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Safety and quality of food (rice and wheat) distributed through Public Food Distribution System (PFDS) in Bangladesh

Results from laboratory tests for selected contaminants

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ACRONYMS AND ABBREVIATIONS

BIDS	Bangladesh Institute of Development Studies
cfu	Colony forming units
CSD	Central Storage Depot
DC Food	District Controller of Food
DG Food	Directorate General of Food
FAO	Food and Agriculture Organization of the United Nations
FPMU	Food Planning and Monitoring Unit
GOB	Government of Bangladesh
gm	Gram
IFPRI	International Food Policy Research Institute
IFPRP	Integrated Food Policy Research Program
IPH	Institute of Public Health
IRRI	International Rice Research Institute
JV	IFPRI-BIDS-UIUC Joint Venture
kg	Kilogram
LSD	Local Supply Depot
MFSP	Modern Food Storage Facilities Project
mg	Milligram
MoF	Ministry of Food
MT	Metric tons
MTID	Markets, Trade, and Institutions Division
NFSL	National Food Safety Laboratory
PFDS	Public Food Distribution System
RC Food	Regional Controller of Food
µg	Microgram
UIUC	University of Illinois at Urbana Champaign
WB	The World Bank
WHO	World Health Organization
WFP	World Food Programme

CHAPTER 1. INTRODUCTION

1.1 Background

Given its focus and objectives as well as allocation of business the Directorate General of Food through its Public food distribution system (PFDS) in Bangladesh procures, stores, transports, and distributes food grains (essentially rice and wheat) and operates with six silos, 13 CSDs, and about 633 LSDs dispersed in different parts of the country. The facilities have an estimated 2.13 million metric tons (MT) of total storage capacity. The Government of Bangladesh has shown a renewed interest in expanding its food grain storage capacity with a view to addressing unanticipated shocks in the future due to extreme weather events and climate change phenomena. The Modern Food Storage Facilities Project (MFSP) being implemented under the Ministry of Food, Government of Bangladesh, includes construction of six rice and two wheat steel silos with a combined capacity of 535,500 MT. In addition to enhancing the country's public food grain storage capacity, the project is intended to improve the government's emergency response and recovery capacity in disaster-prone areas and the efficiency of the PFDS (The World Bank, 2013). Besides, reducing losses and enhancing efficiency is at core of achieving broader policy objectives.

Following the Food Safety Act 2013, 'safe food' means a food that is pure and hygienic for public health according to their use and utility. The Act emphasizes establishment of an efficient and effective authority for coordinated regulation of activities related to food production, storage and distribution (GOB, 2016). Public management of a strategic grain reserve, and distribution through PFDS, represents an opportunity to ensure that the quality of the staple food consumed by majority of vulnerable populations meets safety standards. Thus the core principles of food safety, with a focus on grains distributed through the PFDS in Bangladesh, merits discussions.

Following the Food Safety Act, 2013, the Government formulated the Food Safety Regulations, 2017, that set the maximum allowable or tolerance limit of arsenic and aflatoxin in various food items including edible oils, nuts and milk, etc. However, to the best of our knowledge, the regulation did not address the potential presence of such contaminants in food grain. Although the likelihood of contamination of rice from aflatoxin is low, bringing the contaminants under regulatory focus is rewarding in the context of public health given that per capita consumption of rice is very high in the country. Similarly, since the government procures and stores a large volume of food grains to distribute among the poor and vulnerable groups, the storage procedure for quality maintenance should also be specified into the regulatory framework under the Food Safety Act, 2013.

There is an international consensus that risks related to food safety are best approached through a risk analysis framework that makes important distinction between hazards and risks. While hazards have the potential to cause harm, risk is the probability that a particular hazard will result in harm. Foods may contain many hazards that can make people sick, either immediately or by increasing the likelihood of chronic diseases. Hazards may include microbial pathogens, zoonotic diseases, parasites, adulterants (e.g., formalin), mycotoxins (e.g., aflatoxin), antibiotic drug residues, pesticide residues, and heavy metals (e.g., arsenic). In the case of rice, however, many of these hazards are of little consequence, as rice is cooked thoroughly prior to consumption that kills most of the pathogens. Risk analysis is a two-step sequential process: (i) determining which risks are the most important – that is, which are most likely to cause serious harm to human health; and (ii) deciding about the acceptable level of risk. Entire elimination of risks is impossible. Further, reducing risk typically entails costs. Deciding on the level of acceptable risk is, therefore, a context-specific public policy decision, which depends on available resources and the competing uses to which these resources could be allocated. Thus, the most efficient strategy for risk reduction should be identified in order to maximize the impact of available resources. This study reports findings of laboratory testing of grains in the PFDS system to improve

food-risk surveillance and ensure food safety for the population as a comprehensive assessment of grains in PFDS storage facilities for potential risks hitherto is missing till date.

1.2 Key Challenges for Quality of Grains in Storage

Food-borne disease is a critical issue for developing countries as such diseases impose huge burden due to health and productivity loss (Unnevehr and Hoffmann, 2015). Identification of the involved risk factors is first required for minimizing such burden. In the context of grains stored in the storage, there are a number of primary categories of risk involved, the most important of which is contamination with fungal toxins (mycotoxins). Since fungal growth requires moisture, contamination with molds and mycotoxins can be minimized by ensuring low level of moisture in stored grains. Finally, arsenic contamination risk for rice is also likely given that a large proportion of production areas use arsenic contaminated water for irrigation.

Food grains, such as rice and wheat, are susceptible to various mycotoxins and chemical hazards. Mycotoxins are toxins produced by molds, and are a primary food safety hazard associated with stored grain. Aflatoxin is a type of carcinogenic mycotoxin that can contaminate both rice and wheat through improper pre- and post-harvest operations (Bhat and Vasanthi, 2003; FAO, 2004; Richard, 2007). As the country's climatic condition is conducive to its growth, aflatoxin may turn out to be of greatest concern in stored rice and wheat. Acute exposure to aflatoxins can cause serious illness and even death while chronic exposure increases the risk of liver cancer (WHO/FAO, 1998; Peraica et al., 1999; FAO, 2004; and Liu and Wu, 2014).Although previous surveillance efforts have revealed low levels of aflatoxins in rice and wheat collected from farmers' stores, with the maximum observed value well below the national regulatory standards, the contamination levels were found to be very high in other stored grains such as groundnuts, maize, pulses, etc. (Dawlatana et al., 2002; Reddy et al. 2009; Roy et al., 2013). However, no such surveillance results are available for public storage system where grains are typically stored for long-term. Consequently, an assessment of the levels is warranted since aflatoxin contamination can increase dramatically in long term storage due to mold infestation (Elzupir, 2015; Kalita, 2016).

Moisture level in the grain is critical for mold and aflatoxin development, which again depends on many factors including moisture level at entry, pre-harvest operation, physical condition of storage facilities, temperature and humidity (Bala, 1997; Kabirullah and Rahman, 2001; IRRI, 2013; Adejumo and Adejuro, 2014; Kumar and Kalita, 2017). The storage process is thus important to avoid such hazard and resulting food loss as many studies have documented that major grain losses in the value chain take place in storage (Majumder et al., 2016; Kalita, 2016; Kumar and Kalita, 2017). Bala et al. (2010) reported that 37%-42% of the post-harvest grain loss in Bangladesh is due to poor storage facilities. A recent study found that moisture content in stored grain correlates with grain loss and mold growth, mold contamination decreased by 78% when moisture content is maintained at less than 12% instead of at 20% (Kalita, 2016).

Arsenic is another threat to health and food safety as long-term exposure to it has severe health hazards (WHO/FAO, 2011). Higher concentration of arsenic in irrigation water contaminates soil and the edible part of rice through plant uptake. In Bangladesh, the shallow aquifers are the major source of irrigation for Boro rice production, particularly in the south and southwestern part of the country (Meharg and Rahman, 2003; Heikens, 2006; Zavala and Duxbury, 2008). Approximately 20% of these aquifers contain higher level of arsenic, with concentrations level above the national drinking-water standard of 0.05 mg/L (Mukherjee and Bhattacharya, 2001; Alam et al., 2000). Several studies have confirmed presence of arsenic in rice samples drawn from the affected region, at a level much higher than allowable threshold limit (Williams et al, 2006).

1.3 Context of the Assignment

The Integrated Food Policy Research Program (IFPRP), awarded to an IFPRI-led JV in partnership with the Bangladesh Institute of Development Studies (BIDS) and the University of Illinois, USA, is one of the key components of the MFSP which is designed (1) to enhance institutional capacity in policy and strategic decision making of FPMU and DG Food to carry out their mandates linked to wider food market and, (2) to address analytical gaps and support the development of an evidence-based policy framework to improve the efficiency and performance of the country's overall food storage system and management of strategic grain reserves. The research component focuses on three thematic areas: Theme 1 - Storage and Transport Logistics; Theme 2 - Market and Policy Analysis; and Theme 3 - Capacity Strengthening and Outreach. While the Storage and Transport Logistics theme has six sub-clusters, the other two themes have seven sub-clusters each. This study is related to sub-cluster 2.1.3: Analysis of the safety and quality of food (rice and wheat) distributed through Public Food Distribution System (PFDS) and propose remedial actions, if needed) under the Market and Policy Analysis theme.

