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NEW WHEAT STORAGE STRUCTURES AND THEIR EFFECTS ON GRAIN QUALITY IN SINDH, PAKISTAN

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By

SHAKEEL HUSSAIN CHATTHA

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

NEW WHEAT STORAGE STRUCTURES AND THEIR EFFECTS ON GRAIN QUALITY IN SINDH, PAKISTAN

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Chairman: Associate Professor Hasfalina Che Man, PhD
Faculty : Engineering

A considerable quantum of grains is deteriorated during storage due to several defects in the storage structures. The present study was conducted considering the problems with regard to wheat losses during storage. Thus, a survey was conducted to identify wheat storage methods and associated problems. This followed a practical evaluation of traditional or existing wheat storage structures using Complete Randomized Design (CRD). Three new structures were also developed to cope up with the existing storage problems. These developed structures were tested in-situ under CRD. This study was conducted in four major wheat growing districts of Sindh province namely, Hyderabad, Sukkur, Badin and Shaheed Benazir Abad. The average area of land in the studied districts under wheat crop was 5 acres and the average total production of wheat was 6500 kg out of which 2500 kg of wheat was available for storage by farmers for seed, home consumption and sell to the market. Wheat storage structures which were found to be used by farmers of study areas included: earthen bin (23%), metallic bin (16%), bamboo/straw bin (20%), bulk covered (17%), bags covered (10%) and room type structures (14%). The survey results revealed that the traditional structures were not an insect, rodent, fungi and moisture proof. Traditional structures were found to have various defects such as cracks, holes, leakages and structural failure in the roof, walls and floor of the structures because of poor strength of materials and improper design of structures. Other storage problems were loss of seed germination capacity, discoloration of the grain, and sprouting during storage. Based on the results of the study, the above mentioned problems incur about 10 to 40% of the stored wheat grain loss annually. During the practical evaluation, wheat grain stored in these structures was sampled from July 2013 to July 2014 at 3 months interval and was analyzed for quality deterioration over time and space. This means, the effect of structure, time and location were observed. The highest values of grain temperature (36.08 °C), insect-infestation (12.55%), weight loss (1.65%), fungal incidence (17.25%) and aflatoxin level (8.35 µg kg^{-1}) were observed in grains stored in room store, followed by bags covered, bamboo/straw bin, bulk covered method, metal bin and then earthen bin. Deterioration of grain quality showed an increasing pattern with prolonged storage in traditional structures. The maximum deterioration with respect to location of wheat grain was noted for district Badin followed by Sukkur, Shaheed Benazir Abad and

Hyderabad. Thus, the pests that infested wheat stored in these storage methods were not only contaminating the stored wheat, but also consumed the nutrients of the wheat for their development and proliferation thereby leading to the farmer's food insecurity. Three different types of storage bins (concrete block bin, ferrocement bin and straw-clay bin) of similar dimensions were designed and constructed to solve the grain storage problems. The constructed bins have several advantages such as ease of loading and unloading of grain, capable of bearing the desired load, insect and rodent proof, prevention of temperature and moisture variation, and allow pest control practices over traditional storage structures. Wheat samples were also taken from these bins at 3 months interval from July 2013 to July 2014 to assess the efficiency of bins in retaining the quality and quantity of wheat grains stored at 2 different initial moisture levels (11 and 15%). Storage period greatly affected the quality of stored grains. The maximum values of germination capacity (89.5%), 1000 grain weight (44.03 g), test weight (72.14 kg hl^{-1}), flour yield (64.88%), starch (65.33%), protein (12.25%), dry-gluten (9.31%), fat (2.77%), ash (1.91%), falling number (301.6 sec), water absorption (66.52%), dough development time (6.23 min) and dough stability (9.31 min) were detected from grain stored in straw-clay bin followed by the concrete block bin and then ferrocement bin. However, grain moisture contents at loading (11 and 15%) showed very little effect on the quality characteristics of wheat grain. The developed storage bins have proven to be a promising solution to reduce storage losses by almost more than half of existing losses and preserve quality of wheat grain. Based on the good performance of newly developed structures, it is recommended that the existing structures should be replaced with these newly developed structures in accordance with the farmers' financial condition. This replacement will reduce the wheat grain loss on one hand and on the other it will prosper the farmer in particular and flourish the national economy in general.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

