nawaz Mirani. 2015. Traditional storage methods and their effect on quality characteristics of wheat grain in Sindh, Pakistan. Agric Eng Int: CIGR Journal, 17(4): 346-353.

1 Introduction

Cereals are principal food sources throughout the world which provide more nutrients than any other food commodities. Wheat is one of the most important cereal grains, with high production and utilization containing more than 20% calories (Nadeem et al., 2010). In Pakistan, the most commonly consumed and least expensive product of wheat is unleavened flat bread. Furthermore, wheat is used for various other bakery products like bread, cookies, cakes, buns, pastries, etc. (Mahmood et al., 2004). In Pakistan, about 8693 thousand hectares are grown-up with wheat with the total wheat production of about 24.2 million tons (2787 kg per hectare average yield) that contributes 2.2% to GDP (Government of Pakistan, 2013).

Agricultural products need to be stored from one harvest to the next and sometimes beyond that for multiple reasons. The farmers store their produce for own consumption, for sale at some later date or for seed purposes. Wheat grain is commonly stored for a period of several months from harvest up to processing (Barna et al., 2009). Therefore, grain must be stored under proper conditions in order to maintain the necessary nutritional and rheological properties for usage by the milling and baking industry. Different methods have been adopted by farmers for storage of grains (Hosakoti et al., 2013). During storage, grains experience variations in composition and quality, especially if ambient conditions are unfavorable (Gonzalez-Torralba et al., 2013). Cereal

Received date: 2015-07-29 Accepted date: 2015-09-11
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grain losses can reach up to 50% of the total harvest in some countries during storage mainly due to insect infestation (Fornal et al., 2007).

The chemical, physical as well as biological factors that exist in the system are the main cause of deterioration of stored grains. The main factors that render the quality of wheat grains are storage structures, moisture, geographical locations, temperature, insects and micro-organisms (Govender et al., 2008). Insufficient storage methods tend to reduce the amounts of fat, vitamins, proteins and carbohydrates due to the attack of molds, rodents and insects (Lamboni and Hell, 2009). The physical properties of the grains such as color, test weight, and texture also affected due to deterioration of wheat grains (Nasar-Abbas et al., 2009). Jood (1990) reported the substantial losses of the minerals, vitamins and carbohydrates in the cereal grains contaminated with insects. This leads to the final product with undesirable taste, aroma and become unfit for consumption (Vassanacharoen et al., 2008). The objective ofthe study was to investigate the effects of traditional grain storage methods on the quality of wheat grains.

2 Materials and methods

2.1 Experimental site and wheat grains

The study was conducted in Shaheed Benazir Abad district of Sindh province of Pakistan during 2013-14. Wheat grains were obtained from the farmer's field andassessed for physical properties in terms of moisture, weight of 1000 grain, test weight and insect damage, chemical properties in terms of protein, fat, ash, starch and flour quality characteristics in terms of falling number, water absorption, dough development time and dough stability before storage. These initial values of the data were used as a baseline reference.

2.2 Storage structures

In Shaheed Benazir Abad district farmers commonly used following grain storage structures:

1. Earthen bin: It is usually circular in shape and made of clay mixed with straw as the binding material to provide strength (Figure 1a).

Figure 1Four different types of grain storage methods used in the study (a-Earthen bin, b-Metal bin, c-Bulk covered, d-Room type structure)

2.Metal bin: It is a cylindrical shaped structure made of iron sheets of varying gauge depending upon the size of the bin (Figure1b).

3.Bulk covered: Farmers simply dump the grain on the ground and cover it using straw and mud plaster to avoid grain losses. Ditches are dug around the structure in order to drain rain water (Figure1c).

4. Room type structure: It is usually made of burnt brick masonry construction with mud or cement mortar. It may be composed of multiple rooms closed from all sides and of variable dimensions. It has walls, floor, roof, windows, doors and ventilators (Figure1d).