1.4 Study Objectives

The PFDS in Bangladesh has a long history and played a vital role as the key instrument for social safety net programs. However, the food security situation in the country has improved remarkably from since this warehouse network was established. Although, initially quantity of food grain was the primary criterion for determining the food security status, the recent emphasis added quality aspects of grain into it considering the public health implications. From this perspective, there exists strong rationale to assess the grain quality of the public storage facilities in Bangladesh. Most of the public warehouses in Bangladesh are old, some of which date as far back as the 1940s. Some of these warehouses have become either unusable or have largely lost their useable capacity, resulting in both heightened threat to physical and quality losses over the years. It suggests that food grains stored in these warehouses poses potential food safety risks to the beneficiaries.

As the world has witnessed remarkable technological advancements in the construction, operation, and management of grain storage facilities, which has proven to be more efficient in terms of reducing losses and ensuring safety, the time is ripe to take stock of the efficiency and effectiveness of the nation's storage systems. A few studies have assessed costs of quality deterioration and costs of leakage and losses in the PFDS (Dorosh and Farid, 2003; Ahmed et al., 2004). However, these studies did not conduct any laboratory test to assess food safety—an increasingly important public policy agenda in Bangladesh. The implication of contamination risk and a possible remedy, which has hitherto received little attention, will be included under this assignment. Given the above context, this study aims to address the following objectives:

- Evaluate the grain quality in the public food storage network to understand if the stored grains meet the global standards set for aflatoxins, arsenic, mold and moisture contents, and are safe for public health;
- Assess the magnitude of quality loss and identify the key factors contributing to such loss; and
- Identify remedial actions that can be taken to minimize the quality loss, if any, and improve food safety in the overall distribution system.

CHAPTER 2. APPROACH AND METHODS

This study utilizes data on laboratory tests as well as actual measurement of moisture content in grain samples and data collected through a nationally representative survey of public warehouses. The survey gathered detail information based on official ledger kept at the storage level by trained enumerators during the period from April 2 to May 12, 2017.The enumerators were provided adequate demonstration and instruction on the procedures on collecting the laboratory samples. Since the detail of the survey is already available in a companion report on sub-cluster 1.1.1 (An assessment of current grain losses and the identification of solutions for reducing them), the following mainly comprises an elaboration on laboratory testing procedures.

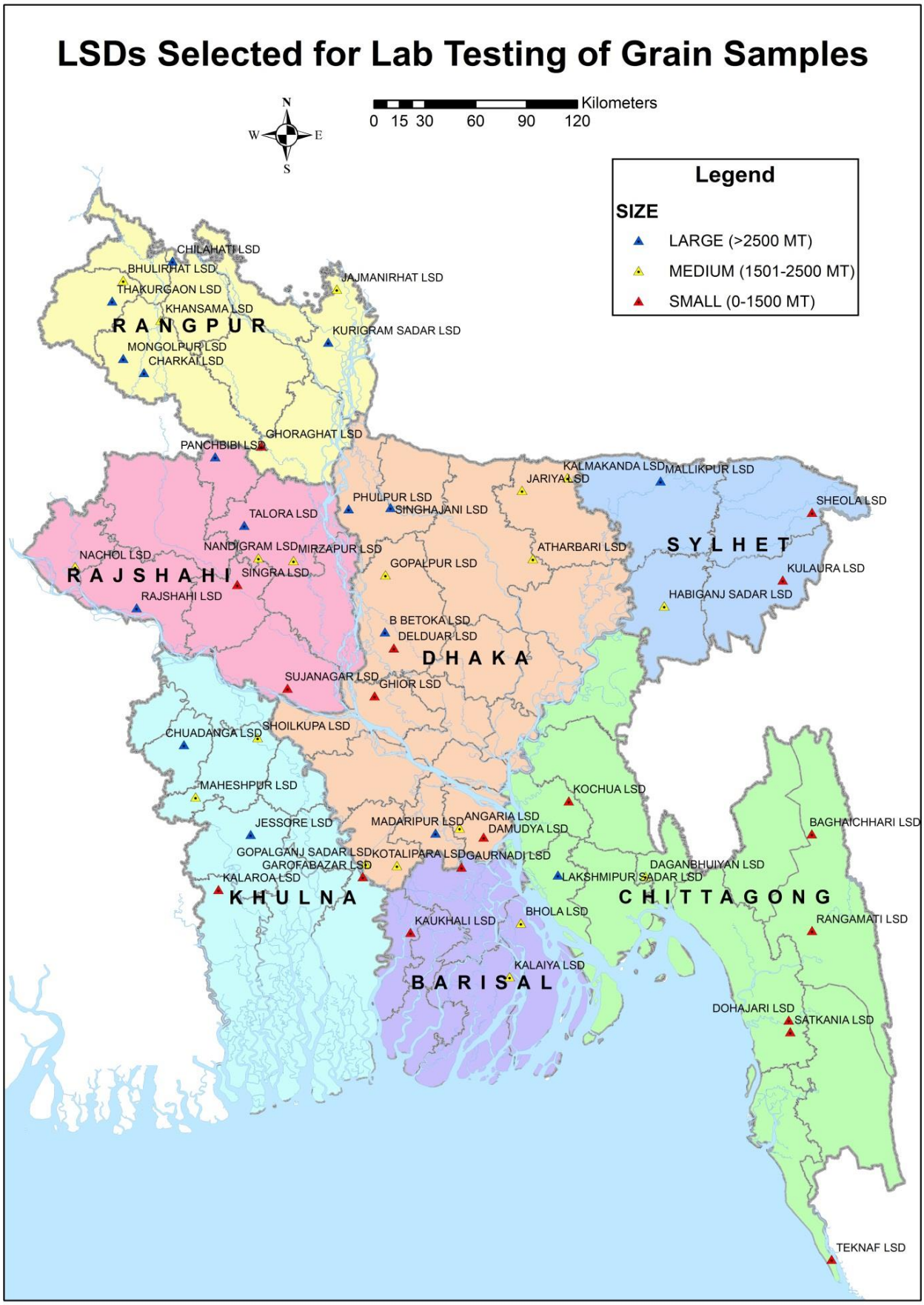
2.1 Study Sites

The LSDs are the primary study sites. Since such facilities are large in number and cover extensive geographic area, only a selected sample of them has been studied. A systematic random sampling method was used to select the LSDs to be covered in the study so that the sample ensures representativeness, especially in terms of the food security status of the location and operational size. In total, 50 of the functioning 580 LSDs in the country were selected following a stratified random sampling method (Figure 2.2). The distribution of these LSDs is balanced by food surplus status (25 form surplus regions and another 25 from deficit regions) and the functional capacity of the storage facilities: 16 small LSDs, 17 medium-sized LSDs, and 17 large LSDs (Table 2.1 and Table A1).

Table 2.1 Sample of LSDs for laboratory testing by regions

Division	LSDs for Laboratory Testing by Size			Total
	Small	Medium	Large	
Barishal	1	2	1	4
Chattogram	4	2	1	7
Dhaka	3	3	1	7
Khulna	2	2	2	6
Mymensingh	1	1	3	5
Rajshahi	2	3	3	8
Rangpur	1	3	5	9
Sylhet	2	1	1	4
Totals	**16**	**17**	**17**	**50**

Figure 2.2 Location of LSDs



2.2 Sample Collection Procedures for Laboratory Screening

The quality loss assessment includes laboratory testing on aflatoxin, arsenic, and mold levels in rice and wheat stocks in addition to measurement of moisture contents. To address the relationship between quality of grain in storage and duration of stocks, samples were drawn both from old and new stocks, where "old" and "new" stocks were operationalized as being older than 3 months and being up to 3 months old respectively. Samples of rice were taken from 2 sacks per facility while sacks were classified by duration of storage for estimating quality losses over time in the PFDS storage facilities. One sack was randomly selected from the stacks of grain that had entered the facility most recently, and the other one from the stacks that had been in the storage facility for the longest period. In contrast, only one sample was drawn for wheat from the stack that had been in the storage for longest period. Dates of entry of the sacks sampled were recorded. Samples were taken from three different points (top, middle, and bottom) of the sack using a sampling spike. Moisture measurement was conducted at each sample location using a portable grain moisture meter. After moisture testing is done, samples from the three different points of the sack were mixed to form a composite sample. The samples were then bagged by types of testing: for mold testing, samples were placed in sterilized food grade bags to prevent further fungal growth while those for aflatoxin and arsenic were placed in regular food grade zipper bags. The composite sample had enough grains (600 gms) to perform one aflatoxin, one arsenic, and one mold test, plus an additional 50% as a margin of safety. The composite grain samples were packaged and transported to National Food Safety Laboratory (NFSL) at the Institute of Public Health (IPH), Dhaka for aflatoxin, arsenic, and mold testing within 24 hours of sample collection. Standard testing methods were adopted for Laboratory Testing at IPH.