STRUKTUR BAHARU PENYIMPANAN GANDUM DAN KESAN-KESAN TERHADAP MUTU BIJIRIN DI SINDH, PAKISTAN

Oleh

SHAKEEL HUSSAIN CHATTHA

September 2015

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Mempertimbangkan jumlah kemerosotan kuantum gandum semasa dalam penyimpanan berikutan terdapat beberapa kecacatan dalam struktur penyimpanan. Kajian terkini telah dijalankan bagi mengenalpasti permasalahan berkaitan dengan kerugian gandum semasa dalam penyimpanan. Oleh itu, kajian yang dijalankan untuk mengenal pasti kaedah penyimpanan gandum dan masalah yang berkaitan. Ini berikutan penilaian amali struktur penyimpanan tradisional atau sedia ada yang menggunakan Reka Bentuk Rawak Lengkap (CRD). Tiga struktur baru telah juga dibangunkan untuk menghadapi masalah simpanan yang sedia ada. Struktur ini dibangunkan dan diuji secara in-situ di bawah CRD. Kajian ini dijalankan di empat daerah pertumbuhan gandum utama di wilayah Sindh iaitu, Hyderabad, Sukkur, Badin dan Shaheed Benazir Abad. Purata kawasan tanah yang dikaji di daerah-daerah dibawah tanaman gandum adalah seluas 5 hektar dan purata jumlah pengeluaran gandum adalah 6500 kg dimana 2500 kg gandum adalah untuk simpanan para petani sebagai benih, kegunaan rumah dan dijual ke pasar. Struktur penyimpanan gandum yang digunakan oleh petani-petani di kawasan kajian termasuk: bekas tanah liat (23%), bekas logam (16%), bekas buluh/jerami (20%), kaedah perlindungan pukal (17%), beg perlindung (10%) dan struktur jenis bilik (14%). Keputusan kaji selidik mendedahkan bahawa struktur tradisional tidak kalis serangga, tikus, kulat dan kelembapan. Didapati struktur tradisional mempunyai pelbagai kecacatan seperti retak, berlubang, bocor dan kelemahan pada struktur bumbung, dinding dan lantai struktur kerana kelemahan pada bahan-bahan dan reka bentuk struktur yang tidak sempurna. Masalah penyimpanan lain ialah kehilangan kapasiti percambahan benih, perubahan warna pada gandum, dan bijirin gandum bercambah semasa dalam penyimpanan. Berdasarkan hasil kajian ini, masalah yang dinyatakan di atas menyebabkan kerugian sebanyak 10 hingga 40% simpanan gandum setiap tahun. Semasa penilaian praktikal, bijirin gandum yang disimpan dalam struktur-struktur ini telah diambil contoh dari Julai 2013 hingga Julai 2014 pada selang 3 bulan dan telah dianalisis untuk kemerosotan kualiti dari semasa ke semasa dan ruang. Ini bermakna, kesan struktur, masa dan tempat telah diperhatikan. Nilai suhu bijirin yang paling tinggi (36.08 °C), serangan serangga (12.55%), penurunan berat (1.65%), kejadian kulat (17.25%) dan tahap aflatoksin (8.35 µg kg^{-1}) telah diperhatikan dalam bijirin yang disimpan di dalam bilik simpanan, diikuti dengan beg perlindung, bekas buluh/jerami, kaedah perlindungan pukal, bekas logam dan bekas tanah liat. Kemerosotan kualiti bijian

