Efficacy of Electronic Color Sorting and Hand Picking to Remove Aflatoxin Contaminated Kernels from Commercial Lots of Shelled Peanuts[1]

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ABSTRACT

Samples (200-lb) from 40 commercial lots of shelled peanuts which contained an average concentration of 48 parts-per-billion aflatoxin were sorted with an electronic color sorter 3 to 5 times and then hand picked in an attempt to remove discolored kernels which usually contain higher concentrations of aflatoxin than other kernels. Prediction equations indicated that cumulative removal of 2, 4, 6, 8 and 10% of the kernels from each sample by electronic sorting would remove an average of 16, 28, 37, 45 and 51% of the aflatoxin, respectively. Electronic sorting became less selective for aflatoxin-contaminated kernels during each additional sorting operation. Careful hand picking for discoloration was far more selective for aflatoxin-contaminated kernels than electronic color sorting. An average 72% of the aflatoxin was in kernels that were removed by electronic sorting and subsequent hand picking. The efficacy of aflatoxin removal with electronic sorting was highly variable among lots. This variability indicates that each lot should be pretested to determine if aflatoxin can be effectively removed before the expense of electronic color sorting is incurred.

Key words: aflatoxin, decontamination, electronic sorting, color sorting, discoloration, hand-picking, selectivity, peanuts, kernels, effectiveness.

All commercial lots of shelled peanuts marketed in the United States are tested for aflatoxin and lots testing higher than 25 parts-per-billion (ppb) are restricted to crushing for oil. Aflatoxin is not present in the oil, after proper refining, but is retained in the meal which is restricted from human or animal food.

Since aflatoxin is a metabolite of *Aspergillus flavus,* kernels discolored by growth of this mold generally have higher concentrations of aflatoxin than other kernels. However, aflatoxin may be found in undiscolored kernels, and may be absent in kernels discolored by many other molds or other causes.

For many years most peanut shellers in the United States have removed discolored kernels from shelled peanuts by electronic color sorters and/or hand picking. Initially this operation was used to reduce the percentage of damaged (discolored) kernels in compliance with grade standards for shelled peanuts. The aflatoxin problem has caused increased use of electronic color sorting throughout the peanut industry, and most lots of shelled peanuts are sorted electronically when they are shelled.

Blanching of peanuts (removal of the skin or testa) followed by electronic sorting and hand picking has been used to remove aflatoxin-contaminated kernels. Discolored kernels are more easily detected when the skin is removed, and the heat treatment used in blanching may cause molded kernels to turn darker. Some molded kernels retain their skins after the blanching process and are easily detected. The market price for blanched peanuts generally is not high enough to offset the additional costs of blanching; so the peanut-shelling industry usually avoids blanching and uses electronic sorting and hand picking in an attempt to remove aflatoxin contamination from restricted lots of shelled peanuts and make them eligible for unrestricted use. Although properly operated electronic sorters effectively remove badly discolored kernels, the authors found no published information concerning the removal of aflatoxin contamination from commercial lots of shelled peanuts which usually have already been electronically sorted and/or hand picked.

The purpose of this study was to determine the efficacy of electronic color sorting and subsequent hand picking to remove aflatoxin-contaminated kernels from commercial lots of shelled peanuts.

Materials and Methods

Minilots (200-lb samples) were taken from 40 commercial lots of shelled peanuts which contained over 25 ppb aflatoxin according to official industry tests (3). These minilots were electronically color sorted and hand picked according to the flow diagram in Figure 1. Before sorting each minilot, the sorter was adjusted to remove about 4% of the kernels in a 1-kg sample. The entire minilot was then sorted; the reject portion was held for aflatoxin analysis and the accept portion was resorted. Resorting was continued until the accept portion had passed through the sorter from 3 to 5 times. For a given minilot, the sorter adjustments remained the same during all runs. Sorting rate was approximately 1800 kernels per minute.

After electronic sorting was completed, the accepted portion was carefully hand picked to remove all kernels with external discoloration. The accepted kernels were then split and carefully hand picked for internal discoloration; the kernel splitter and inspection belt was similar to those used by the Federal-State Inspection Service (1). Examination for discoloration during hand picking was much more thorough than would be feasible for commercial operations (about 80 lbs/man-hr.). The reject portions from hand picking were also held for aflatoxin analysis.

