



A study on the quality of wheat grain stored in straw-clay bin

Shakeel Hussain Chattha^{1*}, Che Man Hasfalina², Teang Shui Lee², Benish Nawaz Mirani³, Muhammad Razif Mahadi²

¹Department of Farm Structures, Sindh Agriculture University, Tandojam, Pakistan

²Department of Biological & Agricultural Engineering, Universiti Putra Malaysia, Selangor, Malaysia

³Institute of Food Sciences & Technology, Sindh Agriculture University Tandojam, Pakistan

Key words: Storage, germination, moisture, fungi, starch.

Article published on January 01, 2015

Abstract

The adoption of poor storage techniques usually results in tremendous post-harvest losses and leads to the shortage of grains to feed the overwhelming population. The straw-clay bin was developed as one of the viable solutions to obtain a high quality stored wheat and higher income to the farmer by storing wheat at harvest and sell it in the off-season at higher rates. Straw-clay bin was evaluated by storing wheat for one year and showed promising results. Fungal damage and grain weight loss were limited to 9% and 1.27%, respectively. Germination capacity, protein, fat, starch and ash of wheat grains decreased from 94 to 74%, 12.46 to 11.78%, 3.03 to 2.4%, 65.55 to 64.87%, and 2.04 to 1.76%, respectively. The study has revealed that straw-clay bin provide a safe and convenient method for farmers to preserve their agricultural commodities. Hence, the adoption of straw-clay bin must be encouraged in the developing countries.

*Corresponding Author: Shakeel Hussain Chattha ✉ shakeel.chattah@gmail.com

Introduction

Wheat (*Triticum aestivum*) is one of the imperative cereals around the world. It is the least expensive and central source of energy and protein for the people of Pakistan (Bostan and Naeem, 2002). In Pakistan, the area and production of wheat were 8693 thousand hectares and 24.2 million tons, respectively for the year 2013. It helps 10.1 percent to the quality included agribusiness and 2.2 percent to GDP (GOP, 2013). Production of wheat is seasonal and its consumption is almost uniform throughout the year. Most of the wheat is retained by the farmers for their own consumption and for seed (Ahmad and Ahmad, 2002). Therefore, the excessive quantity of wheat has to be preserved in order to consume in its off-season.

In numerous parts of the world, grain quality protection is a serious issue during storage (Gras *et al.*, 2000). A decrease in the quantity of fat, carbohydrate, vitamins and protein in grain during storage can happen as a consequence of infestations by insect, mould and rodents where insufficient grain storage methods apply (Lamboni and Hell, 2009). Seed quality is very essential to farmers as it measures the potential performance of the seed in optimal conditions. As good quality seed is free from different diseases and has better seed health, it is expected to produce healthy seedlings with no initial disease inoculums (Nguyen, 2001).

However, main cause of contamination and deterioration of grain quality is improper storage conditions i.e. climatic conditions including increased dampness, temperature and moisture inside the structure (Williams, 2004). Storage structure is regarded as most important factor in handling and storage of grains as farmers require some facilities to store their produce. The important function of any storage structure is to offer high protection from insect, pests, rodents, birds etc., and it must be able to provide hermetic conditions to the stored products as well as easier to fill and empathize it. Most of the

losses in grains occur in storage because poor farmers could not afford high construction costs and use cheap, inadequate structures to store their grains (Obetta and Daniel, 2007). This necessitates improvement of the storage technologies.

Factors that usually affect the farmers' choice of the storage methods include the cost of building the storage method, availability of the materials, expertise for building the storage facility, climatic conditions of the area and the types of pest problems in the area (FAO, 1985). In West Africa, farmers store their crops in homes, on the field, in the open, jute or polypropylene bags, conical structures, raised platforms, clay structures and baskets (Addo *et al.*, 2002). In East and Southern Africa, farmers store crops in small bags, in wood and wire cribs, pits, metal bins, wooden open-air or roofed cribs, and in raised platforms and roofed iron drums enclosed with mud (Kankolongo *et al.*, 2009). In general, the materials from which these storage structures are made, make it easy for rodents to make holes through them as well as absorb moisture from the environment leading to the development of insect pests and moulds in the storage facilities thereby reducing wheat quality.