The laboratory testing for detecting and quantifying aflatoxin (determination of the total content of aflatoxin B1, B2, G1 and G2) in rice and wheat follows high performance liquid chromatographic method (EN-13805-2002). The minimum detection level for total aflatoxin is 0.03 µg/kg (ISO 2003), and maximum residue limit (MRL) for rice and wheat are 10 µg/kg and 4 µg/kg respectively. The arsenic content is detected following similar standard international method (EN-13805-2002) for both rice and wheat. The maximum residue limit for arsenic content is 0.2 mg/kg. The detection of mold contents in grains also followed international standard (ISO-21527-1). The procedure adopts a horizontal method for enumeration of viable molds, osmophilic yeasts, and xerophilic molds in grains, with a water activity level less than or equal to 0.95, by means of the colony count technique at 25 °C ±1 °C. The maximum allowable limit for mold is 104cfu/g. Following the standards set by IRRI and FAO for medium and long-term grain storage, the maximum allowable moisture contents in rice and wheat are set at 14% and 13% respectively (Baloch, 2010).

The laboratory test results enable estimation of quality loss in grains by duration and major sources of contaminants. The contaminant contents in rice is compared across three levels of stock duration—less than three months, three to six months, and six to nine months. Similar comparison for wheat is conducted across two age groups—less than six months and older than six months. The analysis of quality loss assumes that the stock of rice and wheat were free of any contaminant at the time of arrival at LSDs. The laboratory test results are compared with the standardized threshold limits for each of the contaminants to assess if there had been any change in the grain quality during the storage period. If the reported levels of contaminants are found to exceed the allowable limit, it would suggest that storage system and procedures needs a re-evaluation.

2.3 Data Processing and Analysis

The survey data is then combined with laboratory test results to estimate quality loss of grains (possibly by stock duration) and major causes of losses. Once the raw data were computerized, and cleaned, the research team prepared de-identified datasets for statistical analyses. De-identification ensured the anonymity of the

surveyed LSDs. No identifiable information was shared with any members outside the research team. All files kept on the server were protected using an encryption key. Both descriptive and statistical analysis has been carried out to capture variations in quality loss across regions, age of the stocks, broad capacity type of the facilities, and grain types, etc. The findings from quality assessment are compared to the standards set by the international authorities and global practices on food safety.

CHAPTER 3. RESULTS

The findings from laboratory testing on aflatoxins, arsenic, molds and moisture level in stored rice and wheat are reported below. The presence of aflatoxin is detected for 15% of rice stored in PFDS facilities (Table 3.1) but at much lower level than the maximum allowable limit of 10µg/kg in all of the detected cases. As Table 3.1 shows, the mean level of aflatoxins in the stored rice is 0.05µg/kg, with a standard deviation of 0.38 across LSDs. The maximum level detected is 3.43µg/kg, which is approximately 3 times lower than the maximum allowable limit.

Similarly, a positive level of aflatoxin is detected only in 9% of the cases for wheat (Figure 3.3). In all of the cases, aflatoxins are found at well below the allowable limit of 4µg/kg. The mean level of aflatoxin in wheat in the PFDS is 0.01µg/kg while the maximum level detected is 0.23µg/kg. Among the cases for which a positive level of aflatoxin is detected, the mean content in rice and wheat are 0.36µg/kg and 0.098µg/kg respectively. The presence of arsenic in rice is detected in 26% of the cases but none exceeded the maximum allowable limit of 0.21mg/kg. The range of arsenic content in rice is detected in the range of 0.00-0.14 mg/kg, with mean and standard deviation of 0.02 and 0.04 mg/kg respectively. The mean level of arsenic among the detected cases stands at 0.094 mg/kg.

Table 3.1 Mean level of contaminants, and proportion of samples exceeding limit

Contaminant type	Proportion of samples detected with some positive level	Mean	Std. dev.	Min	Max	Allowable/ Recommended Limit	Proportion of samples exceeding maximum limit
RICE							
Aflatoxin	15%	0.05 (0.04)	0.38	0.00	3.43	≤10 µg/kg	0
Arsenic	26%	0.02 (0.00)	0.04	0.00	0.14	≤0.21 mg/kg	0
Mold	67%	376.19 (70.07)	642.21	0.00	3500.0	≤10000 cfu/gm	0
Average Moisture		13.20 (0.04)	0.58	11.33	14.87	14%	8%
WHEAT							
Aflatoxin	9%	0.01 (0.01)	0.04	0.00	0.23	≤4 µg/kg	0
Mold	84%	570.97 (113.23)	630.45	0.00	2400.0	≤10000 cfu/gm	0
Average Moisture		12.71 (0.10)	0.79	10.17	14.23	13%	39%

Note: Standard errors of means are reported in the parentheses. Wheat is not tested for arsenic.

The laboratory test results for molds show that 67% of stored rice and 84% of stored wheat are contaminated with traces of mold, but none of the traces exceeded the maximum allowable limit of 10000cfu/gm. The mold content is found in the range of 0-3400 cfu/gm for rice, with mean and standard deviation of 376.2 and 642.2cfu/gm. The mold content in wheat is found in the range of 0-2400cfu/gm, with mean and standard deviation of 570.97 and 630.45cfu/gm respectively. Among cases where positive level of mold is detected, the mean level of mold in stored rice and wheat are 564.29 and 680.77cfu/gm respectively. Among cases where moisture level is detected above the recommended level, the mean level of moisture content in stored rice and wheat are respectively 14.25% and 13.35%.

It has been found that there are regional variations in quality degradation for both rice (Figure 3.2) and wheat (Figure 3.3). Higher proportions of cases with aflatoxin in rice are detected in Barishal (33%) and Sylhet (29%) while for wheat, relatively higher proportions are detected in Khulna (25%) and Sylhet (100%) regions. Relatively higher proportions of rice with positive levels of arsenic were detected in the facilities of Chattogram (60%), Dhaka (47%), and Mymensingh (29%) divisions. There is also wide variation in the presence of mold in rice and wheat across regions. Approximately 80%-82% of rice stored in LSDs of Khulna, Barishal, and Chattogram regions while all of wheat grains stored in Chattogram, Mymensingh, Rangpur, and Sylhet regions are detected with some positive level of mold. The moisture level in rice stocks in LSDs is mostly maintained at the recommended level of 14% or below, except for Barishal and Mymensingh where 43% and 29% of the stocks exceed the recommended level of moisture in rice in storage. In contrast to rice, moisture content in stored wheat is found to exceed the maximum limit of 13% to a higher extent. A larger proportion of wheat stored in LSDs in Barishal (100%), Mymensingh (100%) and Rangpur (75%) exceeded the recommended level of moisture. Table A3 and A4 in the appendix present regional variation in the level of contaminants detected for both rice and wheat.