The accept portion from each minilot was subdivided into 12-pound samples, which were comminuted in a subsampling mill (2); a 280-g subsample from each sample was analyzed for aflatoxin. Aflatoxin concentra-

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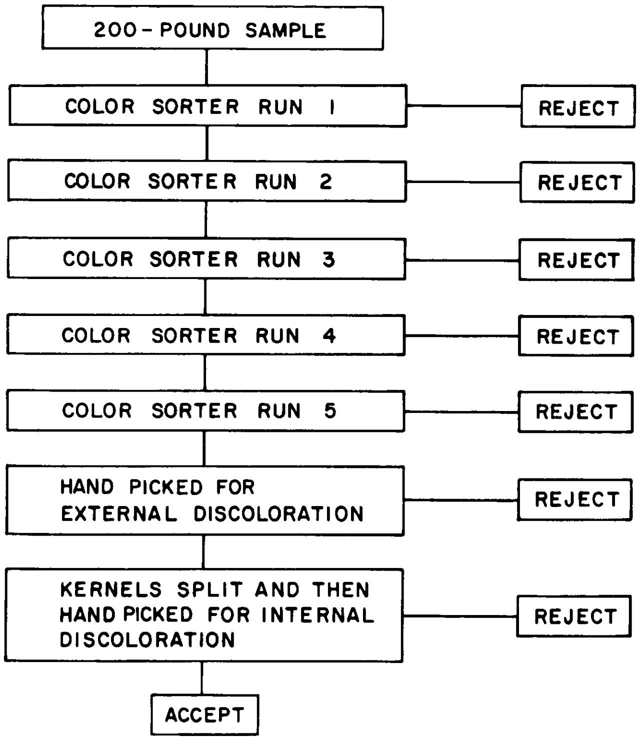

Fig. 1. Flow diagram for electronic-color-sorting and hand-picking 200-pound samples of shelled peanuts from commercial lots which tested over 25 parts-per-billion aflatoxin concentration. (Runs 4 and 5 were optional.)

tion in the accept portion was estimated by averaging the test results. The reject portions were comminuted in a mill similar to the subsampling mill except the meal was not subsampled. If the reject portion weighed 280 g or more, the comminuted sample was subdivided to 280 g for analysis. The aflatoxin concentration of the accept portion after each step in the sorting test was determined by computing weighted averages of the aflatoxin concentrations in the reject portions from every subsequet step and the final accept portion. The Waltking method was used for aflatoxin analysis (4).

Eleven minilots from shelled peanuts produced in 1970 were sorted with a Sortex Model 423 II Special and 29 minilots from shelled peanuts produced in 1971 were sorted with an ICORE Model 5141. Each electronic sorter was installed by a company representative and operated in accordance with his instructions and with literature provided by the manufacturer. This study was not designed to compare the efficacy of the two electronic sorters mentioned. Peanuts used in tests with the two sorters were produced in separate crop years and no attempt was made to avoid differences in market type, market grade, variety, production and storage history, or aflatoxin concentration. Also, one sorter was inadvertently adjusted to reject more kernels than the other sorter during most sorting runs. The effects of variability among lots, sorter adjustment and experimental error, which are discussed below, preclude an objective comparison of the two sorters on the basis of aflatoxin removal in this study.

Results and Discussion

Percentages of minilot weight and of total aflatoxin content removed from each 200-pound minilot by the electronic color sorters are given in Table 1. The lots are ranked by total aflatoxin

Table 1. Percentage of total minilot weight (W) and percentage of total aflatoxin (A) removed from 200-lb. minilots of shelled peanuts by successive passes (runs) through an electronic color sorter.

