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Effects of drying pattern on aflatoxin in stored paddy rice

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Abstract

This study was done to evaluate the impact of drying pattern on the accumulation of aflatoxin in paddy rice during storage. Two drying pattern includes, 1) single step drying to reduced the moisture content of paddy rice 11-12 % within 6 hours and stored for long time; and 2) two steps drying to reduce the moisture up to 18%, in its first step and stored for short term (2 weeks) and in the second step, dried again to reduce the moisture content up to 11-12% and stored for longer time, with twenty five different paddy rice samples having moisture content ranging from 24-22 % were evaluated for the accumulation of aflatoxins in paddy rice during storage. In addition, this study also evaluated the best drying method that can control the accumulation of aflatoxin during prolong storage. The study results revealed that one step drying is safer than that of two steps drying in accumulating aflatoxins in paddy rice during 210 days of storage. The maximum total aflatoxins (B1, B2, G1,G2) was recorded as 27 ppb in paddy rice sample in two steps drying process, on the other hand, non-detectable level or <10 ppb level of aflatoxins was recorded in all the 25 paddy rice samples analyzed.

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Introduction

Rice (*Oryza sativa*) is an important staple food and occupies second place in production area after wheat and maize worldwide. Pakistan is famous for rice production and is the third largest rice producing country after wheat and cotton area wise (Khan, 2010). Pakistan is still using the traditional paddy cultivation and harvesting method, hence, the quality and production yield greatly affected and more than 20 to 30% post-harvest losses have been reported (Khan and Salim, 2005). Drying is a critical step during rice post-harvest practices; inadequate drying and storage operations contribute to increased losses (Kumar and Kalita, 2017). When harvesting the paddy, the moisture content ranged between 24-26%, and the respiration rate is high, this condition favors the microbes, insects and other pests to attach to the paddy. Therefore, drying within short time after harvest is recommended, and drying to obtain maximum 14% moisture content is safe for storage and milling. However, in case of difficulty, drying to obtain moisture content maximum 18% can be done for temporary storage (2 weeks) (Genkawa *et al*., 2008). On the other hand, bad drying practices may cause 1-5% quality losses of paddy (Nguyen and Kunze, 1984). Therefore, to minimize the post-harvest losses, good drying practices are crucial that directly influence safe storage, transportation, distribution and processing quality. The recommended temperature for drying paddy is 43°C and mostly attained with shade drying (Siebenmorgen and Meullenet, 2004). Unlike like other developing countries, the farmers of Pakistan also use sun- or solar drying method due to its cost effectiveness. Although artificial or mechanical drying method speeds up drying process, reduces handling losses, maintains grain quality and gives better control during drying, but yet in common practice. Delayed drying may result in non-enzymatic browning (stack-burning), microbial growth and mycotoxin production (Riaz *et al*., 2017; Taechapairoj *et al*., 2007).

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Aflatoxins are secondary metabolites produced by some strains of mold including *Aspergillus flavus* and other species of *Aspergillus* fungi (Creppy, 2002). The four most common aflatoxins are B1, B2, G1, and G2. Contaminated grains and grain byproducts are the most common sources of aflatoxin (Bennett and Klich, 2003). Aflatoxins are metabolized in ruminants by the liver and are excreted in the bile. Aflatoxin B1 is the most potent mycotoxin and potent carcinogen (cancer causing agent) (de Ruyck *et al*., 2015; Fung and Clark, 2004; Nisa *et al*., 2014). The development of aflatoxins depends on the infestation and growth of the *Aspergillus* mold in grain and higher temperatures and humidity favor the growth. Harvested rice that remains in the field or rice that is stored without adequate drying can be subject to *Aspergillus* growth and aflatoxin production (Prietto *et al*., 2015; Nisa *et al*., 2014). Temperatures between 26-37^{o}C and relative humidity of 85 % (corresponding to 18 percent grain moisture) are optimum for growth of *Aspergillus*. On the other hand, the growth of *Aspergillus* is poor below 12^{o}C, but if the grain is moist enough, toxins can still be produced (Paterson and Lima, 2010; Mannaa *et al*., 2017). However, simply reducing the moisture content to as low as 12 percent, does not kill the fungus, nor reduce the levels of toxins that have already been produced. If moisture and temperature levels rise again above 12 percent, and elevated level, respectively, anytime during storage, then mold growth and toxin production will resume. It is important to note that conditions favoring the growth of *Aspergillus* also favor the growth of other fungi that can have harmful effects on humans if they are inhaled or ingested while working in grain handling facilities (Accinelli *et al*., 2014). Harvesting paddy rice containing 20% moisture content and drying within 24 hours to reduce the moisture content no greater than 14 % greatly inhibit the growth, and toxin production by *Aspergillus*. Maximum moisture content for corn storage should be 14 percent and moisture content below 12 percent is ideal for rice storage (Mohapatra *et al*., 2017; Bradford *et al*., 2017).