Figure 3.2 Quality deterioration of rice in the LSDs by division

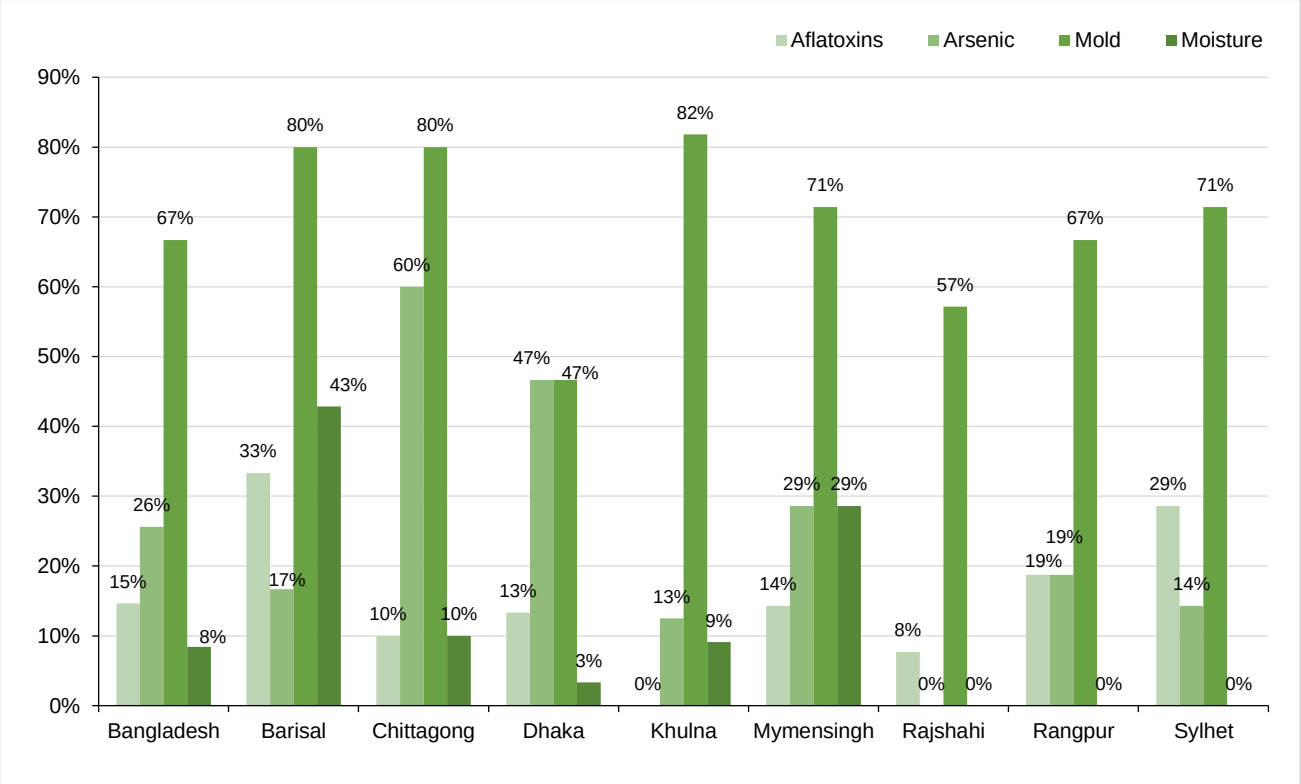
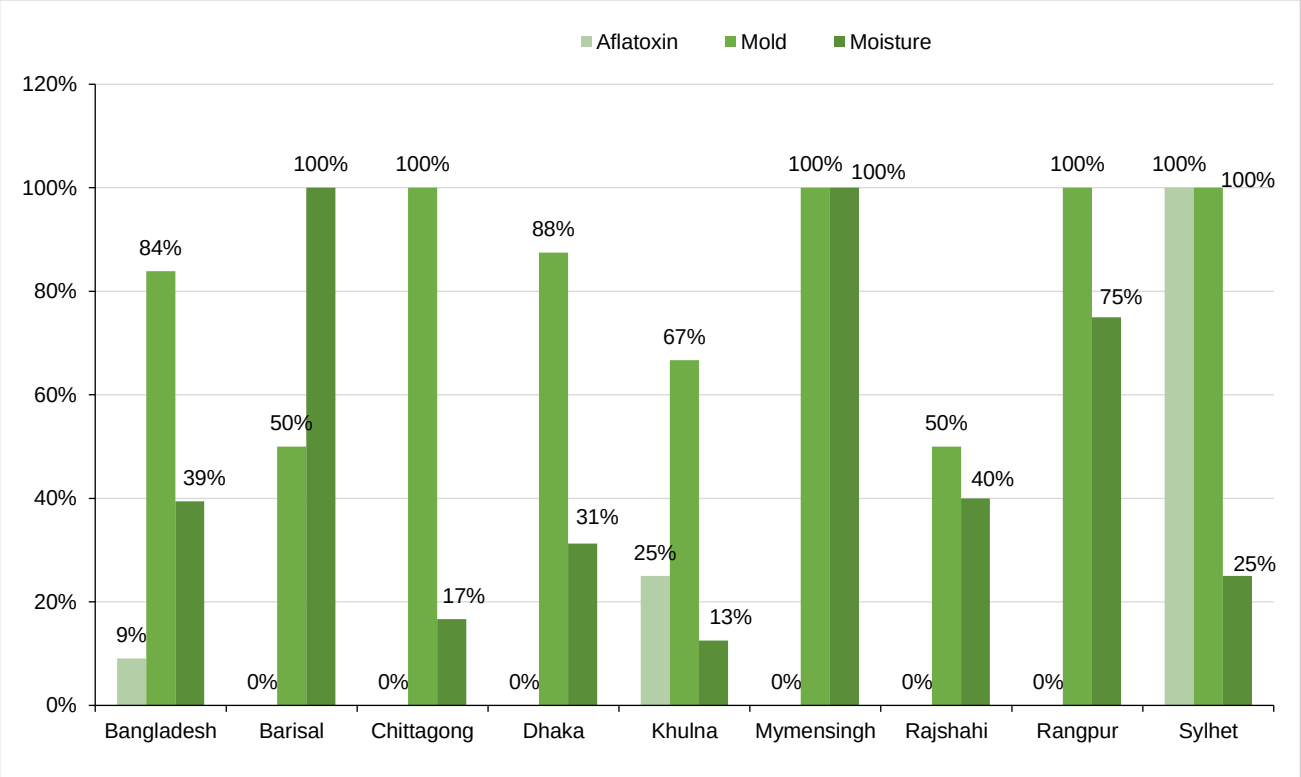


Figure 3.3 Quality deterioration of wheat in the LSDs by division



The quality of stored grains may degrade with the time in storage facilities. This is examined by splitting the samples by duration of stocks. The results are presented in Table 3.4. The findings suggest that the aflatoxin content in rice samples with duration of 3-6 months is higher than those with duration of 0-3 months or 6-9 months. However, the difference in aflatoxin content in rice is only significant between the age group (0-3 months) and (6-9 months). The arsenic content in the rice samples does not vary with duration of stock in the storage facilities. It appears that average mold content is relatively higher in 6-9 months old sample compared to those with storage age of 0-3 months and 3-6 months. The comparison across age-groups suggests that mold content in rice does not vary with duration of stock in a statistically significant manner. Finally, average moisture level in stored rice does not exhibit a statistically significant variation with duration in storage facilities.[1] As wheat samples are heavily drawn from stacks older than 6 months, they are split into two age groups to facilitate the analysis in a meaningful way—less than 6 months and 6-12 months. The findings for wheat, as reported in panel (b) of Table 3.4, does not reveal any significant difference in either of aflatoxin, mold or moisture content across groups by duration of stock in the storage facilities.

[1] Although not reported here, a similar analysis is conducted by splitting the wheat samples into two age groups: 0-3 months and 3-9 months. The results are qualitatively similar to that reported in Table 3.4, and differences in contaminant across age-groups does not turn out to be statistically significant in any of the cases.

Table 3.4 Age of stock and quality degradation

(a) RICE

Contaminant	Stock Duration (Age of stock in LSDs)			Comparison between (0-3) vs. (3-6) months		Comparison between (0-3) vs. (6-9) months		Comparison between (3-6) vs. (6-9) months	
	0 to 3 months	3-6 months	6 to 9 months	difference	p-value	difference	p-value	difference	p-value
Aflatoxins	0.003	0.144	0.045	0.141 (0.103)	0.176	**0.041*** (0.012)**	0.001	-0.099 (0.192)	0.608
Arsenic	0.024	0.025	0.021	0.001 (0.015)	0.913	-0.003 (0.013)	0.797	-0.005 (0.0154)	0.771
Mold	375.556	352.000	421.429	-23.556 (146.657)	0.873	45.873 (210.568)	0.828	69.429 (232.09)	0.767
Moisture	13.183	13.190	13.248	0.007 (0.089)	0.766	0.065 (0.133)	0.626	0.058 (0.1377)	0.674

(b) WHEAT

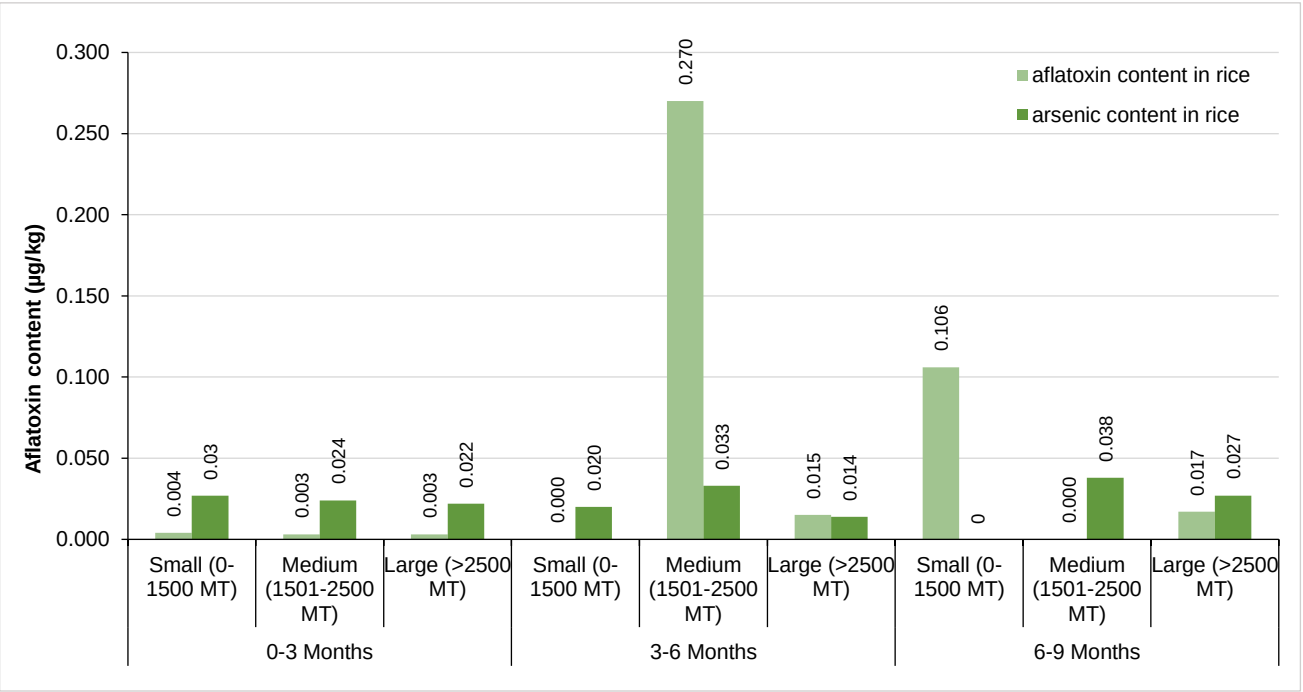
	Stock Duration (Age of stock in LSDs)		Comparison between (0-6) vs. (6-12) months	
	0-6 months	6-12 months	difference	p-value
Aflatoxins	0.024	0.002	0.022 (0.015)	0.142
Mold	491.667	621.053	-129.386 (235.217)	0.587
Moisture	12.291	12.920	**-0.629*** (0.192)**	0.002