Lot No.	PPB*	G**	Run 1 W	Run 1 A	Run 2 W	Run 2 A	Run 3 W	Run 3 A	Run 4 W	Run 4 A	Run 5 W	Run 5 A
1	13	1	3.3	6.3	1.5	1.7	1.4	3.1	1.1	1.3	1.2	1.0
2	14	2	5.4	18.4	3.0	10.9	3.6	2.6	2.2	2.1	1.7	1.1
3	14	2	3.1	15.3	1.9	10.5	1.7	3.2	1.7	1.7	1.4	1.8
4	16	3	3.0	8.9	4.5	12.1	2.3	3.6	2.9	2.7	2.6	4.9
5s	16	2	6.4	15.1	7.2	7.6	5.7	6.5	---	---	---	---
6	16	2	2.5	15.5	2.0	4.8	1.2	1.3	1.5	5.5	---	---
7	18	3	3.2	15.0	1.9	2.0	1.6	1.8	1.4	2.1	---	---
8	18	2	2.2	14.7	2.2	12.3	1.8	7.6	1.3	1.8	1.2	3.4
9	19	1	3.1	9.7	1.2	3.1	1.1	4.9	1.1	7.9	0.9	1.3
10	19	3	3.3	53.4	3.8	2.2	1.8	0.0	0.5	0.0	---	---
11	20	3	3.6	16.0	2.7	8.3	2.2	2.4	0.8	5.9	---	---
12	21	2	3.6	24.1	1.7	8.6	1.8	5.3	1.2	4.2	1.2	3.1
13	23	2	2.7	31.0	4.6	12.4	2.5	5.3	2.0	1.1	---	---
14	24	1	5.0	28.3	2.7	10.8	1.7	5.3	1.8	5.6	1.6	4.6
15	24	2	2.9	20.8	1.2	4.2	1.8	3.4	1.4	7.5	1.3	1.5
16	24	2	1.7	5.0	1.3	0.3	1.7	0.8	1.4	0.2	1.2	0.1
17	25	3	2.3	16.9	3.4	9.1	2.2	1.6	1.8	0.8	1.3	0.2
18s	28	3	5.3	76.9	3.1	11.8	2.7	6.2	---	---	---	---
19	28	2	2.6	15.2	1.7	6.3	1.7	4.0	2.4	4.3	1.8	2.4
20s	30	3	4.2	53.1	3.4	15.1	2.7	6.1	---	---	---	---
21	31	2	2.5	10.7	1.7	6.1	1.3	3.3	1.3	3.4	1.1	2.3
22	34	1	2.6	23.4	0.8	3.3	0.8	0.6	---	---	---	---
23	38	1	2.9	36.2	1.7	25.9	1.7	10.6	---	---	---	---
24	40	2	3.9	45.8	1.3	10.6	2.3	16.5	1.6	9.7	1.4	7.2
25	40	1	3.6	10.7	2.0	3.4	0.6	1.3	1.6	7.5	1.4	1.3
26	41	1	2.8	9.4	1.3	1.6	1.1	1.2	0.9	3.3	0.9	3.0
27	45	2	3.8	42.5	1.8	3.1	1.5	0.6	1.2	1.6	---	---
28s	45	3	5.0	54.2	4.0	25.3	2.6	5.0	---	---	---	---
29	47	2	4.0	16.9	2.4	4.5	2.2	3.5	1.3	1.3	---	---
30	48	4	2.8	61.1	1.6	8.3	0.9	1.8	0.9	1.4	0.8	3.2
31s	51	2	10.1	61.1	6.2	9.4	4.5	3.8	---	---	---	---
32	54	2	5.4	50.8	1.7	4.1	2.3	1.6	1.8	32.1	1.7	5.3
33	54	2	3.0	7.4	2.5	5.1	1.1	1.5	---	----	---	---
34s	65	3	4.7	45.6	3.5	16.1	2.5	4.3	---	---	---	---
35s	78	3	5.8	48.5	2.5	23.2	3.0	1.8	---	---	---	---
36s	86	2	5.9	47.7	3.7	25.0	3.0	5.3	---	---	---	---
37s	95	3	6.4	60.0	4.4	12.9	3.5	6.6	---	---	---	---
38	99	3	1.9	8.8	1.4	1.3	1.3	2.5	1.5	0.9	---	---
39s	123	3	4.6	65.5	3.0	16.1	3.0	1.7	---	---	---	---
40s	400	3	5.8	68.8	3.6	13.9	3.7	1.2	---	---	---	---
Avg	48		3.9	30.8	2.7	9.3	2.2	5.2	---	---	---	---

Note: The Sortex sorter was used when the lot number includes s.
Averages may not agree with tabulated data due to rounding errors.

*Initial parts per billion (ppb) aflatoxin in minilot.

**Grade and type: 1 = US1 Spanish, 2 = US1 runner, 3 = US1 runner with splits, 4 = US medium Virginia.

concentration which ranged from 13 ppb to 400 ppb and averaged 48 ppb. Grade and type for each lot are also given.

Variance of Aflatoxin Tests

Studies on aflatoxin concentrations in peanuts are often unreliable because of sampling errors (5). Even though 200-pound minilots were used, most of the reject portions were so small that the coefficient of variation (CV) among aflatoxin test results would be large if replicated tests were made on several minilots from the same lot. Since it was desirable to test a large number of lots, replicated tests on each lot was not feasible. To guide readers and to caution those who may conduct similar studies, the magnitude of errors that may be associated with these tests are indicated below.

Whitaker et al (5) derived basic equations for sampling variance (σ_s^2), sub-sampling variance (σ_{ss}^2), and analytical variance (σ_a^2). Substitution of constants and terms appropriate for this study gives the following equations:

$$\sigma_s^2 = (10{,}634/n)\ (9.0546\ \mu^{1.3955} - 0.3494\ \mu^{1.7867})$$

$$\sigma_{ss}^2 = (280/w)\ (1-(w/W))\ (0.3494\ \mu^{1.7867} - 0.0637\ \mu^{1.9339})$$

$$\sigma_a^2 = (1/N)\ (0.0637\ \mu^{1.9339})$$

where:

n = number of kernels in sample.

μ = aflatoxin concentration (ppb) in the population sampled.

w = weight of subsample of comminuted peanuts. (Subsamples generally weighed 280 g. If W was less than 280 g, the entire sample was used, and $\sigma_{ss}^2 = 0$).

W = weight of comminuted sample of peanuts

N = number of analyses per subsample. (Only one analysis/subsample was made in this study.)

Total variance for aflatoxin tests σ_t^2 and the coefficient of variation (CV) for the tests can then be computed with the following equations:

$$\sigma_t^2 = \sigma_s^2 + \sigma_{ss}^2 + \sigma_a^2$$

$$CV = 100\ \sigma_t/\mu$$

The above equations were used to calculate expected CV for aflatoxin tests on the four types of samples analyzed in this study. These values are listed in Table 2 along with values for n and μ used in the calculations. All samples within each type were used to obtain average values for n and μ. There was considerable variation in these values within each type and the CV for individual tests would vary accordingly. The tabulated CV indicate that only data based on averages across lots have reasonably low CV.