menunjukkan peningkatan corak dengan penyimpanan yang berpanjangan dalam struktur tradicional. Kemerosotan maksimum berkenaan dengan lokasi bijirin gandum telah dicatat semasa tempoh penyimpanan dibawah daerah Badin diikuti dengan Sukkur, Shaheed Benazir Abad dan Hyderabad. Sehubungan itu, serangga perosak yang memenuhi simpanan gandum dalam kaedah simpanan ini bukan sahaja telah mencemari simpanan gandum, tetapi turut menggunakan segala nutrien gandum untuk perkembangan dan pembiakkan mereka dengan itu telah membawa kepada ketidak terjaminan makanan para petani. Tiga jenis bekas yang berbeza (bekas blok konkrit, bekas ferosimen dan bekas jerami tanah liat) dengan dimensi yang sama telah direka untuk menyelesaikan masalah penyimpanan gandum. Pembinaan bekas-bekas ini mempunyai beberapa kebaikan seperti mengurangkan beban memuat dan memunggah bijirin, berkemampuan menanggung beban yang dikehendaki, kalis serangga dan tikus, pencegahan suhu dan perubahan variasi kelembapan, dan membolehkan amalan kawalan serangga perosak ke atas struktur simpanan tradisional. Sampel-sampel gandum juga turut diambil dari bekas-bekas ini pada tempoh selang 3 bulan dari Julai 2013 hingga Julai 2014 untuk menilai kecekapan bekas-bekas dalam mengekalkan kualiti dan kuantiti bijirin gandum yang disimpan pada 2 tahap kelembapan yang berbeza pada permulaannya (11 dan 15%). Tempoh penyimpanan banyak memberi kesan terhadap kualiti bijirin yang telah disimpan. Nilai maksimum kapasiti percambahan (89.5%), 1000 berat bijirin (44.03 g), ujian berat (72.14 kg hl^{-1}), pengeluaran tepung (64.88%), kanji (65.33%), protein (12.25%), gluten kering (9.31%), lemak (2.77%), abu (1.91%), angka jatuh (301.6 sec), penyerapan air (66.52%), masa pembangunan doh (6.23 min) dan kestabilan doh (9.31 min) dikesan dari gandum yang disimpan dalam bekas jerami tanah liat diikuti dengan bekas blok konkrit dan kemudian bekas ferosimen. Walau bagaimanapun, kandungan kelembapan bijirin di tempat muatan (11 dan 15% menunjukkan sedikit kesan pada karekter kualiti-kualiti pada bijirin gandum. Pengembangan bekas-bekas penyimpanan telah terbukti menjadi penyeselesaian yang menjanjikan pengurangan kerugian dengan hampir lebih separuh daripada kerugian yang sedia ada dalam penyimpanan dan memelihara kualiti bijirin gandum. Berdasarkan prestasi baik daripada struktur-struktur yang baru dibangunkan, adalah disyorkan bahawa struktur yang sedia ada perlu digantikan dengan struktur yang baru dibangunkan ini mengikut kemampuan kewangan para petani. Penggantian ini akan mengurangkan kerugian bijirin gandum di satu pihak dan di pihak yang lain dan ia akan menguntungkan para petani khususnya dan dapat memajukan ekonomi negara secara amnya.

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I certify that a Thesis Examination Committee has met on 29 September 2015 to conduct the final examination of Shakeel Hussain Chattha on his thesis entitled "New Wheat Storage Structures and their Effects on Grain Quality in Sindh, Pakistan" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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This is to confirm that:

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Name of Member of Supervisory Committee: Muhammad Razif Mahadi, PhD

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LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
RH	Relative Humidity
MC	Moisture Content
EU	European Union
USFDA	United States Food and Drug Administration
HDPE	High Density Polyethylene
PICS	Purdue improved cowpea storage
SDC	Swiss Development Cooperation
CRS	Catholic Relief Services
EGSP	Effective Grain Storage Project
PCSIR	Pakistan Council of Scientific and Industrial Research
HPLC	High Performance Liquid Chromatography
BU	Brabender Units
SAU	Sindh Agriculture University
CRD	Complete Randomized Design
PVC	Polyvinyl Chloride
SPSS	Statistical Package for the Social Sciences
PKR	Pakistan Rupee
NWFP	North West Frontier Province
FAO	Food and Agriculture Organization
ANOVA	Analysis of Variance
LSD	Least Significant Difference
WHO	World Health Organization
PASSCO	Pakistan Agricultural Storage and Services Corporation

CHAPTER 1

INTRODUCTION

1.1 Background

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). Pakistan being the 8th largest producer of the wheat with the wheat growing region of about 3.72% contributes 3.17% in the world wheat production (Shuaib *et al*., 2007). In Pakistan, about 8693 thousand hectares are cultivated with wheat crop. The total production of wheat is about 24.2 million tons (2787 kg ha^{-1} average yield), which contributes 10.1% to the value addition and 2.2% to GDP (Government of Pakistan, 2013). It is the inexpensive and the main source of the total protein (60%) and calorie (80%) for the people of Pakistan (Bostan and Naeem, 2002).

