The Impact of Sun Drying on the Occurrence of Aflatoxin in Red Chilies

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Abstract: A major challenge in post-harvest protection of chilies is its rapid drying to prevent quality deterioration as a result of fungal contamination. The speed and efficiency of drying is crucial as the improper and prolonged drying may eventually initiate the buildup of mycotoxins. This research demonstrated levels of aflatoxin in samples at different stages of drying with the objective to assess the efficiency of the common practice of on-farm sun drying in Pakistan. The results indicated that there was no significant pre-harvest contamination of aflatoxins in chilies grown at different locations under study. Sun drying of the harvested chilies over a post drying stage reduced average moisture content from 69.70% to 9.87%, but also led to a gradual increase in the level of aflatoxins. The correlation between the observed increase in aflatoxin levels and the length of the drying period was found to be statistically significant ($P<0.05$) at all the locations investigated. The implications of the findings are discussed in relation to optimizing the post-harvest drying process to minimize the levels of aflatoxin in chilies.

Keywords: Red Chilies, Aflatoxin contamination, Post-harvest practices, Moisture content.

INTRODUCTION

Mycotoxin contamination in food is of severe apprehension all over the world due to its consequences on human and animal health. Mycotoxin intake above permissible level leads to carcinogenicity, mutagenicity, hepatotoxicity, and anti-nutritional impact [1-3]. Aflatoxins, produced by Aspergillus species, make up one of the most important class of mycotoxins that are generally present in a variety of agri-food commodities chilies, etc [4-7]. It has been reported that inappropriate practices from harvesting to marketing resulted in production of aflatoxins [8].

Pakistan is one of the important chili producing and extorting country. Red chilies are demanded around the world on basis of aroma, flavor, color and appearance. It is used in the form of whole pods, powdered and recipe mix. Sindh province is famous for chili production due to agro-ecological suitability and about 90% of the chili is cultivated in Kunri-Umerkot. In 2009-10, chili production in Sindh was 0.17 million tones and around 4,500 tons of raw chili had been exported which added 70 million US dollars of foreign exchange.

The present study was aiming to examine and evaluate the impact of sun drying on occurrence of aflatoxins in a chili variety named 'Dandi cut'. This variety has a large market share due to its high pungency and desirable color. It is generally milled to yield fine powder for direct use and for use as ingredient of pre-mixed spices. This research also demonstrated a few other reasons for the development and occurrence of aflatoxins in chilies.

MATERIALS AND METHODS

This research activity was carried out in chili growing regions of Sindh-Pakistan. Samples (Dandi cut variety) were collected from five different locations of Kunri, Mithi, Nagarparkar, Marjhango and Samaro. Chilies were spread over the soil bed after pickling and dried in open atmosphere by open-air drying method. At many places, the soil was moist and/or saline. The chilies were turned over once or twice a day. The average minimum and maximum temperature, humidity and precipitation during the pre- and post-harvest drying period in the locations under study were recorded and are shown in Table **1**. Samples were drawn from freshly harvested chilies to determine the possibility of aflatoxins occurrence and initiation in the field. Further samples were taken during and after drying at intervals of 7, 15 and 30 days. Samples were collected and transferred to the laboratory in cotton bags, where these were placed in pre-sterilized glass jars. All samples were stored at refrigeration temperature (4°C) and analyzed within a week of collection for aflatoxins and moisture content.