Note: Standard errors of mean differences are reported in parentheses. Due to the sampling procedures followed, the comparison is facilitated across three age-groups for rice and two age-groups for wheat.

The linear association between contaminants type is examined by grain types and duration of stack, and the results are reported in Table A.4 in the appendix. For duration of stack of 0-3 months, there is significant positive association between arsenic and aflatoxins contaminants in rice. In the rice samples with stack duration of 6-9 months, there is a significantly high positive association between aflatoxins and mold content. In the pooled sample (0-9 months), a significantly positive association is observed between arsenic and mold contamination in rice. However, no such significant association is observed for any pair of contaminants in wheat. Although average moisture level is detected at higher than the recommended level and high moisture is conducive to mold growth, the correlation coefficient of mold and moisture did not turn out to be statistically significant in any of the cases.

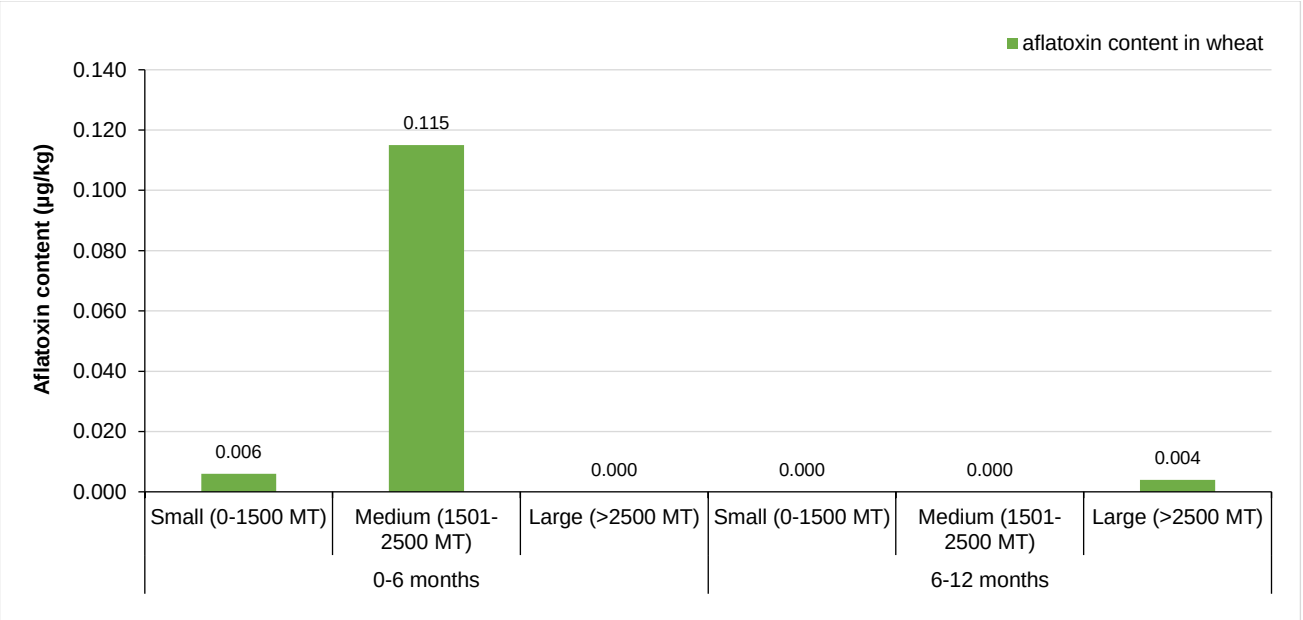
As described in the methodology section, the grains for laboratory testing are collected from three types of storage facilities based on their rated capacities-small, medium and large. As presented in Figure 3.5, the presence of aflatoxin content in rice samples drawn from medium LSDs with stack duration in the range of 3-6 months is remarkably higher compared to the mean level in the pooled samples (0.27 vs. 0.05µg/kg). In contrast to aflatoxin, arsenic content in rice does not reveal any systematic pattern across capacity-age groups. The aflatoxin content is also found high in 6-9 months old stack of rice drawn from small sized LSDs (0.11 µg/kg). In the case of wheat, as Figure 3.6 shows, aflatoxin content in 0-6 months old stack stored in medium sized LSDs is higher compared to other capacity-age groups.

Figure 3.5 Quality of stored rice by facility type and age of stock



The results from similar types of comparison for mold and moisture are presented in Figure A.5-Figure A.8 in the appendix. The mold content in rice samples drawn from small sized LSDs is relatively higher than that drawn from medium and large LSDs, and this pattern is consistent across stack duration or age of storage. In contrast, mold content is always higher in wheat stored in large LSDs compared to medium and small LSDs irrespective of duration of stack. For moisture contents in stored rice, no distinct pattern is observed across LSDs with variation in rated capacities and stock duration (Figure A.7). In the case of stored wheat, average moisture content is found relatively high in samples drawn from large and medium sized LSDs compared to smaller LSDs, with stack duration of 6-12 months (Figure A.8).

Figure 3.6 Quality of stored wheat by facility type and age of stock



CHAPTER 4. DISCUSSION OF RESULTS

The contaminant levels in stored grains are largely comparable with findings from similar studies. The data on lower average aflatoxin content of rice and wheat in the LSDs corroborate with the low mean levels of aflatoxins reported in Dawlatana et al. (2002)—less than 0.1 mg/kg on average, and Roy et al. (2013)—in the range of 0-0.9 mg/kg with the mean of 0.3 mg/kg for rice while in the range of 0.9-1.6 mg/kg with mean of 1.4 mg/kg for wheat. In fact, the mean level of aflatoxin detected in rice (0.05 mg/kg) and wheat (0.01 mg/kg) samples collected for this study is much lower than that reported in the above studies. The rice and wheat stocks in the LSDs seem to comply much better with aflatoxin standard given that aflatoxin content in rice is detected at much higher level in other Asian countries (Elzupir et al., 2015). For example, average aflatoxin levels in rice in China, Korea, Pakistan, and Vietnam are detected at 0.79, 4.8, 3.31, 11.3mg/kg respectively while in India aflatoxins B1 is detected in the range of 0-308 mg/kg (Elzupir et al., 2015; Wang & Liu, 2007; Iqbal, 2012; and Reddy, 2009). However, the proportions of samples detected with aflatoxins (15% in rice and 9% in wheat) in this study is higher than that reported in Joarder et al (1980)-3.9% of the 1184 samples were detected with aflatoxin with 2 samples exceeded the maximum limit.

The mean level of arsenic content (0.02 mg/kg) detected in this study is also much lower than those reported in similar studies conducted on rice samples drawn from Bangladesh. For example, arsenic content is reported at 0.14 mg/kg in Das et al (2004), 0.11 mg/kg in Al Rmalli et al. (2005), 0.24 mg/kg in Williams et al. (2007) and 0.3-0.7 mg/kg in Rahman et al (2007). However, a few of these studies were based on data from regions where source of irrigation is typically arsenic contaminated groundwater that results in arsenic estimates on the higher side. In contrast, these findings are nationally representative, where highest level of arsenic content detected at 0.14 mg/kg, and approximately, only six percent of the samples revealed to have arsenic content greater than 0.1 mg/kg. The maximum level of arsenic content detected in the sample is also found lower than the FAO recommended level for Bangladesh (0.14 mg/kg vs. 0.15 mg/kg). As arsenic contamination in grains is not detected at level exceeding the maximum allowable limit, even in the areas where groundwater is allegedly contaminated by arsenic—south and southwestern—it suggests that using low arsenic content water for cooking rice would keep the daily total arsenic intake within a reasonable limit in high arsenic concentration areas.