In Pakistan the procurement and storage of wheat is dealt by public and private agencies to meet food requirement of people round the year. Deterioration of grain quality may begin in fields before harvesting, which further aggravates during improper storage (Kent and Evers, 1993). Proper storage condition can bring about considerable improvement in national economy by controlling the losses that are about 10% of the stored food grains (GOP, 2008). This shows that storage technologies play a major role in determining the quality of grain. Thus, ensuring maximum efficiency of the storage technologies is crucial to the safety of stored grain and health of the consumers.

Thus, the objective of the current research is to establish the most efficient, economically feasible, low

labour intensive and safe (without chemicals/fertilizers) storage structure that would benefit farmers by reducing losses due to damage caused by pests and reduction in quality associated with long term storage.

Materials and methods

The study was conducted at research centre of Sindh Agriculture University, Tandojam, Pakistan to develop straw-clay bin and to investigate the effect of straw-clay bin on quality of wheat grain during storage from 1st July 2013 to 1st July 2014.

Capacity and construction of straw-clay bin

According to a survey carried out in the major wheat growing regions of Sindh, Pakistan, it was found that the average land area under wheat crop possessed by the farmer is 5 acres and the average crop yield in wheat cultivation is 1200 to 1300 kg per acre. In a season a farmer gets 6500 kg of wheat under a favourable weather conditions. Usually 4000 kg of the harvested wheat is available for sale and the rest is stored for home consumption and for seed purpose. Therefore, straw-clay bin of 2500 kg grain holding capacity was constructed in order to enable the farmers to keep their grains for some time with a minimum loss of quality and quantity (Fig. 2).

The foundation of the bin was constructed using burnt clay bricks to a height of 50 cm beyond the level of ground to provide protection from moisture or rain water. Floor of the structure was constructed from a stratum of bitumen and polythene sheet between two stratum of cement concrete placed over a well compacted base layer to prevent damp rising from the soil. In order to fabricate wall, it is needed to do one by one horizontal layers of straw and clay bundles. Three PVC pipes were inserted across the wall of bin at top, middle and bottom position in order to monitor the stored grain. A wooden grain inlet was provided at the top of wall and a wooden grain outlet was provided at the bottom of wall. A conical roof was constructed with bamboo and over hanged from the

wall to protect the wall from rain. The roof was then covered with straw-clay bundles.

Grain sampling

Grain testing was done from top, base and centre of straw-clay bin at two months interval for one year storage. The samples of grain were completely blended keeping in mind the end goal to obtain a composite sample. The examination of the samples was completed at the research facility of Pakistan Council of Scientific and Industrial Research (PCSIR), Hyderabad for the quality evaluation attributes of grain.

Measurement of grain quality characteristics

The moisture of grain samples was calculated according to the system of AACC (2000) method No. 44-15A. Seed germination was resolved as per techniques of ISTA (1996). One hundred wheat seeds were arbitrarily gathered from sample and reserved in petri dishes lined with filter paper and dampened with 4 ml of refined water in 3 duplicates. The petri dishes were then placed in an incubator at 25 °C for 5-7 days. The examination for fungi in the grain samples was carried out using seed plating technique. The rate of grain contaminated was dictated by shaking around 100 grains for 1 min in 2% sodium hypochlorite (NaOCl) arrangement, flushing twice with sterile refined water, and plating on malt agar (MSAT) containing 6% sodium chloride in addition to Tergitol (Stroshine *et al.*, 1984). After brooding at 25-27 °C for 5-7 days, the fungi becoming in every grain were distinguished and the rate of fungi contamination was noted. The grain weight reduction was ascertained utilizing the count and weigh method. Insect damaged grains were differentiated from grain sample of 50 g. Number and weight of insect damaged grains and undamaged grains were recorded and weight reduction because of insect attack was noted by the following formula (Harris and Blad, 1978).