Table 2. Approximate coefficients of variation (CV) expected for aflatoxin tests on four types of samples. All samples with each type were used to obtain the tabulated averaged number of kernels (n) and prats-per-billion of aflatoxin concentration (μ).

	n*	μ	Individual Test CV	CV for Averages: No. tests in average	CV for Averages: CV
ACCEPT PORTION	10,634	9	155		
All samples averaged within lot				15	40
All samples averaged across lots (15 X 40)				600	6
REJECT FROM ELECTRONIC SORTING	4,519	230	80		
5 Runs averaged within lot				5	36
5 Runs averaged across 18 lots (5 X 18)				90	8
1 Run averaged across 18 lots (1 X 18)				18	19
1 Run averaged across 40 lots (1 X 40)				40	13
All Runs averaged across all lots (14 X 3) + (8 X 4) + (18 X 5)				164	6
REJECT FROM HAND PICKING FOR EXTERNAL DISCOLORATION	1,241	2388	43		
Averaged across 40 lots				40	7
REJECT FROM HAND PICKING FOR INTERNAL DISCOLORATION	177	2346	101		
Averaged across 40 lots				40	16

*An average of 886 kernels/pound was assumed for all samples

SELECTIVITY OF ELECTRONIC SORTING

Average percentages of the original minilot weight rejected by each of 3 sorting runs on all 40 minilots and by 5 sorting runs on 18 minilots are plotted in Figure 2. The average concentrations of aflatoxin in the rejected portions from these minilots are also plotted. Projections of the curves for percent weight rejected indicate that at least 1% of the original weight of the minilots would be removed for each of several more consecutive sorting runs. If the sorters were highly selective for aflatoxin-contaminated kernels, the first run would have removed most of these kernels and each subsequent run would have removed very few. With the exception of Run 4, lower concentrations of aflatoxin were found in the reject portion from each subsequent run. This may result from a lower percentage of aflatoxin-contaminated kernels and/or lower aflatoxin concentrations in the contaminated kernels in the reject portion from each subsequent run.

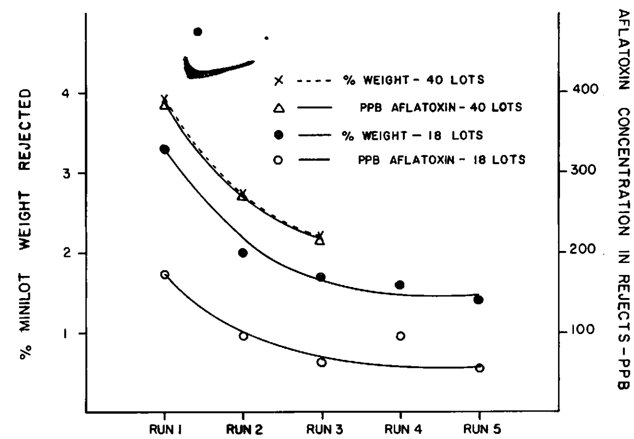

Fig. 2. Average percentages of original minilot weights rejected by each of 3 sorting runs on all 40 minilots or 5 sorting runs on 18 minilots and average parts-per-billion (ppb) aflatoxin concentrations in each rejected portion.

The sorter adjustments used in this study were more sensitive than those normally used for commercial sorting, and they probably caused rejection of a high percentage of aflatoxin-free kernels each run. Peanut kernels may vary in skin color, shape, size and other characteristics which affect the amount of light they reflect during electronic sorting. Also, orientation of kernels during the short interval of illumination and reflectance measurement affects the amount of reflected light detected by the sorter photocells. When the electronic sorter is adjusted to remove kernels with small amounts of discoloration caused by mold, variation in these kernel characteristics and kernel orientation cause the sorter to be less selective for aflatoxin - contaminated kernels. However, some selectivity for aflatoxin-contaminated kernels in Run 5 is indicated by the 53 ppb aflatoxin concentration in the reject portion compared to 18 ppb in the accept portion. (Data for aflatoxin concentration in the accept portion are not shown).

In order to estimate the percentages of aflatoxin (A) that would have been removed if designated percentages of minilot weight (W) were removed, a regression equation of the form $A = 100\ (1-e^{-0.01\ BW})$ was fitted to the data in Table 1. Values for B and the regression correlation coefficient r are listed for each lot in Table 3. Computed percentages of aflatoxin that would have been removed if 2, 4, 6, 8 or 10% of each minilot were removed in 2% increments by repetitive sorting are also listed. When the average percentage weight removed (W) increased from 2% to 10% the averaged percentage aflatoxin removed (A) increased from 15.9% to 50.7%, but the ratio (A/W) dropped from 8.0 to 5.1. This drop in A/W as A and W increase agrees with Figure 2 and shows that the electronic color sorters become less selective for aflatoxin-contaminated kernels after a portion of the kernels and aflatoxin have been removed.