Moisture level is the key determinant for maintaining the grain safe from mold growth and mycotoxin development, discoloration, and insect infestation. The average level of moisture content reported for PFDS grain is compliant with the standard, and to some extent better than that reported by Kabirullah and Rahman (2001)-in the range if 11.01-14.66% with the average of 13.72%. However, in contrast to Kabirullah and Rahman, the moisture content in rice stored in LSDs appears to be invariant with the stock age while moisture content in stored wheat is found to increase with storage age. The average moisture contents for wheat is marginally higher than that reported by IFPRI in 2002-2003, where moisture content in wheat stored in PFDS ranged of 10.65-11.46, which were all compliant with the standard set by the Ministry of Food at a maximum of 13% by (Akhter et al. 2004).

The mold content in both rice and wheat is detected at much lower and safer level in comparison to the high fungus load reported in Joarder et al. (1980), and that in PFDS grains reported in Kabirullah and Rahman (2001)- where fungus was detected in the range of 100-33300 cfu/gm with mean of 45438 cfu/gm. Since mold growth is related to moisture content in grains, the lower level of mold detection in this report as well as its invariance with storage period can partly be attributed to current moisture management practices in comparison to that prevailed in the early 2000, the study period of Kabirullah and Rahman. However, as mold contamination can take place at pre-harvest stage, some screening for mold content while the grains enter the storage facility may help control the extent of mold infestation.

CHAPTER 5. CONCLUSIONS

In brief, the laboratory test results of grains stored in the LSDs suggest that rice and wheat stocks are, in general, in compliance with the maximum allowable limits set for aflatoxins, arsenic and mold contents. The average moisture content in the stored grains is maintained at the recommended level in most of the cases. The findings from this study, in general, suggests that grain stored in LSDs do not contain aflatoxins, arsenic and mold at levels exceeding the maximum allowable limits, and therefore, do not pose serious threat to public health. The evidence of lower level of detection for a selected set of contaminants in stored grains in public facilities suggest that quality control has been effective in the sampled LSDs, and food recipients through these LSDs in public distribution channel are largely safe from food hazards related to aflatoxin, arsenic and molds. However, from the point of view of public food safety, few points are worth mentioning.

Although average moisture content in the stored grain is largely (95%) compliant with the PFDS standard set at 14% at maximum, this study observes that approximately 10% of the grain samples (9.2% of rice and 1.5% of the wheat) are non-compliant with the recommended moisture level at least in any one part -upper, middle, and bottom- of the sack from which the grain sample is drawn. In addition to this, a large proportion of rice and wheat samples stored in the LSDs are found to exceed the maximum moisture content level of 13% as recommended by FAO and IRRI (2013) for long-term grain storage. Since excessive moisture in grain creates a conducive environment for mold growth, the evidence that 45% of the wheat sample older than 3 months and 67% of the rice sample older than 4 months have moisture content greater than 13% has implication for further mold growth, discoloration, and quality degradation of grain reserves in the LSDs.

Storage time is a key determinant of both mold and aflatoxins growth in rice and wheat, especially in tropical climate like Bangladesh. Note that the survey is held in an atypical year with very low share of long-duration grain reserves in public storage facilities in the context of widespread uncertainty due to damage of crop production in the greater Sylhet and northern region due to flash flood. Accordingly, most of the grain samples tested in laboratory are of relatively shorter storage duration, at most nine months for rice and 1-year for wheat. This suggests that caution is warranted while extrapolating the results over longer horizon. Similarly, a large proportion of grains (67% of rice and 84% of wheat) in public storages have been detected with traces of mold. In addition to that for mold, since aflatoxin contamination in grains can take place during both pre-and-post harvest operations, determining which channel contributed to the samples detected positive is important to design an effective and efficient storage facility, although it is out of scope of the current study design. Finally, the construction of silos under MFSP with central air and moisture control mechanisms will strengthen the capacity of PFDS authority in storing the grains for longer periods and providing the staple food with better quality and standards.

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APPENDIX - A. SUPPLEMENTARY TABLES AND FIGURES

Table A.1 List of 50 LSDs for laboratory testing

No.	Division	District	Upazila	LSD Name	Capacity
1	Barishal	Barishal	Gaurnadi	Gaurnadi LSD	Up to 1500 MT
2	Barishal	Patuakhali	Baufol	Kalaiya LSD	1501-2500 MT
3	Barishal	Pirojpur	Kaukhali	Kaukhali LSD	1501-2500 MT
4	Barishal	Bhola	Bhola	Bhola LSD	More than 2500 MT
5	Chattogram	Chandpur	Kochua	Kochua LSD	Up to 1500 MT
6	Chattogram	Chattogram	Chandanaish	Dohajari LSD	Up to 1500 MT
7	Chattogram	Cox's Bazar	Teknaf	Teknaf LSD	Up to 1500 MT
8	Chattogram	Rangamati	Baghaichhari	Baghaichori LSD	Up to 1500 MT
9	Chattogram	Chattogram	Satkania	Satkania LSD	1501-2500 MT
10	Chattogram	Feni	Daganbhuiyan	Dagonbhuiya LSD	1501-2500 MT
11	Chattogram	Lakshmipur	Lakshmipur Sadar	Lakshmipur Sadar LSD	More than 2500 MT
12	Dhaka	Manikganj	Ghior	Ghior LSD	Up to 1500 MT
13	Dhaka	Netrokona	Kalmakanda	Kalmakanda LSD	Up to 1500 MT
14	Dhaka	Shariatpur	Damudya	Damudya LSD	Up to 1500 MT
15	Dhaka	Tangail	Delduar	Delduar LSD	Up to 1500 MT
16	Dhaka	Gopalganj	Gopalganj Sadar	Gopalganj Sadar LSD	1501-2500 MT
17	Dhaka	Gopalganj	Kotalipara	Kotalipara LSD	1501-2500 MT
18	Dhaka	Mymensingh	Ishwarganj	Atharbari LSD	1501-2500 MT
19	Dhaka	Shariatpur	Shariatpur Sadar	Angaria LSD	1501-2500 MT
20	Dhaka	Jamalpur	Jamalpur Sadar	Singhajani LSD	More than 2500 MT
21	Dhaka	Mymensingh	Phulpur	Phulpur LSD	More than 2500 MT
22	Dhaka	Netrokona	Purbodhola	Jariya LSD	More than 2500 MT
23	Dhaka	Tangail	Tangail Sadar	B. Betoka LSD	More than 2500 MT
24	Khulna	Bagerhat	Mollahat	Garofabazar LSD	Up to 1500 MT
25	Khulna	Satkhira	Kalaroa	Kalaroa LSD	Up to 1500 MT
26	Khulna	Jhenaidaha	Maheshpur	Maheshpur LSD	1501-2500 MT
27	Khulna	Jhenaidaha	Shoilkupa	Shoilkupa LSD	1501-2500 MT
28	Khulna	Chuadanga	Chuadanga	Chuadanga LSD	More than 2500 MT
29	Khulna	Jessore	Jessore	Jessore LSD	More than 2500 MT
30	Rajshahi	Natore	Singra	Singra LSD	Up to 1500 MT
31	Rajshahi	Pabna	Sujanagar	Sujanagar LSD	Up to 1500 MT
32	Rajshahi	Bogra	Nandigram	Nandigram LSD	1501-2500 MT
33	Rajshahi	Bogra	Sherpur	Mirzapur LSD	1501-2500 MT
34	Rajshahi	Chapai Nababganj	Nachole	Nachole LSD	1501-2500 MT
35	Rajshahi	Bogra	Dhupchachiya	Talora LSD	More than 2500 MT
36	Rajshahi	Jaipurhat	Panchbibi	Panchbibi LSD	More than 2500 MT
37	Rajshahi	Rajshahi	Boalia	Rajshahi LSD	More than 2500 MT
38	Rangpur	Dinajpur	Ghoraghat	Ghoraghat LSD	Up to 1500 MT
39	Rangpur	Dinajpur	Khansama	Khansama LSD	1501-2500 MT

No.	Division	District	Upazila	LSD Name	Capacity
40	Rangpur	Kurigram	Bhurungamari	Jajmanirhat LSD	1501-2500 MT
41	Rangpur	Thakurgaon	Thakurgaon Sadar	Bhulirhat LSD	1501-2500 MT
42	Rangpur	Dinajpur	Birampur	Charkai LSD	More than 2500 MT
43	Rangpur	Dinajpur	Biral	Mongolpur LSD	More than 2500 MT
44	Rangpur	Kurigram	Kurigram Sadar	Kurigram Sadar LSD	More than 2500 MT
45	Rangpur	Nilphamari	Domar	Chilahati LSD	More than 2500 MT
46	Rangpur	Thakurgaon	Thakurgaon Sadar	Thakurgaon LSD	More than 2500 MT
47	Sylhet	Maulvibazar	Kulaura	Kulaura LSD	Up to 1500 MT
48	Sylhet	Sylhet	Biyanibazar	Sheola LSD	Up to 1500 MT
49	Sylhet	Habiganj	Habiganj Sadar	Habiganj Sadar LSD	1501-2500 MT
50	Sylhet	Sunamganj	Sunamganj Sadar	Mallikpur LSD	More than 2500 MT