Wheat is the most important staple food, with a highly seasonal production and relatively constant consumption over the year. Therefore, storage of grains is an important post-harvest function which involves holding and preserving of agricultural commodities from the time they are harvested until they are needed for consumption. 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. Different methods have been adopted by farmers for storage of grains (Hosakoti *et al.*, 2013). The major objectives of grain storage are to keep the quality of the produce for a long time. Storage conditions should be able to keep nutritional characteristics of fresh harvested grains for a long period of time and preventing them from major deterioration (Fleurat-Lessard, 2002). Wheat grain is commonly stored for a period of several months from harvest up to processing. During storage, grains experience variations in composition and quality, especially if ambient conditions are unfavorable (Gonzalez-Torralba *et al*., 2013). Cereal grain losses can reach up to 50% of the total harvest in some countries during storage mainly due to insects infestation (Fornal *et al*., 2007; FAO, 2012).

In Pakistan, about 65- 75% of the total wheat is stored by farmers. Farmers of smaller levels keep more grains for seed and consumption purpose, hence an insignificant amount of 4.5 hectare wheat is sent to the commercial channels. The major portion of wheat grains is stored on farm in the houses or in the courtyard inside the mud bins with protective covers, loose in the room, pots, heaps covered with straw, metal bins, bags or in the baskets. Such storage practices throughout the Pakistan explain a wide range of the storage losses in the country (Prikhodko and Zrilyi, 2013). Godown sheds are most widely used, but silos, hexagonal bins and binishells are also used for wheat storage. Food commodities are frequently contaminated by molds, and the associated toxins generated by some of them during storage, transportation and post-harvest processing and suffer significant losses in quality, quantity, nutrient composition, and thereby reduce market value. According to the Food and Agriculture Organization

(FAO), about 1000 million metric tons of food is spoiled globally each year due to mycotoxins produced by storage molds (Bhat *et al*., 2010).

Amongst many constraints, grain quality, postharvest drying and storage facilities are considered major index parameters required for better wheat production. Pasha (2006) described that the quality of seed can be enhanced by preserving under appropriate storage conditions up to the next planting season. The grain storage problems differ broadly throughout Pakistan and depend mainly on the climatic conditions of the growing region. After harvesting the great quantities of cereals obtained must be preserved until they are ready to be processed (Barna *et al*., 2009). The post-harvest loss of wheat grains has been observed highest during storage (Magan, 2003). In spite of different control methods, around 9.3 to 42% of wheat production is exhausted due to attack of different pests, insects and weeds (Dhaliwal and Arora, 2001).

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, micro-organisms and seed characteristics (Govender *et al*., 2008). Even at high relative humidity (RH) and low temperature during storage seed maintained its quality (Labuschagne *et al*., 2014). The stored wheat grain damage leads to the reduction in the rate of germination and an increase in fatty acid content (Nithya *et al.*, 2011). The physical properties of the grains such as color, apparent volumic mass, and texture also affected due to deterioration of wheat grains (Nasar-Abbas *et al*., 2009). Grain MC and temperature are the major factors affecting the ecosystem of the stored wheat grains (Thorpe, 2002; Sorour and Uchino, 2004). Increase of MC and temperature increased germination loss and mold infection (Sun *et al.*, 2014). These factors affect the quality of the stored wheat by inducing the growth and proliferation of the microbes, insects and molds (Sathya *et al*., 2008; Rajarammanna *et al*., 2010; Nithya *et al*., 2011). The rapid deterioration of the quality of the grains may occur if these variables would not be controlled and monitored properly (Gonzales *et al*., 2009).

The major groups of storage pests are insects, fungi, bacteria and rodents which contribute to storage losses apart from the losses that occur during handling, transportation, pillaging of grains in unhygienic conditions. The situation is more chronic and critical in tropical and subtropical areas because of their favorable environmental conditions for mold growth and mycotoxin production. Different molds and mycotoxins have been regularly reported with a variety of food items including cereals, grains, nuts, fruits, vegetables and spices (Prakash *et al*., 2011; Shukla *et al*., 2009; Tripathi and Dubey, 2004). The factors that favor the growth and proliferation of the fungi include MC (Amusa *et al.*, 2002), pH (Aderiye, 2004), RH (MacDonald, 2006) and temperature (Abaka and Norman, 2000).