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

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

Glucosylase technique was utilized in order to establish starch content (Buriro *et al.*, 2012). The ash in each one grain specimen was resolved as a whole inorganic material according to AACC (2000) method No. 08-01. Oven dried 5 g sample was ignited at 550-600 °C till greyish ash produced. The fat content in grain specimen assessed by running dried specimens through Soxhlet mechanical assembly utilizing petroleum ether as a solvent for 2-3 hours by AACC (2000) method No.30-10. The amount of nitrogen in grain specimens was evaluated by utilizing Kjeldahl's strategy as indicated by the methodology depicted in AACC (2000) system No. 46-10. The percentage of protein was computed by multiplying a factor of 5.7 with the amount of nitrogen.

Data analysis

The analysis of data for the specimens was performed in triplicate and standard deviations (SD) were computed according to the method of Steel & Torrie (1980). Means comparison was ascertained by least significant difference (LSD) at 5% probability level.

Results and discussion

The mean ambient temperature and relative humidity of the experimental area remained around 33.6 °C and 69%, respectively during whole storage time (Fig.

1). The maximum average temperature of 40.31°C was recorded in the month of May while the minimum of 23.62 °C was noted in January. The relative humidity was high (76%) in July while the least of 62% occurred in the month of January (Fig. 1). This temperature and humidity conditions were suitable for insect and fungal growth. High temperature and humidity conditions of the environment affect the temperature and moisture of the grain during storage (Metananda, 2001). The growth of insect and microorganisms was observed higher at high temperature and moisture content of grain during storage (Ileleja *et al.*, 2007). Fluctuation in temperature and humidity conditions greatly affect the quality of stored grain such as loss of nutritional value, loss of grain weight, loss of seed germination capacity etc (Shah *et al.*, 2002; South *et al.*, 1991).

The moisture of grain showed a declining pattern i.e. from 14.68 to 12.10% at 6 months storage duration and then gradually increased up to 12.67% until 12 months (Table 1). The rise in grain moisture content might be because of respiration of fungi and insects during storage. Moisture is the product of respiration process which increases the moisture content of the stored grain. Previous studies have also found an increase in grain moisture content during storage mainly due to the activities of insect and fungi (Jood *et al.*, 1996; Sinha, 1984; Stephen and Olajuyigbe, 2006).

Table 1. Moisture, fungi, weight loss and germination of wheat grains during storage in straw-clay bin.

Storage period	Characteristics			
	Moisture (%)	Fungi (%)	Weight loss (%)	Germination (%)
Initial	14.68 ±0.03 a	2 ±1 d	0 ±0 g	94 ±1 a
2 months	14.35 ±0.01 b	2 ±0 d	0.16 ±0.01 f	94 ±0 a
4 months	13.50 ±0.01 c	4 ±1 c	0.35 ±0.01 e	90 ±0 b
6 months	12.10 ±0.02 d	5 ±1 c	0.46 ±0.02 d	86 ±1 c
8 months	12.28 ±0.03 e	7 ±0 b	0.62 ±0.01 c	82 ±0 d
10 months	12.51 ±0.01 f	7 ±1 b	0.88 ±0.03 b	79 ±1 e
12 months	12.67 ±0.03 g	9 ±1 a	1.27 ±0.01 a	75 ±1 f
LSD (0.05)	0.0132	1.3448	0.0132	1.3238

Mean values \pm standard deviation of three replicates followed by different letters within each column are significantly different at 5% probability level.

The increase in moisture of grain could also be because of change in humidity and temperature of the study area during storage period. Various studies have reported a rise in moisture content of the stored grain due to the presence of high humidity and temperature of the surrounding (Ogendo *et al.*, 2004; Hossain *et al.*, 2011). The current study results are also in agreement with findings of GC (2006) they reported that maize grains stored in metal bins had lower moisture percentage as compared with jute bags because the jute bags were permeable and allow the surrounding moisture to come in contact with stored grain.