Table A.2 Contamination of rice in storage by contaminant types and division

	Barishal	Chattogram	Dhaka	Khulna	Mymensingh	Rajshahi	Rangpur	Sylhet
Aflatoxin								
Percentage with any detectable level	33%	10%	13%	0%	14%	8%	19%	29%
Mean level	0.014	0.006	0.020	0.000	0.004	0.003	0.224	0.031
Std. dev.	0.022	0.019	0.065	0.000	0.011	0.011	0.855	0.058
Arsenic								
Percentage with any detectable level	17%	60%	47%	13%	29%	0%	19%	14%
Mean level	0.014	0.056	0.049	0.009	0.030	0.000	0.014	0.012
Std. dev.	0.033	0.049	0.056	0.026	0.054	0.000	0.029	0.032
Mold								
Percentage with any detectable level	80%	80%	47%	82%	71%	57%	67%	71%
Mean level	500.000	440.000	186.667	354.546	514.286	371.429	320.000	628.571
Std. dev.	644.205	790.499	387.052	518.389	669.399	562.178	555.749	1275.035
Moisture								
Percentage with above recommended level of moisture	43%	10%	3%	9%	29%	0%	0%	0%
Mean level	13.557	13.098	12.885	13.287	13.639	13.110	13.248	13.229
Std. dev.	0.388	0.767	0.694	0.515	0.316	0.592	0.336	0.535

Table A.3 Contamination of wheat in storage by contaminant types and division

	Barishal	Chattogram	Dhaka	Khulna	Mymensingh	Rajshahi	Rangpur	Sylhet
Aflatoxin								
Percentage with any detectable level	0%	0%	0%	25%	0%	0%	0%	100%
Mean level	0.000	0.000	0.000	0.009	0.000	0.000	0.000	0.130
Std. dev.	.	0.000	0.000	0.017	.	0.000	0.000	0.141
Mold								
Percentage with any detectable level	50%	100%	88%	67%	100%	50%	100%	100%
Mean level	100.00	566.67	562.50	333.33	900.00	175.00	1220.00	450.00
Std. dev.	141.42	571.55	824.51	351.19	.	206.16	593.30	494.97
Moisture								
Percentage with above recommended level of moisture	100%	17%	31%	13%	100%	40%	75%	25%
Mean level	13.450	12.489	12.433	12.663	13.300	12.737	13.239	12.258
Std. dev.	0.354	0.569	1.194	0.396	0.141	0.424	0.554	0.699

Table A.4 Coefficient of correlation across contaminants by age of stack

	RICE															
	0-3 months				3-6 months				6-9 months				Pool: 0-9 months			
	Aflatoxins	Arsenic	Mold	Moisture	Aflatoxins	Arsenic	Mold	Moisture	Aflatoxins	Arsenic	Mold	Moisture	Aflatoxins	Arsenic	Mold	Moisture
Arsenic	**0.29*** **(0.06)**				0.191 (0.36)				-0.22 (0.47)				0.12 (0.30)			
Mold	-0.14 (0.54)	-0.32 (0.14)			-0.16 (0.62)	-0.277 (0.38)			**0.81**** **(0.01)**	-0.27 (0.51)			-0.05 (0.68)	**-0.26**** **(0.03)**		
Moisture	-0.095 (0.54)	-0.05 (0.75)	-0.04 (0.82)		-0.065 (0.76)	0.204 (0.33)	0.111 (0.60)		-0.167 (0.59)	0.01 (0.98)	0.04 (0.89)		-0.04 (0.76)	0.04 (0.72)	0.021 (0.85)	

	WHEAT					
	0-6 months		6-12 months		Pool: 0-12 months	
	Aflatoxins	Mold	Aflatoxins	Mold	Aflatoxins	Mold
Mold	0.12 (0.74)		-0.123 (0.64)		-0.05 (0.68)	
Moisture	0.25 (0.45)	-0.07 (0.83)	-0.24 (0.29)	0.30 (0.21)	0.03 (0.87)	0.19 (0.31)

Note: Significance levels are presented in parentheses. ***, **, * respectively represent significance level at less than 1 percent, 5 percent, and 10 percent levels. Since wheat samples are heavily drawn from old stacks, they are grouped into two-(i) less than or equal to 6 months, and (ii) more than 6 months. In contrast to rice, wheat samples are tested for arsenic. Moisture level is the average of moistures measured at the upper part, middle part and bottom parts of the stack containing grain.

