

## Correlation Between Climatic Data and Aflatoxin Contamination of Iranian Pistachio Nuts

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### ABSTRACT

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All shipments of Iranian pistachio nuts to the USA must be inspected for aflatoxin contamination and at irregular intervals some of them are rejected. The only point-of-origin climatic factors correlated with rejections

were rainfall and number of calm days per month from August through November, the period of ripening and harvest. These conclusions support those of previous studies.

*Additional key words:* relative humidity, temperature, mold, *Aspergillus flavus*.

In 1971, U.S. Food and Drug Administration (FDA) personnel first observed that some shipments of pistachio nuts arriving in the USA from Turkey and Iran were contaminated with aflatoxins. Intensive research was initiated at what is now the Regional Mycotoxin Research and Training Institute at the University of Isfahan. Several years of systematic investigation revealed that pistachio nuts became contaminated on the trees after ripening but before harvest and that complete protection of the nuts on the trees could be obtained by spraying them with captan over a period of 30 days (2). Further systematic checking of the U.S. Department of Agriculture (USDA) inspection reports for all pistachio nut imports revealed wide year-to-year variation in the amount of aflatoxin contamination. The present investigation was initiated to determine whether the variation in aflatoxin contamination of Iranian pistachio nuts was associated with climatic variations.

### MATERIALS AND METHODS

Data on aflatoxin contamination of Iranian pistachio nuts being shipped to the United States were obtained from the USDA, which in 1972 began checking all shipments. The data were compared with climatic data obtained from the Iranian Government Meteorological Station at the airport in Kerman which is in the main pistachio-growing area which ships nearly 90% of the Iranian pistachio nut exports. Statistical evaluations involved calculating correlation coefficients ( $r$  values), regression lines with standard errors of estimate, and  $P$  values based on the null point hypothesis, and  $t$  distributions (6). In some instances, Spearman's rank correlation coefficient ( $R$ ) was determined and from this the  $t$  distribution and  $P$  values were calculated (6).

### RESULTS

The data in Table 1 are means and mean deviations for Iranian climatic data for the crop years 1970 through 1974 and the percentage of rejections for all shipments of pistachio nuts exported to the United States. The Table has been subdivided to show values based on data derived over the whole year (Table 1A)

and values based on data for the months August through November (Table 1B). The period August-November is the critical period during which initial infection of the nuts occurs (4) and the pistachio nuts can remain on the trees for as long as 3 mo, depending on the size of the crop. Ripening can vary as much as 1 mo from year to year. Because the shipments may be enroute into the next calendar year, the values indicated for a given year were

TABLE 1. Climatic data and percent rejections due to aflatoxin contamination of shipments of pistachio nuts from Iran to the USA<sup>a</sup>

Year	Shipments rejected (%)	Rain (mm)	Relative humidity (%)	Temperature (C)	Wind <sup>b</sup>
A. Total year					
1970	76.9	178.8	18.3 ± 7.0	17.1 ± 15.0	...
1971	12.2	164.4	22.0 ± 8.8	...	8.0 ± 4.7
1972	0.1	179.4	25.0 ± 11.0	14.1 ± 2.5	4.0 ± 2.5
1973	11.6	76.8	22.8 ± 9.3	15.4 ± 7.3	9.0 ± 8.2
1974	5.7	256.8	38.0 ± 12.0	14.7 ± 7.5	...
$r$		-0.503	-0.280	-0.565	+0.967
$P$		>0.05	>0.05	>0.05	<0.05
B. August through November					
1970	76.9	61.0	14.3 ± 1.3	18.6 ± 5.7	...
1971	12.2	3.0	15.3 ± 3.4	...	7.5 ± 4.5
1972	0.1	0.0	14.8 ± 2.7	16.8 ± 4.4	5.0 ± 2.5
1973	11.6	2.3	13.8 ± 1.3	17.0 ± 5.3	14.8 ± 8.3
1974	5.7	2.0	27.3 ± 0.8	16.5 ± 6.2	...
$r$		+0.948	-0.213	+0.134	+0.665
$P$		<0.05	>0.05	>0.05	<0.05

<sup>a</sup> Percentage of shipments withheld in 1970 were not used in calculation because the data were derived by criteria other than those used for the years 1971-1974. Data for rain and percentage of shipments withheld for the total year and for August through November are actual values; other data are given as means and mean (+) deviations.  $P$  calculated on the null point hypothesis and  $t$  test;  $P > 0.05$  = not significant.