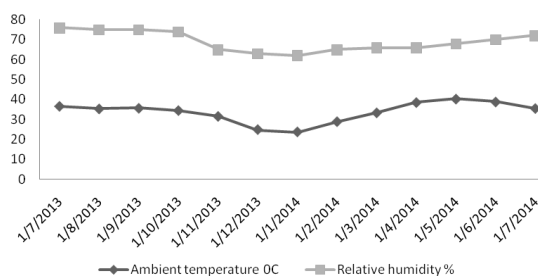


Fig. 1. Ambient temperature and relative humidity changes of study site during storage.



Fig. 2. Three dimensional view of the straw-clay bin.

Fungal attack under the effect of storage periods indicated significant differences. Storage period increased fungal infestation throughout the experiment. The highest increase in fungal infestation from the initial value of 2 to 9% was noted in grains stored from initial to 12 month, respectively (Table 1). This increase of fungi percentage can be attributed to the presence of higher grain moisture and temperature. Paraginski *et al.* (2014) and Aktaruzzaman *et al.* (2010) have noted a significantly increase of fungi in stored grain because of high moisture and temperature of grain resulting from inadequate storage systems. Whereas, Malaker *et al.* (2008) have found fungal incidence continuously expanded in all stores (bamboo dole, earthen pitcher, tin holder and polyethylene sack) at 25-30 °C with the exception of refrigerator at 10 °C.

Wheat grain stored for different periods displayed significant differences for grain weight loss. An increasing pattern in grain weight loss was noted during whole storage period. Weight loss in grain had minimum value of 0.16% at 2 months of storage, whereas maximum weight loss (1.27%) of grain was detected at 12 months storage period (Table 1). The loss of grain weight could be because of higher insect infestation. There was a positive correlation between weight loss of grain and insect infestation level as observed by earlier works of Khattak *et al.* (2000) and Sayed *et al.* (2006). Likewise, Eticha and Tadesse (1999) conducted studies in Ethiopia on the stored sorghum in traditional structures and found about 38.7% sorghum grain damage and 15% grains weight loss.

Germination percentage as influenced by storage periods displayed significant differences. Germination decreased continuously with respect to the increase of storage duration. The maximum value of seed germination percentage was recorded 94% at initial level of storage which decreased up to 75%

when stored for 12 month (Table 1). The reduction of germination percentage of wheat seed can be attributed to high moisture and temperature of the stored grain. Weinberg *et al.*, 2008 and Rani *et al.*, 2013 have found a negative correlation between seed germination percentage and high temperature and moisture of the grain during storage. The loss of seed germination percentage might also be because presence of insect and fungi during storage. Different studies have found a highly negative correlation between seed germination and attack of insects and fungi (White and Jayas, 1991; Lemessa *et al.*, 2000).

Wheat grain stored for different periods indicated significant differences for ash content. Storage period reduced ash content throughout the storage time.

Grain samples had the highest ash content of 2.04% at the start of the experiment, which attained maximum decrease to 1.76% at 12 months of storage (Table 2). The loss of grain ash content can be due to insect and microbial infestation during storage. The studies of Rehman *et al.* (2011) clarified a diminishing in the ash content of wheat grain during storage because of development of fungi as contrasted with the newly harvested grain. Saleemullah *et al.* (2006) have observed a significantly decline in ash percentage both in cereals and nuts because of fungal attack. Whereas, Bamaiyi *et al.* (2006) observed the ash content of cowpea grain in the control after 3 months storage was higher than the insect infested grains and it decreased with storage period.

Table 2. Protein, fat, starch and ash content of wheat grains during storage in straw-clay bin.