The quantitative analysis of total aflatoxins was analyzed through a competitive direct Enzyme Linked

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Table 1: Average Minimum and Maximum Temperature, Humidity and Precipitation Recorded at the Study Sites

	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov
Temperature (^oC)										
Maximum	30.9	38.5	41.9	43.8	40.4	37.7	35.1	35.8	38.0	32.2
Minimum	9.1	18.3	23.4	26.6	27.4	27.5	26.2	24.7	21.2	15.1
Precipitation (mm)	6.0	0.0	0.0	0.0	37.0	67.4	212.8	52.8	8.35	33.2
Relative humidity (%)										
At 0000 UTC	75.0	73.5	68.5	74.5	81.0	82.5	89.9	88.5	83.0	83.5
At 1200 UTC	26.0	25.0	19.0	21.5	36.5	53.5	65.0	54.0	31.5	40.5

Immunosorbent Assay (ELISA) by using a commercially available immunoassay kit Veratox (Neogen Corp., Lansing, MI. USA) and following a method documented in previous report [9]. Specified weight (10 g) of chili pods were weighed and placed in a drying chamber of Brabender moisture tester (MT-E) and moisture content was determined by exposing the pods to 130^{o}C for 1 hour.

All samples were collected and analyzed in triplicate. Statistically source of variation was calculated by applying two way ANOVA (analysis of variance) for a factorial design. Duncan's test was further used to analyze the standard deviation within treatments. All statistical analyses were performed by using SPSS software (SPSS version 17, Inc., USA).

RESULTS AND DISCUSSION

Figure **1** shows the occurrence of aflatoxins in freshly harvested chilies as well as sun dried chilies during and post drying stages. Such drying conditions represent the common practice at farm and market levels all over the chili producing areas in Pakistan. On harvest, aflatoxin was not detected in samples collected from all the locations, except a negligibly small quantity (0.33ppb) at one of the site i.e. Samaro. This indicates that possibly aflatoxins are not produced at pre-harvest stage. In an earlier article, aflatoxins development can initiate at pre-harvest level as a result of pre-existing fungal infestation [10]. Several other studies found it to be associated with crop damage by birds, mammals, insects or mechanical injury, and/or a result of hot and dry weather [11-15].

The samples that were taken during drying stage (7th day) showed slightly different results. Only a negligible quantity of aflatoxins was detected in chili samples collected from four of the localities. The maximum levels of 0.95 ppb (dry basis) were found in samples collected at Mithi, followed by Samaro and Morjhango. These results indicate that fungal contamination and resultant aflatoxin production initiated somewhere within the first fifteen days of drying. The occurrence of fungi especially *A. flavus and A. niger* in chilies[16]. Fungal growth in red pepper becomes stable in 20 days under favorable conditions and aflatoxin production initiates after about 10 days of incubation [17]. Aflatoxin synthesis occurs both in fungal hyphae and conidia, and maximum concentration of aflatoxins synthesis is attained when fungal mycelium /biomass reaches optimal levels [18].

The results as reflected in Figure **1**, exhibit a significant increase in the aflatoxin content in dried chilies over the 30 days as compared to the 7 and 15 days. After the stage 15 days the aflatoxin levels at all the sites in dried red chilies were found to range between 8.61 and 9.96 ppb (X=9.16). The increase in aflatoxins to improper drying and unsuitable storage practices [19]. The dried samples collected from all the locations after 30 days showed a further increase in aflatoxins to range between 30.47 and 32.66 ppb (X = 31.69). The average aflatoxin level during drying and post sun drying period is shown in Figure **2**. Analysis of variance (F=17523; P<0.001) shows that the length of drying period is the main source of influencing the aflatoxins levels in chilies. Improper post-harvest handling along with the poor horticultural and weather conditions may provoke the post-harvest production of aflatoxins in different agricultural commodities [20-22].

Figure **3** shows the rate of increase in aflatoxin levels in chilies with the increase in drying period. It was found that the maximum increase took place in second period of drying, followed by the first drying stage. It is therefore apparent that the critical period of aflatoxins development starts immediately after picking. The possible reasons are the average higher moisture contents (X=22% ±3.6) that were recorded during