2.3 Sample collection

Total of 3 kg grain samplewas collected from top (1kg), bottom (1kg) and middle (1kg) of each storage structure by using the sampling probe after 12 months storage. The grain samples were kept separately in plastic bags, labeled, sealed and brought to the Laboratory of Pakistan Council of Scientific and Industrial Research (PCSIR), Hyderabad Sindh for quality analysis.

2.4 Measurement of grain quality characteristics

Wheat grains were tested for physical properties such as moisture and test weight by following the procedure given in AACC (2000) method No. 44-15A and 55-10, respectively. 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 a number of insect damaged and undamaged grains by the presence of holes in each grain. Weight of 1000-grain was calculated from randomly selected 1000 grain from each storage structure and weighed on digital balance.

Chemical properties of wheat grains such as protein, fat, ash and starch contents were determined according to AACC (2000), methods No. 46-10, 30-25, 32-10 and 08-01, respectively.

Flour quality tests such as falling number and dough rheological studies were determined by using falling number apparatus and Farinograph (Brabender D-4100 SEW; Germany) respectively according to the procedure described in AACC (2000). The farinograms were interpreted for different characteristics like water absorption, dough development time and dough stability.

2.5 Statistical analysis

All determinations were carried out in triplicate and standard deviations (S.D) were calculated according to the method ofSteel andTorrie (1980). Means were compared with LSD test at 5% probability level.

3 Results and discussion

The freshly harvested wheat grains were dry (14.3% average moisture) and showed no indication of insect attack. They had high average weight of 1000 grains (43.01 g), test weight (74 kg/hl), protein (11.82%), fat (2.93%), ash (2.03%), starch (66%), falling number (312 s), water absorption (66.4%), dough development time (6.82 min) and dough stability (10.13 min).

Climatic data on the experimental site showed an ambient temperature range from 24.92 ℃ to 43.80 ℃ with a mean value of 36.03 ℃, while the relative humidity was ranging from 61 to 83% with an average value of 75% during the whole storage time (Table 1). In the present study, it was observed that the moisture and temperature were optimum for the growth of insects for causing maximum damage and maximum contamination. These pests start to grow when the temperature reaches 18 ℃ and continue to increase in number even at 25- 35 ℃ inside the stored grains (Ilelejia et al., 2007). While, Nasir et al. (2003) have found that the mold growth and insect infestation were more in treatments having higher moisture during storage while the treatments with lower moisture showed no infestation during storage in polypropylene bags for 60 days. They further concluded that 9 and 10% moisture is suitable for storage stability of wheat.

Table 1 Relative humidity and ambient temperature of the study area

Storage period	Ambient temperature ℃	Relative humidity %
1 July, 2013	41.38	76.00
1 August, 2013	39.80	76.00
1 September, 2013	39.13	78.00
1 October, 2013	35.60	79.00
1 November, 2013	34.60	80.00
1 December, 2013	25.60	81.00
1 January, 2014	24.92	83.00
1 February, 2014	29.40	80.00
1 March, 2014	33.00	78.00
1 April, 2014	40.40	63.00
1 May, 2014	43.80	61.00
1 June, 2014	42.20	65.00
1 July, 2014	38.51	75.00
Mean	36.03	75.00

After 12 months of storage moisture content of grain was significantly raised in all the traditional storage structures (F=57.9; $P \leq 0.000$). Moisture percentage of grain when stored in earthen bin, metal bin, bulk covered and room structure was 14.90%, 14.91%, 15% and 15.2%, respectively after 12 months of storage (Table 2).