Storage period	Characteristics			
	Protein (%)	Fat (%)	Starch (%)	Ash (%)
Initial	12.46 ±0.01 a	3.03 ±0.01 a	65.55 ±0.02 a	2.04 ±0.01 a
2 months	12.42 ±0.03 b	2.99 ±0.01 b	65.50 ±0.01 b	1.99 ±0.01 b
4 months	12.37 ±0.01 c	2.94 ±0.02 c	65.46 ±0.02 c	1.95 ±0.02 c
6 months	12.30 ±0.01 d	2.89 ±0.01 d	65.40 ±0.02 d	1.93 ±0.01 d
8 months	12.23 ±0.02 e	2.80 ±0.01 e	65.27 ±0.03 e	1.87 ±0.01 e
10 months	12.02 ±0.01 f	2.57 ±0.03 f	65.10 ±0.01 f	1.65 ±0.03 f
12 months	11.78 ±0.03 g	2.40 ±0.01 g	64.87 ±0.02 g	1.76 ±0.01 g
LSD (0.05)	0.0132	0.0115	0.0132	0.0132

Mean values ± standard deviation of three replicates followed by different letters within each column are significantly different at 5% probability level.

It was declared from the results that fat content was 3.03% at loading which gradually decreased with time and reached to the level of 2.4% at 12 months of storage (Table 2). This decrease of grain fat content may be because of the insect and fungal attack in grains during storage. The findings of the current research are in line with Samuels and Modgil (1999) who observed a decline in fat content of wheat during storage in jute packs, polythene sacks and metal receptacles because of insects. The loss was most extreme in wheat, during storage in jute sack and least in metal bin. Likewise, Reed *et al.* (2007) have noted a reduction in fat percentage of maize grain during storage at temperature of 25 °C and relative humidity of 85% for 2 months due to deterioration by mould or fungi. The fungi are known to use both fat

and sugar for vitality. The loss of grain fat content could also be attributed to the high temperature and moisture content of the stored grain. A decrease in fat content of wheat grains with higher moisture was noted during storage in polypropylene bags for 60 days (Nasir *et al.*, 2003). Similarly, Sur *et al.* (1993) observed a decrease in fat content of wheat samples during storage for 135 days at temperature of 34.8 °C and relative humidity of 66.7%.

Protein content under the effect of storage periods revealed significant differences. The grain samples had protein content of 12.46% at the beginning of storage which decreased in all structures during whole storage duration up to the level of 11.78% (Table 2). The loss of grain protein content could be

due to the higher temperature and moisture of stored grain. Grain moisture and storage conditions may cause changes in protein content (Huyghebaert & Schoner, 1999). The earlier study of Nasir *et al.* (2003) showed a decrease in protein content of wheat grains with higher moisture during storage in polypropylene bags for 60 days. Stephen and Olajuyigbe (2006) observed a decrease in protein content during storage in food grains because of fungal activity at a temperature ranged between 25 to 30 °C. Arian *et al.* (2004) also recorded a decline in percentage of protein of wheat infested with insects throughout storage. Likewise, Jood and Kapoor (1993) have noted a significant reduction in true protein contents of wheat, maize and sorghum grains at 75% of insect infestation level.

Starch content of grain significantly decreased with respect to the storage duration. The decrease in seed starch content was ranging between 65.55 to 64.87% from initial to 12 month, respectively (Table 2). The deterioration of starch content can be because of the increased insect and fungal growth in the stored grain. It has been reported that insect invasion levels of 75% in wheat, maize, and sorghum grains resulted significant reduction in starch percentage (Jood *et al.*, 1993). As according to Hameed *et al.* (1984) who found a significant decline in starch percentage of wheat grains because of presence of insects. It has been reported that fungal attack badly affects the quality of stored wheat and decreases its carbohydrates or starch content (Barabara *et al.*, 2004). The decrease in starch content of the stored wheat may also be due to higher temperature and moisture 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 report of Simic *et al.* (2007) where starch was reduced when exposed to high temperatures (25 °C) for 6 months of storage.

Conclusion

The experimental study for the construction and evaluation of straw-clay grain storage bin proved that the wheat at farmer level can be stored safely with least deterioration until it is disposed at a higher price by farmers. This may help in income generation and poverty alleviation. Since construction of the straw-clay bin does not require high expertise, trainings and modern technologies, the ordinary person with little technical knowledge in the rural villages can easily build up this bin.