Aflatoxicosis can only be prevented by consuming toxin free diet and poor post harvest handling is the major cause of aflatoxin production in food grains. (Ashiq, 2015; Nisa *et al*., 2016). In general, hot and humid conditions are very favorable for the growth of toxigenic fungi and mycotoxin production in agricultural produce. (Neme and Mohammed, 2017; Medina *et al*., 2017). Thus, drying the food grains up to an optimum moisture level soon after harvest is of utmost importance in order to control aflatoxin production in agricultural commodities. The aim of present work is to evaluate the accumaltion of aflatoxin in paddy by comparing two different drying patterns includes, 1) single step drying to reduce the moisture content of paddy rice 11-12 % within 6 hours and stored for long time; and 2) two steps drying to reduce the moisture up to 18%, in its first step and stored for two weeks and in the second step, dried again to reduce the moisture content up to 11-12% for prolong storage.

Materials and methods

Freshly harvested paddy samples were collected from different lots procured from Gujranwala district of Punjab province of Pakistan. Total fifty samples were collected from 25 lots i.e two samples from each lot and analyzed for the presence of aflatoxin. Five (5 kg) kilogram of each of the twenty five samples were dried up to moisture level 12 -13 % in a Mitchell cabinet tray dryers (Mitchell Dryers Ltd, Manchester, UK) within twenty four hours of harvesting and stored at temperature 35^{0}C while other twenty five samples from same lot were sun dried and husked as per traditional practices. Huskers dried the sample in two steps: 1) at first samples were dried up to 11 to 12 % moisture level for 3 days then stored at temperature 30^{0}C and humidity 60 % in a godown. 2) final drying was carried out to reduce the moisture level up to 13% after 2 weeks of first drying. After seven months of storage all samples were analyzed for alfatoxin content using VITCAM flouromer model 4EX (VITCAM, MA, USA) according to the manufacturer's instructions or as described by Mehan *et al*., 1985.

Statistical Analysis

All the samples were analyzed in triplicates and data evaluated statistically by using one way ANOVA (SPSS ver. 8.0) and means comparison were performed with a significant differences ($p< 0.05$) (Steel *et al*., 1997).

Results and discussion

This study explored whether there would be aflatoxin production in rice grains from different drying and storage treatments in Pakistan. In single step mechanical drying, it takes 6 hours to reduce the moisture content from 22% to 11-12% and after storage at 30^{0}C and under 60% moisture content for 210 days showed maximum aflatoxins accumulation in rice karnel was 4.35 ppb while six samples showed below detection level of aflatoxins accumulation (Table I). On the other have, some samples showed little aflatoxins accumulation. It was observed that when the moisture content of the dried paddy rice was in the range

Table I. Aflatoxin accumulation in paddy rice samples during 210 days of storage using single step drying pattern