Data are not available from this study to determine if the reject portion from an aflatoxin-contaminated lot of shelled peanuts would contain a higher aflatoxin concentration if all of the kernels were removed in one run rather than in several successive runs. The indication that background noise causes aflatoxin-free kernels to be rejected during each run suggests that more selective rejection may be obtained by removing all of the rejects in one run. However, the high sensitivity required to remove a high percentage of rejects in one run may cause more background noise and rejection of more aflatoxin-free kernels than would be rejected in multiple runs.

VARIABILITY AMONG LOTS

Efficacy of aflatoxin removal by electronic sorting was highly variable among minilots listed in Table 3. Percentage of aflatoxin removed when 2% of the minilot weight was removed by electronic sorting ranged from 2.3% to 47.9% and averaged 15.9%. When 10% of the minilot weight was removed in 2% increments by repetitive electronic sorting, the percentage of aflatoxin removed ranged from 11.0% to 96.2% and averaged 50.7%. These apparent differences among minilots are probably due to differences in electric color sorting and hand picking operations performed on the lots before the minilots were taken for this study, to differences in the nature of the aflatoxin contamination, to differences in kernel characteristics which affect the selectivity of color sorting (discussed in the previous section), and to aflatoxin-testing errors already discussed.

Previous sorting and hand-picking operations performed on each lot probably affect the efficacy of subsequent color sorting to remove aflatoxin contamination from that lot. If lots contain aflatoxin after proper sorting and handpicking, further sorting operations probably will not be effective. However, color sorting may be highly effective on those lots which were not properly sorted during the milling operation.

The effects of the nature of aflatoxin contamination on the efficacy of aflatoxin removal by electronic sorting are indicated in Table 4. After an average 10.3% of the minilot weights was rejected by electronic sorting (ES), the accept portions were hand picked for external discoloration (HPAE). Kernels in the accept portions after HPAE were then split open and hand picked for internal discoloration (HPAI). The percentage of aflatoxin removed by HPAE ranged from 0.2% to 85.2% of the total aflatoxin in individual minilots and averaged 21.8%. After HPAE the accept portions contained an average of 28.7% (11.4% + 17.3%) of the aflatoxin initially in the minilots.

Table 3. Estimated percentages of aflatoxin conntent (A) removed if 2, 4, 6, 8 or 10% of minilot weight (W) were removed in 2% intervals by repetitive electronic sorting. Percentages were computed from data in Table 1 with the regression equation: $A = 100\ (1-e^{-0.01\ BW})$. Values for B and the regression correlation coefficient r are listed.

Lot No.	PPB*	B	r	Cumulative Percentage of Minilot Removed (W) 2	4	6	8	10
1	13	1.79	1.00	3.5	6.9	10.2	13.3	16.3
2	14	3.04	0.99	5.9	11.4	16.6	21.6	26.2
3	14	4.56	0.99	8.7	16.7	23.9	30.6	36.6
4	16	2.67	1.00	5.2	10.1	14.8	19.3	23.5
5s	16	1.86	0.99	3.7	7.2	10.6	13.9	17.0
6	16	4.64	0.99	8.9	17.0	27.3	31.0	37.2
7	18	3.18	0.98	6.2	12.0	17.4	22.5	27.3
8	18	6.28	1.00	11.8	22.2	31.4	39.5	46.6
9	19	4.02	0.99	7.7	14.9	21.4	27.5	33.1
10	19	10.11	0.96	18.3	33.3	45.5	55.4	63.6
11	20	4.44	1.00	7.9	15.3	22.0	28.2	33.9
12	21	6.67	1.00	12.5	23.4	33.0	41.3	48.7
13	23	6.71	0.98	12.6	23.5	33.2	41.5	48.9
14	24	6.28	1.00	11.8	22.2	31.3	39.5	46.6
15	24	5.99	0.99	11.3	21.3	30.2	38.1	45.1
16	24	1.16	0.95	2.3	4.5	6.7	8.9	11.0
17	25	3.68	0.97	7.1	13.7	19.8	25.5	30.8
18s	28	26.82	1.00	41.5	65.8	80.0	88.3	93.2
19	28	4.32	0.99	8.3	15.9	22.8	29.2	35.1
20s	30	14.29	1.00	24.8	43.5	57.6	68.1	76.0
21	31	3.99	1.00	7.7	14.8	21.3	27.3	32.9
22	34	8.47	0.99	15.6	28.7	39.9	49.2	57.1
23	38	20.37	1.00	33.5	55.7	70.5	80.4	87.0
24	40	19.15	0.99	31.8	53.5	68.3	78.4	86.3
25	40	2.97	1.00	5.8	11.2	16.3	21.2	25.7
26	41	2.77	1.00	5.4	10.5	15.3	19.9	24.2
27	45	9.23	0.98	16.9	30.9	42.5	52.2	60.3
28s	45	16.67	1.00	20.4	40.7	63.2	73.6	81.1
29	47	3.40	0.99	6.6	12.7	18.5	23.8	28.8
30	48	22.80	0.99	36.6	59.8	74.5	83.9	89.9
31s	51	7.18	0.99	13.4	25.0	35.0	73.7	51.2
32	54	16.95	0.96	28.8	49.2	63.8	74.2	81.6
33	54	3.74	0.95	7.2	13.9	20.1	25.9	31.2
34s	65	10.91	1.00	19.6	35.4	48.0	58.2	66.4
35s	78	17.49	0.98	29.5	50.3	65.0	75.3	82.6
36s	86	11.39	1.00	20.4	36.6	49.5	59.8	68.0
37s	95	11.71	1.00	20.9	37.4	50.5	60.8	69.0
38	99	2.76	0.98	5.4	10.5	15.3	19.8	24.2
39s	123	32.61	0.97	47.9	72.9	85.9	19.6	96.2
40s	400	21.03	1.00	34.3	56.9	71.7	81.4	87.8
Avg.	48			15.9	27.9	37.2	44.6	50.7
Ratio of Average A to Average W				8.0	7.0	6.2	5.6	5.1