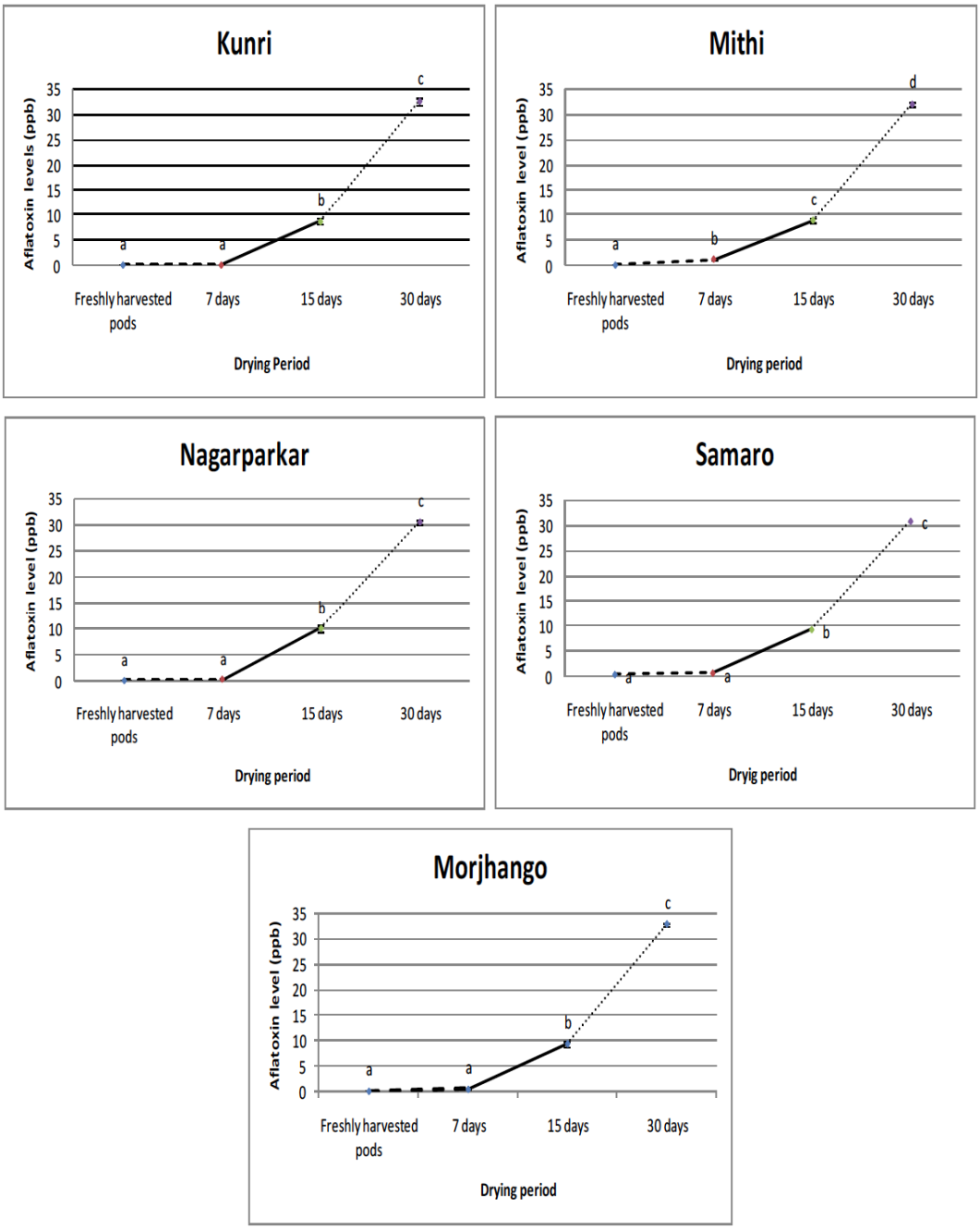

Figure 1: Aflatoxin content of red chilies during and after sun drying. Different small letters within different drying period are significantly different at $p < 0.05$.

drying stage of 7 days (Table **3**) and also a prolonged favorable conditions for fungal development and the resultant aflatoxin production.