Table 2 Effect of storage methods on different physical parameters of wheat after one year storage (Means ± S.D)

Storage method	Characteristics			
	Moisture (%)	Insect attack (%)	Test weight (kg/hl)	1000 grain weight (g)
Earthen bin	14.90 ± 0.01^{c}	16 ± 1^{c}	66.8 ± 0^{a}	39.67 ± 0.02^{a}
Metal bin	14.91 ± 0.02^{c}	17 ± 1^{c}	66.6 ± 0.02^{b}	39.62 ± 0.02^{b}
Bulk covered	15.00 ± 0.03^{a}	19 ± 1^{b}	66.4 ± 0.03^{c}	39.53 ± 0.01^{c}
Room structure	15.20 ± 0.02^{b}	27 ± 1^{a}	65.6 ± 0.03^{d}	39.27 ± 0.02^{d}
LSD (0.05)	0.0399	1.8828	0.0442	0.0339

Note: Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at P<0.05

The maximum grain moisture percentage in bulk covered storage can be due to high respiration of insects, fungi and grains. The previous work of Stephen and Olajuyigbe (2006) also indicated an increase in moisture of the cereal grains due to aerobic respiration of fungi during storage at 25℃ - 30℃. Khaldun and Ehsan-ul-Haque (2009) reported that the early moisture percentage of grain in tin, poly bag, and cloth bag was 10.66%, 10.13%, and 9.89%, respectively, but it increased with time period i.e., after 60 days it became 11.08%, 10.67%, and 10.98%, respectively mainly because of respiration of insects and fungi.

Insect-infestation of the grains was significantly increased in all the structures after 12 months of storage (F=74.8; $P \leq 0.000$), having 16%, 17%, 19% and 27% insect infestation in the grains stored in earthen bin, metal bin, bulk covered and room type structure, respectively (Table 2). The maximum insect-infestation was observed in room structure might be due to high temperature and moisture conditions. The results regarding insect infestation found in the existing study are in harmony with the previous inferences of Dubale et al. (2012) who found that over 6 months of the storage period in gombisa and sacks traditional storage systems, insect-infestation increase from 2.42%- 20.75%.

After 12 months of storage test weight of the stored grain was significantly decreased (F=1509; $P \leq 0.000$). Test weight was higher (66.8 kg/hl) when the grain stored in earthen bin followed by 66.6 kg/hl in a metal bin. The minimum test weight was noted (65.6 kg/hl) in room store (Table 2). This might be due to the high grain moisture, which causes an increase in respiration rate leading to loss of test weight of the stored grain. This could also be due to the presence of high insect and fungi in the stored grain which reduce the test weight. The results regarding the test weight are supported by Karaoglu et al. (2010) who stated the increase in temperature, storage time and seed moisture percentage lead to a significant loss in test weight of grains. The prolonged storage period with high dampness is the cause of high insect infestation and finally loss in seed weight (Mersal et al., 2006). According to Sisman and Ergin (2011) the decrease in test weight of wheat grain was higher when stored in masonry structures than reinforced concrete.

1000 grain weight of the stored grains significantly decreased after 12 months of storage (F=293; $P \leq 0.000$). The higher 1000 grain weight (39.67g) was observed from grain stored in earthen bin followed by 39.62 g in a metal bin compared to lower 1000 grain weight of 39.27 g in room store (Table 2). The least weight of 1000 grains in the room type structure can be because of high insect and fungi attack. Basunia et al. (1997) recorded the lowest weight of 1000 grain in the top layer of the bamboo bin because of high insect infestation as compared to wooden and metal bins. 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.

Protein content of grain was also significantly decreased after 12 months of storage in all the structures (F=446; $P \leq 0.000$), having 8.9%, 8.87%, 8.8% and 8.57% protein content in the grains stored in earthen bin, metal bin, bulk covered and room structure, respectively (Table 3). The loss of protein of stored grain can be due to the occurrence of high temperature and moisture, which increase the activity of proteolytic enzymes (endopeptidases and exopeptidases). It might also be due to fungi and insect-infestation in the stored grain. Naoufal et al. (2012) stated that at extreme temperature storage condition (45 ℃), protein content decreased by 8% and 3.6% for Amal and Arrehane wheat varieties, respectively. Arian et al. (2004) also found a decrease in protein and gluten content of wheat infested with insects during 15 months storage.