Note: Averages and computed data may not agree with tabulated data due to rounding errors. r values of 1.00 are due to rounding.
*Initial parts per billion (ppb) aflatoxin in the minilot.

The percentage of aflatoxin removed by HPAI ranged from 0.0% to 81.6% of the total amount in individual minilots and averaged 11.4%. Aflatoxin-contaminated kernels with only internal discoloration cannot be removed by electronic sorting which only detects external discoloration. After HPAI the percentage of aflatoxin remaining in the accept portion ranged from 0.0% to 53.6% of the initial aflatoxin content of individual minilots with an average of 17.3%. Apparently this aflatoxin was in kernels infected with an aflatoxin-producing mold whose growth was arrested in an early stage of infection by drying or other conditions. These infected kernels contained aflatoxin but did not have enough discoloration to be removed by electronic sorting or hand picking.

COMPARISON OF ELECTRONIC SORTING AND HAND PICKING

Selectivity is indicated for ES, HPAE and HPAI by the ratios A/W in Table 4. Averaged ratios of A/W were 4.8, 31.1 and 104.9 for ES, HPAE and HIPAI, respectively. The 31.1 ratio for HPAE indicates that hand picking is far more selective than electronic sorting and that the selectivity of electronic color sorting might be improved. The 104.9

Table 4. Percentages (A) of total aflatoxin content in portions rejected (or finally accepted) from each 200-pound minilot by electronic color sorting (ES), by hand picking the ES accept portion for external discoloration (HPAE), and by splitting open accepted kernels from HPAE and hand picking for internal discoloration (HPAI). "W" indicates the percentage of the minilot weight in each rejected (or finally accepted) portion.