<sup>b</sup> Wind data = mean number of calm days (at 1200 hours) per month.

determined from data that represented the year in which the crop was produced.

Table 1A shows a large year-to-year variation (0.1–76.9) in the percentage of nut shipments rejected by the United States. The 1970 value is an approximation based on incomplete data and is presented for comparative purposes only. Except for the number of calm days per month, climatic data were not significantly correlated with percent of nuts rejected. As a matter of interest, total mean values of the number of calm days in the months between January and July are presented; these data might be useful for predicting the percentage of nut shipments likely to be rejected by the United States for an approaching season (based on the regression line equation  $y = 0.2x + 3.2$ , in which  $y$  = mean number per month of calm days at 1200 hours and  $x$  = percentage of nut shipments rejected).

For the period August through November only the amount of rain was correlated with percent rejection of nuts. Moreover, the degree of correlation of the number of calm days and percent rejection of nuts, was lower for August through November ( $r = 0.665$ ) than for the total year ( $r = 0.967$ ). It should be noted that although 1973 was a year of low total rainfall (76.8 mm), 2.3 mm of rain fell during the critical August–November period and the United States rejection rate was 11.6%. In 1972, a total of 179.4 mm of rain fell but none fell during the critical period and the rejection rate was only 0.1%.

There was a linear increase in nuts imported monthly from January (2.6%), to a maximum in August (20%), and then a decline to zero in December. The percent rejection each month increased beginning in January to a maximum in April and May and thereafter decreased to the end of the year.

## DISCUSSION

The number of Iranian pistachio nut shipments that were denied entry into the USA due to aflatoxin contamination varied markedly from year to year. Undoubtedly, similar observations could be made for imports from other countries. The yearly variation apparently is directly related to the amount of rainfall in the period from after ripening to harvesting, when the nuts are still on the trees. It is during this time that aflatoxin contamination of the pistachio nuts occurs as was shown in an earlier report (4).

When ripe, 85–95% of the outer integuments of Iranian pistachio nuts have split which allows the entry of airborne spores of aflatoxin-producing molds (2). Only when rainfall occurs does the relative humidity (RH) rise sufficiently to allow *Aspergillus flavus* spores to germinate and produce aflatoxin. Denizel et al (1) reported that 82% RH is the minimum humidity required for *A. flavus* spore germination and aflatoxin production in Turkish pistachio nuts. This is well above the relative humidity maximum (62%) recorded for any month in the pistachio-growing area of Iran

(3), except when it rains. Also, when nuts are commercially picked they are immediately processed and patio-sun-dried which usually requires 48 hr; this period may be increased to 120 hr if it rains. This increased drying time would favor fungal spore germination. Not absolutely ruled out is the possibility that a particular insect, or insects, may appear and its population drastically increase when it rains during the August–November critical period. These insects introduce aflatoxin-producing fungi into ripened pistachio nuts as has been reported for other crops (5).

The extent of aflatoxin contamination in pistachio nuts was affected more by the amount of precipitation during the post-ripening/preharvest period than by storage and shipment conditions. Although the monthly shipments of pistachio nuts to the USA reached a maximum in August, the maximum percentage of shipments that were denied entry for each year occurred in April and May and decreased thereafter. By means of the Spearman significance rank correlation ( $R$ ) (6), (which is based on assigning a positive value only when increased nut contamination was positively associated with storage and shipping time) for each of three complete years for which import data are available, it was determined that aflatoxin contamination and storage and shipping time were not positively correlated (1972,  $R = +0.079$ ; 1973,  $R = -0.63$ ; 1974,  $R = -0.76$  corresponding to  $P =$  not significant,  $P = <0.05$ , and  $P = <0.05$ , respectively). A negative Spearman rank correlation coefficient suggests that the aflatoxin contamination decreased instead of increasing as might be expected with the longer storage periods.

Thus, these observations indicate that aflatoxin contamination of Iranian pistachio nuts is correlated with rainfall after ripening but before harvest and therefore explain the denial of entry of the nuts into the United States.

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