Figure A.5 Mold content in stored rice by facility type and age of stack

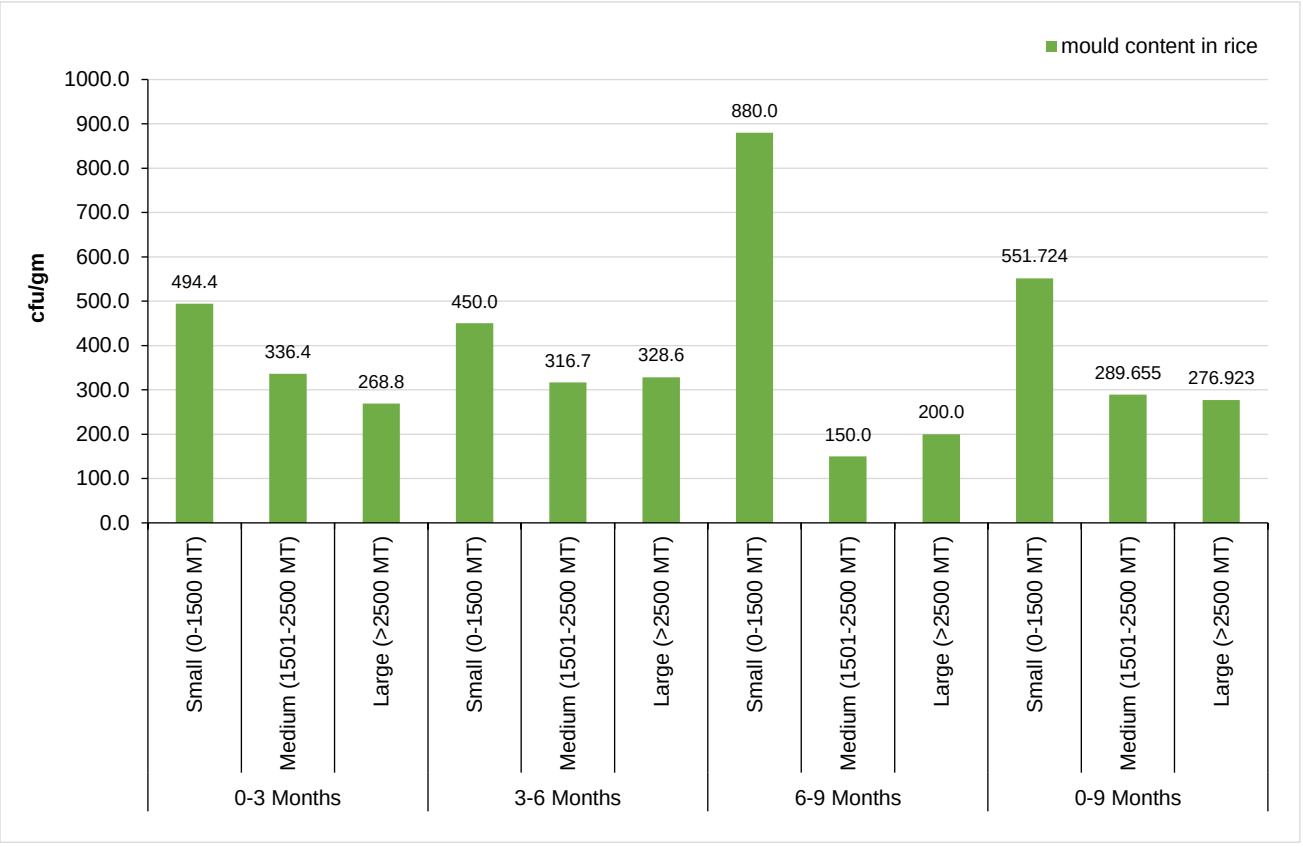


Figure A.6 Moisture content in stored rice by facility type and age of stack

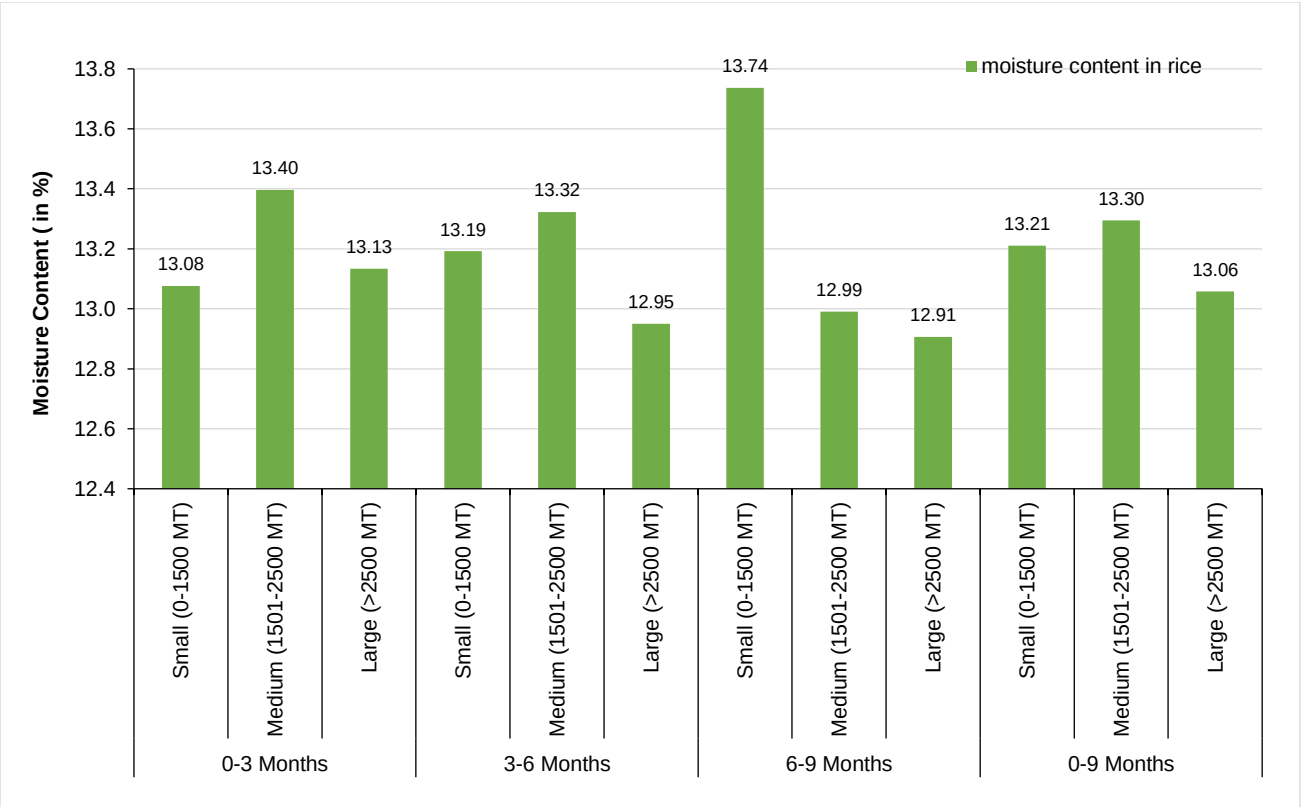


Figure A.7 Mold content in stored wheat by facility type and age of stack

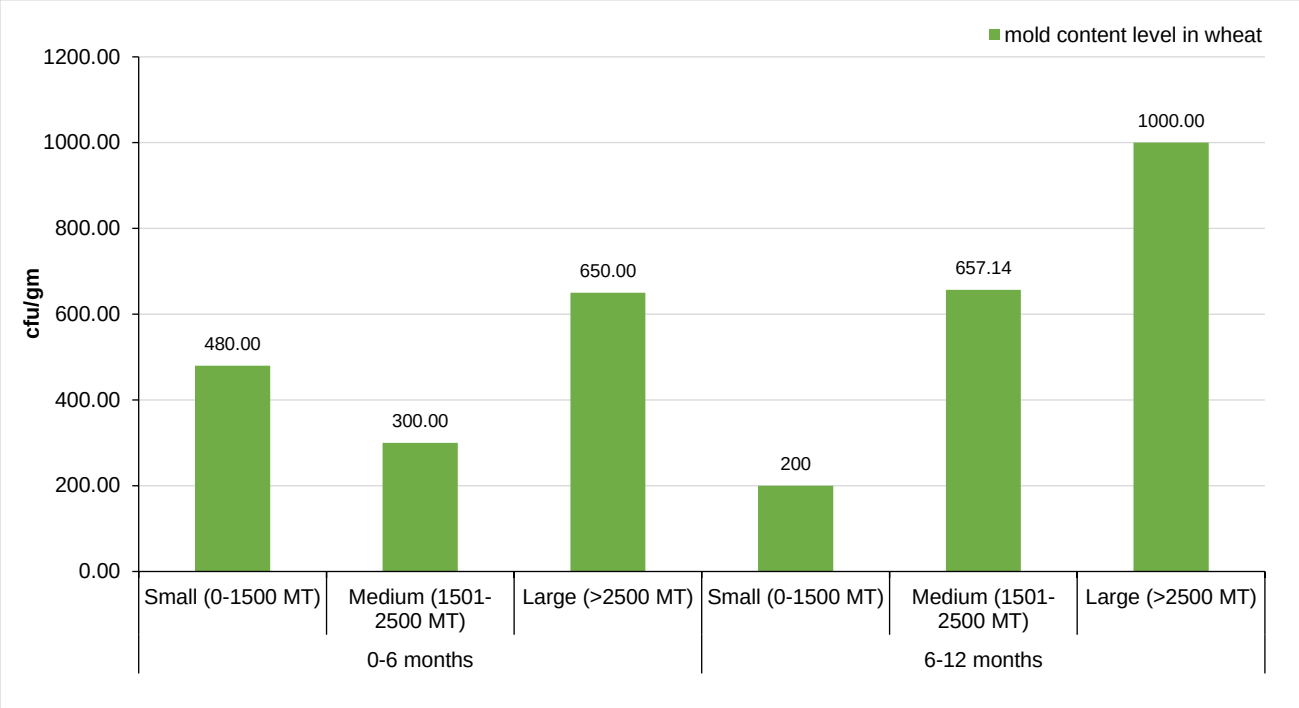
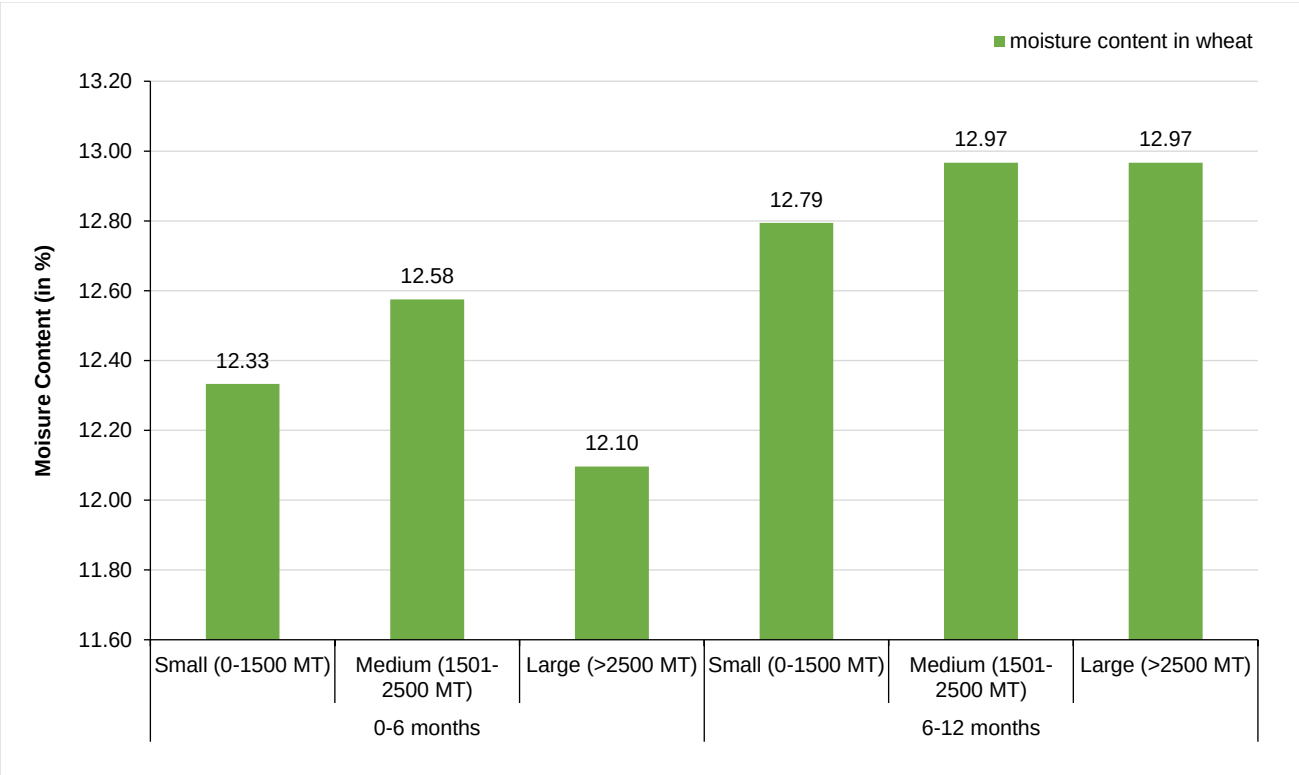


Figure A.8 Moisture content in stored wheat by facility type and age of stack



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