Table **2** shows the moisture content in chili samples collected from various locations. A scrutiny of the data shows that on harvest the average moisture content (MC) was found to range between 67.9 and 72.1% (X=69.7). As a result of sun drying and subsequent environmental conditions during drying the average MC declined to 10.72% and subsequently 9.87% after fifteen days of drying stage. The progressive reduction in moisture during drying was a net result of natural process that desorbed the moisture from chili pods to develop and maintain moisture-humidity equilibrium under the influence of prevailing atmospheric conditions. Although the progressive reduction in moisture of chilies reflect the efficiency of sun drying, the process was too slow and drying the chilies to the desired level (MC 10% or below) took several days. The presence of high moisture in the produce during the drying period, coupled with favorable atmospheric

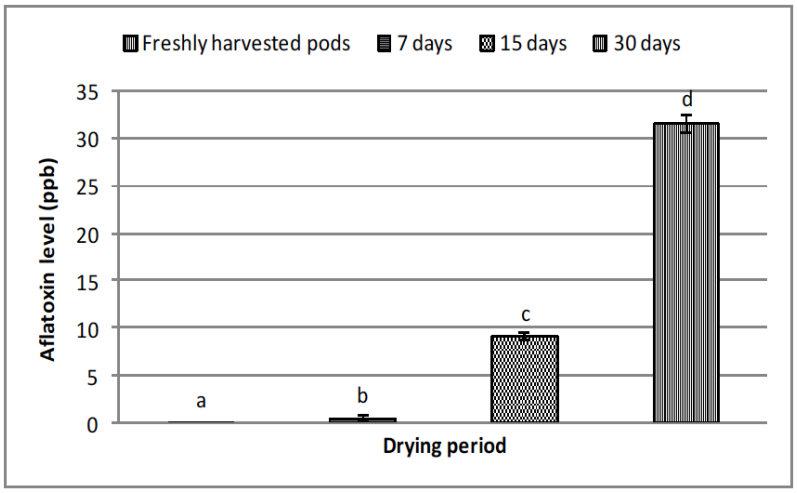

Figure 2: Average aflatoxin level of red chilies during and after sun drying. Different small letters within different drying period are significantly different at $p < 0.05$.

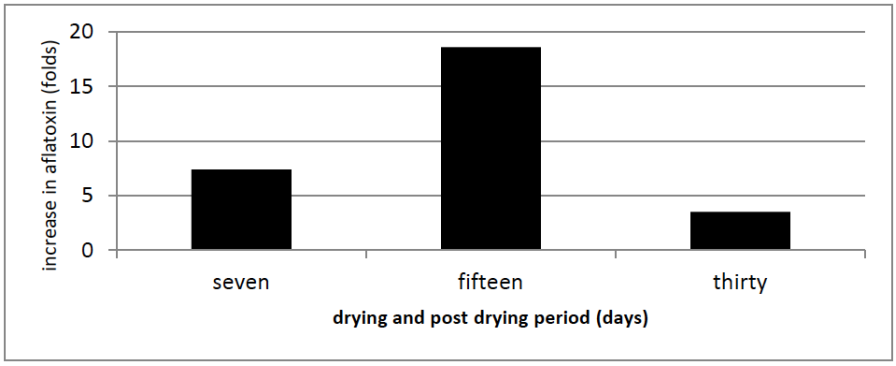

Figure 3: Increase in aflatoxins with respect to the drying and post drying period.

Table 2: Moisture Content (%) in Red Chilies after Different Drying Periods

Study Location	Freshly harvested	Moisture content (%)		
		Length of time (days)		
		Seven	Fifteen	Thirty
Kunri	69.46±0.45 ^{a,A}	25.86±0.35 ^{b,A}	10.6±0.08 ^{c,A}	9.96±0.15 ^{c,A}
Mithi	72.1±0.38 ^{a,B}	17.07±0.55 ^{b,B}	10.71±0.15 ^{c,A}	9.87±0.11 ^{c,A}
Nagarparkar	69.22±0.52 ^{a,A}	19.38±0.61 ^{b,C}	10.93±0.66 ^{c,ABC}	9.89±0.09 ^{c,A}
Morjhango	67.96±0.25 ^{a,C}	24.53±0.43 ^{b,D}	10.02±0.15 ^{c,C}	9.81±0.13 ^{c,A}
Samaro	69.79±0.56 ^{a,D}	23.2±0.88 ^{b,D}	11.38±0.38 ^{c,B}	9.84±0.12 ^{d,A}
Mean	69.7±1.5	22.0±3.6	10.72±0.49	9.87±0.05