Acknowledgements

Authors are appreciative to the department of Farm Structures, Sindh Agriculture University Tandojam for encouraging the study.

References

- AACC.** 2000. Approved methods of american association of cereal chemists. The American Association of Cereal Chemists. Inc., St. Paul, Minnesota, USA.
- Addo S, Birkinshaw LA, Hodges RJ.** 2002. Ten years after the arrival in Ghana of larger grain borer: farmers' responses and adoption of IPM strategies. *International Journal of Pest Management* **48**, 315-325.
- Adejumo BA.** 2012. Development of a sandcrete block rhombus. *Journal of Agriculture and Veterinary Sciences* **4**, 16-22.
- Ahmad M, Ahmad A.** 2002. Storage of food grains. *Farming Outlook* **1**, 16-20.
- Aktaruzzaman M, Azad MOK, Shiton AKR, Akter MM, Habiba U.** 2010. Effect of biotic and a biotic factors on quality of okra seed kept in different containers. *Bangladesh Research Publications Journal* **3**, 1012- 1020.

- Arian MA, Tasneem A, Afzal M.** 2004. Quantitative and qualitative losses of Khapra beetle infestation in stored wheat and cost/benefit ratio of fumigation. *Pakistan Entomologist* **26**, 69-74.
- Bamaiyi LJ, Onu I, Amatobi CI, Dike MC.** 2006. Effect of *callosobruchus maculatus* infestation on nutritional loss on stored cowpea grains. *Archives of Phytopathology and Plant Protection* **39**, 119-127.
- Barabara K, Mona T, Estein S, Birgitte A.** 2004. *Alternaria* and *Fusarium* in Norwegian grains of reduced quality –a matched pair sample study. *International Journal of Food Microbiology* **93**, 51-62.
- Bostan N, Naeem M.** 2002. Evaluation of resistance in some wheat cultivars to *Tribolium castaneum* under laboratory conditions. *Asian Journal of Plant Sciences* **1**, 95-98.
- Buriro M, Oad FC, Keerio MI, Gandahi AW, Laghari GM.** 2012. Impact of storage sources on physicochemical properties of various wheat varieties. *Sarhad Journal of Agriculture* **28**, 185-190.
- Eticha F, Tadesse A.** 1999. Insect pests of farm-stored sorghum in the Bako area. *Pest Management Journal of Ethiopia* **3**, 53-60.
- FAO.** 1987. Construction and operation of small solid wall bins. *FAO Agricultural Bulletin* No. 69. FAO, Rome.
- FAO.** 1985. Prevention of post-harvest food losses: a training manual. FAO, Rome.
- GC YD.** 2006. Efficacy of indigenous plant materials and modified storage structures to insect pests of maize seed during on farm storage. *Journal of the Institute of Agriculture and Animal Science* **27**, 69-76.
- Government of Pakistan (GOP).** 2013. Pakistan economic survey, finance division, economic advisor's wing, Islamabad, Pakistan. p. 21-22.
- Government of Pakistan (GOP).** 2008. Economic survey, finance division, economic advisor's wing, Islamabad, Pakistan. p. 22.
- Gras PW, Kaur S, Lewis DA, Riordan BO, Suter DAI, Thomson WKT.** 2000. How and why to keep wheat quality constant. In: Australian Post Harvest Conference, p. 195-198.
- Hameed A, Qayyum HA, Ali A.** 1984. Biochemical factors affecting susceptibility of flour wheat varieties to *Trogoderma granarium* Everts. *Pakistan Entomologist* **6**, 57-64.
- Harris KL, Blad CJL.** 1978. Post harvest loss assessment. American Association of Cereal Chemist. Washington, DC, USA.
- Hossain MS, Kabiraj RC, Hasan MA, Shaheen MRUB, Alazad MAK.** 2011. Effect of biotic and abiotic factors on the quality of black gram seed. *Bangladesh Research Publications Journal* **5**, 103-110.
- Huyghebaert G, Schoner FJ.** 1999. Influence of storage and addition of enzyme on metabolisable energy content of wheat. 1. Impact of storage and enzyme addition. *Archiv Fur Geflugelkunde* **63**, 13-20.
- Ileleja KE, Maier DE, Woloshukb CP.** 2007. Evaluation of different temperature management strategies for suppression of *Sitophilus zeamais* (Motschulsky) in stored maize. *Journal of Stored Products Research* **43**, 480-488.
- ISTA.** 1996. International rules for seed testing. Vol. 24, International Seed Testing Association, Zurich, Switzerland.
- Jood S, Kapoor AC, Singh R.** 1993. Available carbohydrates of cereal grains as affected by storage