Sample No.	Moisture %	Temperature ^{o}C/ Humidity%	Storage time in days	Total Aflatoxin (B1,B2,G1,G2) (ppb)
1	11.4	32/60	210	1.9
2	11.5	32/60	210	1.4
3	12.2	32/60	210	0.64
4	12	32/60	210	1.8
5	11.8	32/60	210	0.61
6	11.5	32/60	210	ND
7	12.0	32/60	210	ND
8	12.2	32/60	210	ND
9	11.8	32/60	210	2.9
10	11.5	32/60	210	4.35
11	11.0	32/60	210	1.2
12	11.5	32/60	210	0.90
13	11.0	32/60	210	ND
14	11.5	32/60	210	ND
15	12.4	32/60	210	1.1
16	12.0	32/60	210	2.8
17	12.1	32/60	210	0.52
18	11.5	32/60	210	0.5 3
19	11.2	32/60	210	2.4
20	11.6	32/60	210	1.3
21	12.1	32/60	210	ND
22	12.0	32/60	210	0.73
23	11.8	32/60	210	1.0
24	11.6	32/60	210	1.7
25	11.5	32/60	210	3.0

ND = Not Detected, Detection limit = 0.5ppb

between 11.0-12.0%, six samples did not show any accumulation of aflatoxins. However, when moisture content was little above 12% then aflatoxins accumulation was observed almost all the samples. However this accumulation is below the recommended level. This finding suggested that drying below 12% moisture content provide better protection of consumers from aflatoxicosis. On the other hand in two step traditional drying methods, the moisture content of paddy rice was above 12% therefore aflatoxin accumulation was occurred in all the samples and maximum aflatoxins content was recorded as 27ppb in two step drying method (Table II). This study results showed that the single step drying method was safe as there was no development of aflatoxins during 210 days of storage as compared to two step drying methods, because in single step drying, paddy rice are dried up to safe moisture contents which does not favour the fungal growth. Similar results were reported by George (1988) who illustrated that fungi require moisture to cause food spoilage by producing secondary metabolites within moisture limits of 13-13.2%. When the high moistured semi dried rice is filled in bags, heat is produced due to respiration. Hot and humid environment of paddy rice in filled bags provide favorable environment for the growth of aflatoxins. In another report, Carlos *et al*. (2000) reported that hot and

Table II. Aflatoxin accumulation in paddy rice samples during 210 days of storage using two step drying pattern

Sample No.	Moisture %		Temperature ^{o}C/ Humidity %	Storage time in days	Total Aflatoxin (B1,B2,G1,G2) (ppb)
	Semidried	Final dried			
1	18	13	32/60	210	16
2	18	13	32/60	210	3.8
3	18	14	32/60	210	3.9
4	18	13.5	32/60	210	18
5	18.5	14	32/60	210	4.3
6	18.5	13.5	32/60	210	17.5
7	18	14	32/60	210	15
8	19	13.7	32/60	210	27
9	18	13	32/60	210	2.4
10	17	13	32/60	210	13
11	17	12.0	32/60	210	6
12	18	12.5	32/60	210	12
13	17	14.0	32/60	210	6.2
14	18	13.0	32/60	210	6.2
15	17.6	12.4	32/60	210	4.3
16	18	13.0	32/60	210	3.1
17	17.8	12.5	32/60	210	5.0
18	18.2	13.0	32/60	210	5.5
19	18.0	13.5	32/60	210	3.7
20	18.0	14.0	32/60	210	15.2
21	18.0	13.5	32/60	210	6.2
22	17.7	13.0	32/60	210	15
23	18.2	13.0	32/60	210	3.0
24	17.5	12.6	32/60	210	10
25	18.0	13.0	32/60	210	4.5

humid environment during prolongs storage favours aflatoxin contamination. The results of this study will contribute in formulation of local standards and legislative measures of permissible limit of aflatoxin in food grains in Pakistan. Single step drying technology should be introduced to the farmers and government initiative and financial assistance to install mechanical dryer in rice producing area could be done to produce safe rice for the people.

However, further studies relating to aflatoxins on rice storage could examine the effects of other common practices of farmers such as keeping wet grains over different periods, piling bundles of cut crop for different periods, seasonal variations, and low cost technology in drying could improve the safety of the crops for human consumption.

Conclusion

Aflatoxins are highly hazardous for livestock, poultry, and people and seriously impair human health and productivity. Drying method significantly affect the occurrence of aflatoxins in food commodities during storage. Cereal grains must be dried up to safe moisture level < 14 % in single step drying after harvest and avoid short term or long term storage after semidrying the food commodities.

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