Lot No.	PPB*	ES			HPAE			HPAI			ACCEPT	
		A	W	A/W	A	W	A/W	A	W	A/W	A	W
1	13	13.4	8.5	1.6	5.0	0.7	7.1	81.64	0.17	480.2	0.0	90.6
2	14	35.0	16.1	2.2	26.8	0.4	66.0	19.71	0.21	93.8	18.5	83.4
3	14	32.6	9.8	3.3	5.4	0.2	27.0	27.66	0.24	94.4	39.3	89.7
4	16	32.2	15.2	2.1	47.9	1.8	26.6	19.89	0.16	124.3	0.0	82.9
5s	16	29.2	19.4	1.5	70.8	0.1	708.0	0.00	0.00	-----	0.0	80.5
6	16	27.1	7.1	3.8	39.1	0.1	391.1	16.30	0.27	60.4	17.5	92.5
7	18	20.8	8.2	2.5	45.7	0.4	114.1	7.52	0.25	30.1	25.9	91.2
8	18	39.8	8.7	4.6	16.5	0.3	55.0	18.61	0.20	93.0	25.1	90.8
9	19	27.0	7.4	3.6	13.3	0.9	14.8	16.08	0.10	160.8	43.7	91.6
10	19	55.7	9.4	5.9	17.8	0.6	29.7	7.80	0.07	29.4	18.8	89.9
11	20	32.6	9.3	3.5	7.2	0.6	12.0	19.50	0.07	278.6	40.7	90.0
12	21	45.3	9.5	4.8	26.7	0.2	133.5	6.85	0.29	23.6	21.5	89.9
13	23	49.8	11.8	4.2	8.9	0.4	22.2	18.40	0.04	460.0	22.9	87.8
14	24	54.6	12.8	4.3	23.0	0.9	32.8	14.99	0.14	107.1	7.4	86.3
15	24	37.4	8.5	4.4	0.8	0.6	1.3	28.21	0.20	141.0	53.6	90.7
16	24	6.6	7.4	0.9	15.3	0.5	50.6	40.61	0.29	140.0	37.4	91.8
17	25	28.7	11.0	2.6	39.4	1.1	35.5	7.33	0.05	146.6	24.6	87.8
18s	28	95.0	11.1	8.6	5.0	0.3	16.7	0.00	0.00	-----	0.0	88.7
19	28	32.3	10.2	3.2	27.2	0.2	136.0	11.90	0.14	85.0	28.5	89.4
20s	30	74.4	10.3	7.2	7.9	0.3	26.3	0.00	0.00	-----	17.6	89.4
21	31	25.8	7.9	3.3	10.7	0.3	35.7	24.90	0.14	177.8	38.5	91.7
22	34	27.3	4.2	6.5	3.3	0.4	8.2	18.70	0.10	187.0	50.7	95.2
23	38	72.7	6.2	11.7	9.7	0.5	19.4	0.66	0.03	22.0	17.0	93.2
24	40	89.8	10.6	8.5	1.7	0.3	5.7	6.32	0.10	63.2	2.2	89.0
25	40	24.4	9.3	2.6	52.2	0.7	74.6	7.87	0.09	87.4	15.5	89.8
26	41	18.5	7.1	2.6	48.5	0.7	69.3	1.23	0.25	4.9	31.7	91.9
27	45	47.8	8.3	5.8	44.1	2.9	15.2	4.17	0.08	52.1	3.9	88.7
28s	45	84.5	11.5	7.3	1.8	0.4	4.5	0.00	0.00	----	13.6	88.1
29	47	26.3	9.9	2.7	43.4	0.5	86.8	11.42	0.07	163.1	18.9	89.5
30	48	75.8	7.0	10.8	1.3	0.7	1.9	7.73	0.09	85.9	15.2	92.1
31s	51	74.4	20.9	3.6	21.0	0.1	210.0	0.00	0.00	----	4.6	78.9
32	54	93.9	12.8	7.3	0.2	0.8	0.2	2.67	0.05	53.4	3.2	86.3
33	54	27.6	6.6	4.2	48.7	2.6	18.7	12.13	0.11	110.3	11.7	90.6
34s	65	66.0	10.7	6.2	8.0	0.2	40.0	0.00	0.00	-----	25.9	89.1
35s	78	90.0	11.3	8.0	8.9	0.2	44.5	0.00	0.00	-----	1.1	88.4
36s	86	74.9	12.5	6.0	16.0	0.1	160.0	0.00	0.00	-----	9.1	87.4
37s	95	79.5	14.3	5.6	15.1	0.4	37.8	0.00	0.00	-----	5.4	85.3
38	99	13.5	6.1	2.2	85.2	5.5	15.5	1.28	0.30	4.3	0.0	88.1
39s	123	98.7	11.1	8.9	1.3	0.2	6.5	0.00	0.00	-----	1.7	86.7
40s	400	94.6	13.1	7.2	3.6	0.3	12.0	0.00	0.00	-----	1.7	86.7
Avg.	48	49.4	10.3	4.8	21.8	0.7	31.1	11.43	0.11	104.9	17.3	88.8

*Initial parts per billion (ppb) aflatoxin in sample.

ratio for HPAI indicates a high correlation between internal damage and aflatoxin contamination in kernels from contaminated lots. However, most shelled peanuts are sold as whole kernels; splitting and inspection for internal damage are not commercial practices.

COMPARISON OF EXPERIMENTAL RESULTS WITH INDUSTRIAL EXPERIENCE

Table 5 lists aflatoxin concentrations in the minilots before color sorting, after various percentages of minilot weight were removed and after color sorting following by hand picking. Twenty-three of the minilots contained more than 25 ppb aflatoxin prior to color sorting. Removal of 2, 4, 6, 8 and 10% of the minilot weights reduced the aflatoxin concentration to less than 25 ppb in 9, 30, 43, 56, and 61% of these lots, respectively. The average aflatoxin concentration in all of the minilots was reduced from 48 ppb to 37, 31, 26, 22 and 19 ppb by removal of 2, 4, 6, 8, and 10% of the minilot weights, respectively. Most commercial color-sorting operations remove less than 2% of the lot weight; so they probably are not effective in reducing aflatoxin concentrations to 25 ppb or less in most lots.

Color sorting followed by hand picking for external discoloration removed an average of 11% of the minilot weights and lowered the aflatoxin concentration to 25 ppb or less in all lots. The

Table 5. Aflatoxin concentration in parts per billion (ppb) in accept portions of 200-pound minilots of shelled peanuts when 2, 4, 6, 8, 10 or WES% of total lot weight was removed by electronic sorting (ES) and when WHP% of total lot weight was removed by ES plus hand picking for external discoloration[1].