and insect infestation. *Plant Foods for Human Nutrition* **43**, 45-54.

Jood S, Kapoor AC. 1993. Protein and uric acid contents of cereal grains as affected by insect infestation. *Food Chemistry* **46**, 143- 146.

Jood S, Kapoor AC, Singh R. 1996. Chemical composition of cereal grains as affected by storage and insect infestation. *Tropical Agriculture* **73**, 161- 164.

Kankolongo MA, Hell K, Nawa IN. 2009. Assessment for fungal, mycotoxin and insect spoilage in maize stored for human consumption in Zambia. *Journal of the Science of Food and Agriculture* **89**, 1366- 1375.

Kent NL, Evers AD. 1993. *Technology of cereals*. 4th ed. Elsevier Science Ltd, U.K. p. 104.

Khattak SU, Kamal S, Ullah K, Ahmad S, Khan AU, Jabbar A. 2000. Appraisal of rainfed wheat lines against Khapra beetle, *Trogoderma granarium* Everts. *Pakistan Journal of Zoology* **32**, 131- 134.

Lamboni Y, Hell K. 2009. Propagation of mycotoxigenic fungi in maize stores by postharvest insects. *International Journal of Tropical Insect Science* **29**, 31- 39.

Lemessa F, Bultosa G, Wakgari W. 2000. Quality of grain sorghum (*Sorghum bicolor* (L.) Moench) stored in traditional underground pits: Case studies in two agro-climatic zones in Hararghe, Ethiopia. *Journal of Food Science and Technology* **37**, 238- 244.

Malaker PK, Mian IH, Bhuiyan RK, Akanda AM, Reza MM. 2008. Effect of storage containers and time on seed quality of wheat. *Bangladesh Journal of Agricultural Research* **33**, 469- 477.

Mersal IF, El-Emam AA, Amal M. 2006. Effect of storage period, seed moisture content and

insecticides treatment on wheat (*Triticum aestivum* L.) seed quality. *Annals of Agricultural Science, Moshtohor* **44**, 111- 124.

Metananda KA, Weerasena SL, Liyanage Y. 2001. Effect of Storage Environment, Packaging material and Seed Moisture Content on Storability of Maize (*Zea mays* L.) seeds. *Annals of Srilanka Department of Agriculture* **3**, 131- 142.

Nasir M, Butt M, Anjum FM, Sharif K, Minhas R. 2003. Effect of moisture on shelf life of wheat flour. *International Journal of Agriculture and Biology* **5**, 458- 459.

Nguyen VN. 2001. *Rice Production, Consumption and Nutrition*. FAO, Rome.

Obetta S, Daniel C. 2007. Preliminary investigation in to some quality control indices for selected stored grain in Makurdi, Nigeria. *Nigerian Food Journal* **25**, 117- 129.

Ogendo JO, Deng AL, Belmain SR, Walker DJ, Musandu AAO. 2004. Effect of insecticidal plant materials, *Lantana camara* L. and *Tephrosia vogelii* Hook, on the quality parameters of stored maize grains. *Journal of Food Technology in Africa* **9**, 29- 35.

Paraginski RT, Vanier NL, Berrios JDJ, Oliveira M, Elias MC. 2014. Physicochemical and pasting properties of maize as affected by storage temperature. *Journal of Stored Products Research* **59**, 209- 214.