Table 3 Effect of storage methods on different chemical parameters of wheat after one year storage (Means ± S.D)

Storage method	Characteristics			
	Protein content (%)	Fat/ Lipid (%)	Ash content (%)	Starch content (%)
Earthen bin	8.90 ± 0^{a}	1.82 ± 0.02^{a}	1.62 ± 0.01^{a}	61.64 ± 0.02^{a}
Metal bin	8.87 ± 0.02^{b}	1.75 ± 0.01^{b}	1.60 ± 0.01^{b}	61.57 ± 0.01^{b}
Bulk covered	8.80 ± 0.01^{c}	1.71 ± 0^{c}	1.57 ± 0.01^{c}	61.32 ± 0.01^{c}
Room structure	8.57 ± 0.01^{d}	1.63 ± 0.02^{d}	1.43 ± 0.01^{d}	60.55 ± 0.01^{d}
LSD (0.05)	0.0231	0.0282	0.0163	0.0249

Note: Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at P<0.05

Fat content of stored grains was significantly decreased after 12 months of storage (F=83.9; $P \leq 0.000$). The highest value of fat content (1.82%) was noted in grain samples collected from earthen bin followed by metal bin (1.75%), whereas the lowest fat content (1.63%) was found in room store (Table 3). The decrease in fat content can be attributed to the presence of fungi and insect on the stored grain. Rehman et al. (2011) have also found a decrease in the fat content of stored wheat grain due to the growth of fungi as compared to the freshly harvested grain. Bamaiyi et al. (2006) observed a decrease in fat content of cowpea grain due to insect infestation during 3 months storage.

Ash content of grains was significantly reduced after 12 months of storage (F=295; $P \leq 0.000$). The maximum ash content (1.62%) was recorded in grain samples taken from earthen bin followed by metal bin (1.60%), bulk covered (1.57%) and room store (1.43%) as shown in Table 3. The lowest grain ash content was found in the room type structure might be due to high insect and fungi percentage. Danjumma et al. (2009) from their research findings also found a reduction in the ash content in maize after 3 months of infestation. Whereas, Rehman et al. (2011) explained a decrease in the ash content of stored wheat grain due to the growth of fungi as compared to the freshly harvested grain.

In all the structures after 12 months of storage, starch content of wheat grains was decreased significantly (F=4273; $P \leq 0.000$). The maximum value of starch content (61.64%) was noted in grain samples taken from earthen bin, while the metal bin ranked second which was observed as 61.57%. The lowest starch content (60.55%) was found in grain stored in room store (Table 3). The highest loss of starch content of wheat in room structure could be attributed to high temperature, moisture, fungi and insect-infestation. Bamaiyi et al. (2006) found a decline in carbohydrate content of cowpea grain during 3 months storage under insect infestation. The control samples had higher carbohydrate than the infested ones. Bhattacharya and Raha (2002) reported a decline in the total carbohydrate contents of maize during 12 months storage period due to the utilization of carbohydrates as a source of energy by the storage fungi.

Falling number was also significantly decreased after six months of storage in all the selected structures (F=35.9; P ≤0.000). Falling number of grains after 12 months of storage in earthen bin, metal bin, bulk covered and room structure was 285 s, 283 s, 281 s and 272 s, respectively (Table 4). The loss of falling number may be due to the pre-germination process that might have occurred due to high moisture of stored grain. The decrease in falling number suggests that the alpha-amylase activity increased over the storage period. The increase in alpha-amylase activity has a very drastic effect on the dough and the 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). Warchalewski et al. (1985) found a decrease of falling number from 360- 307 s during long term wheat storage, i.e. 4 years in closed containers at 20℃ and 74% relative humidity.