Lot No.	Initial PPB	PPB after 2, 4, 6, 8, 10 and WES% of total weight removed by ES								PPB after WHP% of weight removed
		2	4	6	8	10	WES	WES	WHP	
1	13	13	13	12	12	12	12	8.5	9.2	11
2	14	13	13	12	12	12	10	16.1	16.4	6
3	14	13	12	11	11	10	10	9.8	10.0	9
4	16	16	15	14	14	14	12	15.2	16.9	4
5s	16	16	16	15	15	15	14	19.4	19.5	0
6	16	15	14	13	12	11	12	7.1	7.3	6
7	18	17	16	16	15	14	15	8.2	8.6	6
8	18	16	15	13	12	11	12	8.7	9.0	9
9	19	18	17	16	15	14	15	7.4	8.3	12
10	19	16	13	11	9	8	9	9.4	10.0	6
11	20	19	18	17	16	15	15	9.3	9.9	13
12	21	19	17	15	13	12	13	9.5	9.8	7
13	23	20	18	16	15	13	13	11.8	13.2	11
14	24	22	19	17	16	14	12	12.8	13.5	6
15	24	22	20	18	16	15	17	8.5	9.1	17
16	24	24	24	24	24	24	25	7.4	7.9	21
17	25	24	22	21	20	19	20	11.0	12.1	9
18s	28	17	10	6	4	2	2	11.1	11.3	0
19	28	26	24	23	22	20	21	10.2	11.5	13
20s	30	23	17	14	10	8	9	10.3	10.6	5
21	31	29	27	26	24	23	25	7.9	8.2	21
22	34	29	25	22	19	16	26	4.2	4.6	25
23	38	26	18	12	8	6	11	6.2	7.7	7
24	40	28	19	14	9	7	5	10.6	10.9	4
25	40	38	37	36	34	33	34	9.3	10.1	11
26	41	40	38	37	36	35	36	7.1	7.8	15
27	45	38	32	28	23	20	26	8.3	11.2	4
28s	45	33	28	18	13	9	8	11.5	11.9	7
29	47	45	43	41	39	37	39	9.9	10.4	16
30	48	31	20	13	8	5	13	7.0	7.8	12
31s	51	45	40	35	31	28	17	20.9	21.0	3
32	54	39	28	21	15	11	5	12.8	13.7	4
33	54	51	48	46	44	41	42	6.6	9.2	14
34s	65	53	44	36	30	24	25	10.7	10.9	19
35s	78	56	40	29	21	15	9	11.3	11.5	1
36s	86	70	57	46	38	31	25	12.5	12.6	9
37s	95	77	62	50	40	33	23	14.3	14.7	6
38	99	96	92	89	86	83	91	6.1	11.6	1
39s	123	65	35	18	10	5	2	11.1	11.4	0
40s	400	268	180	120	81	54	25	13.1	13.3	8
Avg	48	37	31	26	22	19	19	10.3	11.0	10

1/ Calculations of ppb after 2, 4, 6, 8 and 10% weight removal were based on data given in Table 3. Calculations of ppb after WES% and WHP% weight removal were based on direct measurements. Values for WES are sums for values of W in Table 1.

average concentration in all lots was reduced from 48 ppb to 10 ppb. There is no correlation between the initial aflatoxin concentrations in the minilots and the concentrations after color sorting and hand picking. Unfortunately, the careful hand picking procedures used in this study probably would not be commercially feasible.

Limited success in removing aflatoxin contamination with electronic sorting in this study disagrees with the apparent success experienced by the peanut industry. However, this discrepancy is probably due to errors in aflatoxin testing. For example 42% of the 200-pound samples in this study tested 25 ppb or less, although they came from commercial lots which were restricted because they tested over 25 ppb by industry procedures. Statistical analyses based upon procedures similar to those proposed by Whitaker *et al* (6) suggest that about 30% of all commercial lots restricted by present peanut industry test procedures actually contain 25 ppb aflatoxin or less and that 46% of all restricted lots would test 25 ppb or less if tested by the same industry procedures a second time. These results indicate that many of the restricted lots which test less than 25 ppb after electronic sorting would have tested the same without sorting. Apparently, lower aflatoxin tests after electronic sorting are often due to the effects of aflatoxin testing efforts before and/or after sorting rather than to removal of aflatoxin by electronic sorting.

Recommendations

This study indicates that the peanut industry would benefit from the following procedures before incurring the costs of electronic sorting and hand-picking restricted lots of peanuts. (1) Make sufficient tests to confirm the presence of unacceptable aflatoxin concentrations in each restricted lot. (2) Consider previous sorting and milling operations on the lot and their effect on the probability of successful aflatoxin removal by additional sorting. (3) Conduct preliminary studies to determine if electronic sorting alone or electronic sorting plus hand picking will successfully remove the aflatoxin contamination.

Proper adjustment of electronic sorters should be maintained and over-loading avoided. Careful hand picking is extremely important for many lots. If careful hand picking of the entire lot is not economically feasible, at least 10% of the lot should be removed by electronic sorting. Part of this reject portion can be reclaimed by additional electronic sorting and careful hand picking.

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