Rani PR, Chelladurai V, Jayas DS, White NDG, Kavitha-Abirami CV. 2013. Storage studies on pinto beans under different moisture contents and temperature regimes. *Journal of Stored Products Research* **52**, 78- 85.

Reed C, Doyungan S, Loerger B, Getchell A. 2007. Response of Storage Molds to Different Initial

- Moisture Contents of Maize (Corn) Stored at 25 °C, and effect on respiration rate and nutrient Composition. *Journal of Stored Products Research* **43**, 443- 458.
- Rehman A, Sultana K, Minhas N, Gulfraz M, Raja GK, Anwar Z.** 2011. Study of most prevalent wheat seed-borne mycoflora and its effect on seed nutritional value. *African Journal of Microbiology Research* **5**, 4328- 4337.
- Saleemullah, Iqbal A, Khalil IA, Shah H.** 2006. Aflatoxin contents of stored and artificially inoculated cereals and nuts. *Food Chemistry* **98**, 699- 703.
- Samuels R, Modgil R.** 1999. Physico-chemical changes in insect infested wheat stored in different storage structures. *Journal of Food Science and Technology* **36**, 479- 482.
- Sayed TS, Hiram FY, Abro GH.** 2006. Resistance of different stored wheat varieties to khapra beetle, *trogoderma granarium* (Everst) and lesser grain borer, *Rhizopertha Dominica* (Fabricus). *Pakistan Journal of Biological Sciences* **9**, 1567- 1571.
- Shah WH, Rehman ZU, Kausar T, Hussain A.** 2002. Storage of wheat with ears. *Pakistan Journal of Scientific and Industrial Research* **17**, 206- 209.
- Simic B, Popovic R, Sudaric A, Rozman V, Kalinovic I, Cosic J.** 2007. Effect of storage condition on seed oil content of maize, soybean and sunflower. *Agriculturae Conspectus Scientificus* **72**, 211- 213.
- Sinha RN.** 1984. Effect of weevil (Coleoptera: Curculionidae) infestation on abiotic and biotic quality of stored wheat. *Journal of Economic Entomology* **77**, 1483- 1488.
- South JB, Morrison WR, Nelson OE.** 1991. A relationship between the amylose and lipid contents of starches from various mutants for amylose contents in maize. *Journal of Cereal Science* **14**, 267- 278.
- Steel RGD, Torrie JH.** 1980. Principles and procedures of statistics. London: McGraw Hill.
- Stephen OF, Olajuyigbe O.** 2006. Studies on stored cereal degradation by *Alternaria tenuissima*. *Acta Botanica Mexicana* **77**, 31- 40.
- Strelec I, Komlenic DK, Jurkovic V, Jurkovic Z, Ugarcic-Hardi Z.** 2010. Quality parameter changes in wheat varieties during storage at four different storage conditions. *Agriculturae Conspectus Scientificus* **75**, 105- 111.
- Stroshine R, Tuite J, Foster G, Baker K.** 1984. Self-study guide for grain drying and storage. Purdue Research Foundation, W. Lafayette, IN, p.131.
- Sur R, Nagi HPS, Saarma S, Sekhon KS.** 1993. Storage changes in the quality of sound and sprouted flour. *Plant Foods for Human Nutrition* **44**, 35- 44.
- Weinberg YY, Chen Y, Finkelman S, Ashbell G, Navarro S.** 2008. The effect of moisture level on high-moisture maize (*Zea mays* L.) under hermetic storage conditions- in vitro studies. *Journal of Stored Products Research* **44**, 136- 144.
- White NDG, Jayas DS.** 1991. Factors affecting the deterioration of stored flaxseed including the potential of insect infestation. *Canadian Journal of Plant Science* **71**, 327- 337.
- Williams JH.** 2004. Human aflatoxicosis in developing countries: a review of toxicology, exposure, potential health consequences and interventions. *African Journal of Clinical Nutrition* **80**, 1106- 1122.