Poor storage conditions can lead to biochemical changes (including amylase and starch content) in grain kernels during storage. The contamination on the surface was noted at higher temperatures (25 and 35 °C). Increased time duration along with higher temperatures causes the decline in nutrient content while increased the number of yeast and mold inside the stored wheat grains (Wang *et al*., 2014). It is reported by

Rajashekar *et al*. (2010) that infestation of agricultural commodities with pests are responsible for the 10- 40% per annum losses of stored grains throughout the world. 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).

Post-harvest contamination of grains with molds under unfavorable conditions causes the loss of quality and marketing of wheat grains. The most commonly found genera of the molds include *Alternaria*, *Fusarium*, *Penicillium*, *Aspergillus*, *Mucor* and *Rhizopus* with the percentage of 28, 19, 18, 14, 8 and 7%, respectively, while *Paecilomyces*, *Trichothecium*, *Chaetomium*, *Geotrichum*, *Ulocladium*, *Aureobasidium*, *Chrysonilia* (anamorphic Neurospora), *Mucorales*, *Lichtheiia* and *Syncephalastrum* accounted for the remainder of 6% of the total (Belkacem-Hanf *et al*., 2013). Thus, although infestations may be low at harvest time, rapid multiplication of the insects occurs in unprotected storage conditions causes severe damage in the form of holes in grains, dry weight loss and loss of seed viability. Insect exuviae, dead insects and frass also lower palatability. Studies have further shown that highly infested grains contain less nutritional value (Oke and Akintunde, 2013) and may contain toxic substances that harm health of the consumers (Modgil, 2003). Hence, proper monitoring and management of these biotic and abiotic factors help to reduce the qualitative and quantitative losses in stored grains (Jayas, 2012). During respiratory metabolism, the insects and fungi consume nutrients (from the grains) and oxygen from the storage and generate carbon dioxide, water vapor, and releases energy in the form of heat (Dillahunty *et al*., 2000). The drying of grains to proper moisture levels is not sustainable from the economic point of view for farmers in developing countries. Though, the grains kept under acceptable moisture levels, important production losses still occur due to the attack of insects, rodents and birds (Rickman and Aquino, 2007).

The most treacherous microbial infestation in the stored wheat grains is the fungal contamination which results in the loss of nutrients, quality and germination capacity of the grains (Nithya *et al*., 2011). Visible mold can appear sooner in higher MC seeds irrespective of storage temperature (Sathya *et al*., 2008). Aflatoxins (secondary metabolites) are the group of mycotoxins, that are produced by toxigenic fungus such as *Aspergillus flavus* and *A. parasiticus* (Iqbal *et al.*, 2010) that grow and contaminate various food and feed commodities, particularly in warm and damp regions worldwide (Murphy *et al.*, 2006). The genus *Aspergillus* is most commonly found during post-harvest, drying and storage, while the genus *Fusarium* is a plant pathogen capable of producing mycotoxins under both field and storage conditions (Bryden, 2012). The invasion of Aflatoxins has become a worldwide problem, since the ingestion of food contaminated by these toxins can cause serious impacts on human and animal health, agricultural production and on the international grain trade (Bryden, 2012; Ono *et al*., 2008).

Traditional grain storage methods in emerging countries cannot assure the safety of their grains from storage pests along with various types of defects which occur mainly in the wall, foundation and roof of the structures. The majority of these storage structures are not airtight and are not rodent and moisture proof (Alonge, 2005). The

lack of proper storage structures for grain storage and absence of storage management technologies often compels the farmers to sell their produce immediately after harvest to avoid losses. Therefore, farmers get low market prices for any excess grain produce (Kimenju *et al*., 2009). At 12- 13% MC and normal temperature conditions the seeds can retain their germination capacity for up to one year. However, to store the seeds for more than 1 year it is necessary to keep the seeds with the MC of less than 11% and the temperature of the storage must not increase from 20 °C (Copeland, 2001). The increased MC during storage, insects and fungi leads to the reduced germination rate and weight loss of stored grains (Chitio *et al*., 2004).