Different small letters within same rows are significantly different at $p < 0.05$.
Different capital letters within same columns are significantly different at $p < 0.05$.

temperatures and humidity, provided substrate for possible fungal growth that led to the observed buildup of aflatoxins [23, 24].

Thus the speed and efficiency of the drying process is very crucial to maintain quality during storage of dried chilies and chili products until they are consumed. In Pakistan, almost all the chili produced is subjected to sun drying. The effectiveness of the drying process under sunlight in uncontrolled climatic conditions may possibly be influenced by several factors, such as the surface area of drying yards, thickness of the pile,

frequency of turning over, and the duration of drying etc. Local environmental conditions may also affect the drying process, e.g. fluctuations in temperature during day/night, soil moisture/salinity, air humidity, dew factor etc. Also, the farm workers involved in the drying process, which lacks any scientific support or training, and in the absence of suitable equipment for monitoring moisture content, etc, mainly relies on visual judgments to make decisions on the course of the drying process.

The effect of moisture content on aflatoxins at different time intervals is shown in Figure **4**. There appear to be no direct relationship between the increase in aflatoxins and the decrease in moisture content of chilies. Apparently the increase in aflatoxins seems to be inversely proportional to the moisture content. This can be explained on account of understanding the "optimum zone of moisture contents for fungal development" that lies between 12% and 25% MC at 25°C [25]. The chilies subjected to drying in the present study remained within this optimum zone of MC for the more than 15 days and possibly provided a breeding period for fungal development that led to subsequent aflatoxin production. However the independency of moisture-aflatoxins relationship requires further investigations as there may be other factors that likely affect the ultimate aflatoxins contents. Some of these may include the presence of green pods that contains relatively higher moisture, nature and extent of fungal development, presence and propagation of aflatoxin producing fungal strains, percentage of pods that are broken or with open viscera, etc. The results, however, clearly indicate that the post-harvest period between 0 to 15 days should be considered as critical for the development of aflatoxins in chilies. The results of the present study have shown that the prevalent practice of sun drying of chilies in Pakistan is inadequate in general. Although the sun drying reduces the moisture content of chilies to desired levels, it however fails to arrest fungal growth and the consequent aflatoxin development. It is also apparent from the results that aflatoxins in chilies do not originate in the field. Their presence therefore reflects the improper drying and handling practices that needs to be improved for safe production of chilies in the country.

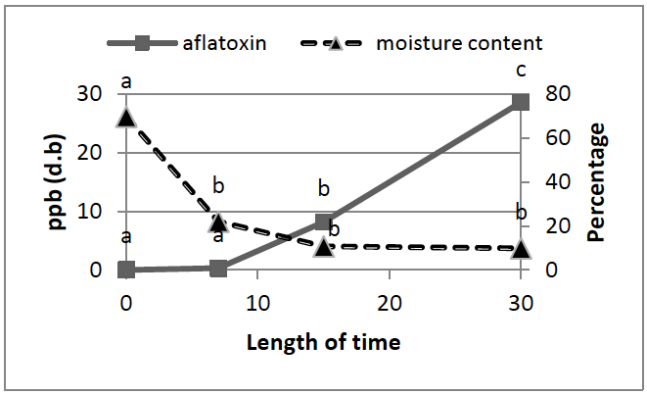

Figure 4: Moisture content and occurrence of aflatoxins in chilies samples at different time intervals. Different letters within same lines are significantly different at $p<0.05$.

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