Table 4 Effect of storage methods on different flour quality parameters of wheat after one year storage (Means ±S.D)

Storage method	Characteristics			
	Falling number (Sec)	Water absorption (%)	Dough development time (min)	Dough stability (min)
Earthen bin	285±3[a]	62.54±0.01[a]	4.70±0[a]	7.47±0.01[a]
Metal bin	283±0[ab]	62.52±0[a]	4.52±0.01[b]	7.35±0.01[b]
Bulk covered	281±1[b]	62.15±0.02[b]	4.35±0.01[c]	7.20±0.02[c]
Room structure	272±1[c]	60.75±0.01[c]	3.70±0.01[d]	6.54±0.01[d]
LSD (0.05)	3.1223	0.0231	0.0163	0.0249

Note: Mean values ± SD triplicate determinations. Mean values within a column with different superscripts are significantly different at P<0.05

Water absorption was significantly decreased in the stored grain after 12 months of storage (F=14311; P ≤0. 000), having 62.54%, 62.52%, 62.15% and 60.75% water absorption in the grains stored in earthen bin, metal bin, bulk covered and room structure, respectively (Table 4). The reduction of farinograph water absorption may be attributed to the loss of protein and gluten of stored grain resulted from fungi attack, insect attack and high temperature and moisture conditions. The water absorption capacity is used to determine the protein quality and content of the wheat flour and it is the is the most important physical parameter which has drastic effects on the farinogram (Finney et al., 1987). The flour which has a high water absorption capacity helps to improve the texture of the breads and other end products (Simon, 1987). Yamamoto et al. (1996) observed higher water absorption percentage in flour with the higher protein content. Furthermore, Marathe et al. (2002) stored wheat flour in pouches made up of polyethylene and stored at 27℃ - 30℃ under relative humidity of 59%- 87% for 3 and 6 months found a decline in water absorption capacity.

Dough development time was significantly decreased in the stored grain after 12 months of storage (F=7596; P ≤0. 000). The maximum dough development time (4.7 min) was noted from grain stored in earthen bin followed by metal bin (4.52 min), while the minimum value (3.7 min) of dough development time was observed in room store (Table 4). The decrease of dough development time can be due to decreased protein and gluten percentage of stored grain resulted from the presence of fungi, insect and high temperature and moisture conditions. The results of the present study are in line with Bashir et al. (2013) who found a decrease of dough development time (5.13- 3.27 min) in the highly infested grains as compared to control after six month storage. Similarly, a decrease in dough development time of wheat samples was observed by Sanchez-Marinez et al. (1997) after 180 days storage at room temperature.

Dough stability of the stored grains significantly decreased after 12 months of storage (F=2952; $P\leq$ 0.000). Grain stored in earthen bin had maximum (7.47 min) dough stability followed by metal bin (7.35 min), bulk covered (7.2 min) and then room store (6.54 min) as shown in Table 4. This could be due to the loss of protein and gluten of stored grain resulted from the presence of high temperature, moisture, fungi and insects in the structures. Bashir et al. (2013) have observed a decrease of dough stability (6.03- 4.30 min) in the highly insect damaged grains after six month storage as compared to control. The results of the present study are also supported by Sanchez-Marinez et al. (1997) who observed a decline in dough stability of stored wheat throughout the storage period.

5 Conclusions

Quality of wheat grains was adversely affected as a result of storage in different types of traditional structures. An earthen bin for wheat storage is the most economical and appropriate storage type in terms of the protection of the quality characteristics and reduction of the quantity losses as compared to metal bin, bulk covered and room structure. Therefore, it is suggested that wheat grains should be stored in earthen bins in order to minimize quality losses. The areas with similar storage practices and climatic conditions can adopt earthen bin for wheat grain storage. For climate other than the current study area, the performance of the earthen bin yet to be evaluated.

Acknowledgements

The Authors would like to thank Higher Education Commission of Pakistan for financial support under the project “Strengthening and Development of Sindh Agriculture University Tandojam”.

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