FAO (1996) reported that metallic silos cause the development of hot spots and moisture condensation under the humid climatic conditions. Alabadan (2002) stated that the primary cause of hot spots development and moisture condensation is elevated temperature and it can be minimized by using wooden silos. The wheat grain/seeds when kept in metal container have the lowest MC followed by polyethylene bags, earthen pots, jute bags and bamboo bins. The metal container can better control the movement of moisture from the atmosphere into the seed than other container (Huda, 2001). Fluctuations in temperature, humidity and prolonged storage results in considerable nutrient loss (Shah *et al*., 2002). Safe storage of grains at the farm level is very important at expected MC and temperatures during storage. This would give information to the farmers for scheduling different safe post-harvest treatments before the degradation and quality loss of the grain (Sathya *et al*., 2009), this would help in food security, income generation prosperity and poverty alleviation of the growers. Therefore, it is essential that proper and low cost storage technologies are readily presented to farmers to safely store and maintain the quality of their produce (Thamaga-Chitja *et al*., 2004).

Keeping in view the wheat storage problems in Sindh, Pakistan, this study was conducted. In this study, the causes of wheat grain deterioration were identified through survey and experimentation. To address the identified problems, three wheat storage structures were designed, constructed and in-situ evaluated. Based on evaluation, the newly developed structures are recommended to be used by the farmers to avoid storage losses to a great extent and retain the quality of wheat grain.

1.2 Problem Statement and Justification for the Study

In Pakistan, cereal crop like wheat is one of the staple foods and produced in huge quantity in winter season and kept for consumption and for seed in the off-season. The last ten years statistics for the Pakistan shows that the wheat production is increasing. At the same time the population of the country is also increasing at the alarming rate (Government of Sindh, 2013). The constraints on agriculture inputs will restrict increase in wheat production. This problem gets further aggravated due to wheat grain losses during storage. Thus, there is a need to avoid post harvest losses. So that at least full production of wheat can be utilized to fulfill the need of food requirement. As already discussed that these losses occur due to changes in temperature, humidity, seed MC, storage type and attack of insects/ pests. Grain storage structures being used by the majority of farmers in Sindh province are unable to protect the grains from

deterioration and inadequate to meet the requirements of food security in terms of quality and quantity. Despite the seriousness of problem, little attention has been given to the issue of storage losses. Only the research to increase wheat production per unit area has been done by several researchers. Development of proper storage structures, duration of storage and deterioration of grain is still questionable among the researchers and seed keepers of Sindh province in Pakistan. The availability of such information will help to take corrective measures in improving post-harvest grain management. Therefore, it is necessary to know the ways and to develop the structures in which grains could be stored for longer time duration without any kind of deterioration. For becoming self-sufficient in food grains and its continuous supply, it is necessary to have a good storage infrastructure and facilities to fulfill country's demand. Thus, this study has been carried out to come up with suitable solutions for this unaddressed problem of storage losses with particular reference of Sindh province, Pakistan.

1.3 Objectives of the Study

1.3.1 Main Objective

To investigate the main cause of wheat deterioration in selected districts of Sindh, Pakistan and to propose strategies to cope up with deterioration problems whilst storage.

1.3.2 Specific Objectives

1. To assess the types of wheat grain storage methods used by farmers and investigate the associated storage problems through personal investigations in Sindh province.
2. To evaluate wheat grain deterioration associated with the various existing storage structures in Sindh province of Pakistan.
3. To develop a relatively efficient method of wheat grain storage.
4. To investigate the effect of newly developed storage structures, initial grain moisture contents and storage periods on grain deterioration.

1.4 Significance of the Study

In this study investigation through a survey and experiment regarding the merits and demerits of existing storage structures for wheat grain were made and in the light of results most suitable structure for grain storage was recommended. Economical and durable storage structures were also constructed and tested. The construction of a proposed grain storage structure was carried out in a farmer's field so that they will be able to store their grain in a locally available structure without any kind of deterioration. The present study has explored various methods of grain storage and provides an efficient solution to reduce grain deterioration. This study will make

contribution in the field of farm structures and will benefit the growers who store grains at farm for consumption and for letter sell at higher rates. This study will also help in food security, poverty alleviation and to raise the economy of Pakistan.

1.5 Organization of the Thesis

The rest of thesis chapters constitute the following.

- Chapter 2 reviews the factors affecting the grain deterioration during storage. The chapter also reviews the different types of storage structures used in farmer level.
- Chapter 3 introduces the methodology.
- Chapter 4 covers the results and discussion of the study.
- Chapter 5 provides a conclusion of the thesis in the light of the results and discusses about the future work related to the present study.

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