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Colour sorting - an effective tool to remove aflatoxin contaminated kernels in groundnut

VINOD KUMAR*, N.B. BAGWAN, V.G. KORADIA and R.D. PADAVI
National Research Centre for Groundnut, Ivnagar Road, Junagadh 362 001

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Aflatoxins are naturally occurring fungal toxins produced mainly by *Aspergillus flavus* Link ex Fr. and *A. parasiticus* Spear and are one of the most potent hepatocarcinogens causing serious food quality and safety issues worldwide. The contamination of groundnut (*Arachis hypogaea L.*) with aflatoxins can occur at various stages before harvest, during field drying, curing and in storage (4). The quality of the produce depends on the careful pre-harvest crop husbandry and optimum post-harvest conditions. However, the contamination of groundnut with aflatoxins may occur despite the most strenuous efforts directed at prevention. Therefore, other approaches must be considered but not as an alternative to good agricultural practices. The distribution of aflatoxins is very heterogeneous in a lot. Most of the aflatoxins in contaminated materials reside in only a small proportion of the kernels, commonly less than 1 per cent (7). If this substandard material could be separated and discarded the remaining high quality nuts will be virtually free from aflatoxins.

Groundnuts are generally blanched before processing and value addition. Blanching is the removal of testa by first heating the kernels at a particular temperature and then removing the testa by abrasion. Though, the removal of testa reduces aflatoxin load to some extent, it does not eliminate it completely. The aflatoxin content of different parts of groundnut kernels containing large amounts have been determined and high concentrations were found deeply embedded in individual groundnut kernels (3). Galvez *et al.* (5) developed a manual sorting procedure in Philippines involving deskinning and subsequent sorting of aflatoxin-contaminated groundnut kernels from sound kernels. The objective of this study was to determine the effectiveness of sorting and grading procedures prior to blanching, followed by a combination of manual and electronic eye sorting (camera sorter) after blanching to get rid of the aflatoxin contaminated kernels from the bulk groundnut lots.

The study was conducted in 2008 at National Research Centre for Groundnut, Junagadh (Gujarat) in collaboration with the groundnut processing unit of M/s Jabsons Foods, Bharuch, Gujarat. Farmers' stock of a Virginia bunch groundnut cultivar, GG-20, presumably containing aflatoxins was passed through sequential processes of shelling, sizing and grading (mechanical and camera sorting), roasting, blanching, colour sorting (camera sorting followed by manual sorting) before value addition and packaging. Ten different lots were taken and sequential sorting was performed.

Groundnuts to be shelled were first thoroughly cleaned and then moved by conveyor belt through shelling machines in which they were forced through perforated grates, which separated the kernels from the shell. The shelled groundnuts were cleaned again to remove foreign materials to obtain good quality genuinely HPS (hand-picked and selected) groundnuts, ensuring whole kernels free from damage and admixture. After shelling, the kernels were passed over the various screens to sort them by size. Thereafter, the camera sorter (electronic eye sorter) separated groundnut kernels by colour grades. The camera sorter used in grading was computer controlled with automatic calibration and self check procedures. To remove the mould-contaminated nuts effectively, sorting was performed both before and after blanching.

Roasting was done in roaster at a temperature of 60ºC. This ensured smooth blanching and reduction of splitting of kernels during blanching operations. Blanching was accomplished by passing the kernels through a pre-heated whole nut blancher at 140°C for 25 minutes. To obtain high-quality kernels for food products, blanched groundnuts were passed through camera sorter followed by manual sorting of kernels on picking tables. This culling was done based on colour sorting principle. The advanced high-resolution camera sorter scanned the individual kernels up to 2000 scans per second producing a very high-resolution image. The resultant image data were automatically compared with user-preset parameters to reject the defective kernels using ultra fast pneumatic ejectors.

From each bag of 50 kg groundnut containing farmers' stock (bulk groundnut lot) about 250 g samples was drawn at random from four places and bulked. This was subdivided to get a 250 g final sample. Similarly, for other grades too random samples were drawn and bulked and by subdividing, 250 g final sample was retained for estimation of level of aflatoxin. The aflatoxin content in samples was estimated through indirect competitive ELISA (Enzyme Linked Immunosorbant Assay) as described by Ajitkumar *et al.* (1).

*Corresponding author: vinod@nrcg.res.in; vinod3kiari@yahoo.co.in

Table 1. Aflatoxin content of different grades of whole groundnut isolated by sequential sorting

Fractions	Percent of sample	AflatoxinB_1* (µg kg^{-1})
Bulk groundnut lot	100	100.0-193.5
Rejected by mechanical screening	3.0	2166.0-3457.1
Rejected by camera sorter	15.4	40.0-74.1
Rejected by manual sorting	0.8	150.1-471.0
Good grade HPS lot	80.8	3.3-29.9

*Range of aflatoxin in 10 samples

The results showed that the sequential sorting process was effective in separating aflatoxin-contaminated kernels from bulk groundnut lot (Table 1). The electronic eye sorting in conjunction with manual sorting resulted in reduction of aflatoxin content of bulk lot from approximately 200 µg kg^{-1} to <30 µg kg^{-1} in the good grade HPS groundnut. The grade of groundnuts rejected by mechanical screening, which comprised of shriveled, immature and discoloured kernels in addition to the split kernels, contained the highest level of aflatoxin (2166.0-3457.1 µg kg^{-1}). This indicated that the electronic camera sorter rejected the discoloured kernels presumably contaminated with *A. flavus* and aflatoxins. Goldblatt (6) had reported that the levels of aflatoxins in groundnuts correlate with the proportion of broken shells in the lot and with the number of shriveled and discoloured kernels. The aflatoxin content in the groundnut lot that was rejected by the camera sorter and the manual sorting was in the range of 40.0-74.1 and 150.1-471.0 µg kg^{-1}. Camera sorter not only removed the aflatoxin-affected kernels but also the low-grade groundnut kernel that got partially burnt and discoloured. Sorting or separation concentrated the majority of aflatoxin-contaminated kernels into relatively small fractions. In the process of sorting, however, about 20 per cent of the bulk groundnut lot was rejected, thus increasing the cost of finished products. The repeated verification showed that the HPS grade groundnut thus obtained after the sequential sorting contained no aflatoxin or contained low levels that were well below the acceptable limit of aflatoxin in the international market.

The data on aflatoxin content in the different grades of blanched kernels indicated that the highest level of aflatoxin ($\frac{5}{8}$ 1000 µg kg^{-1}) was in the blanched kernels having large dark brown spots (Table 2). The typical discolouration of aflatoxin-affected kernels could be easily discernible even by the naked eye after blanching (Fig. 1). Blanched kernel with large dark brown spots had aflatoxin in the range of 879.74-1015.18 µg kg^{-1} while kernel with small dark brown spots had aflatoxin in the range of 4.97-40.08 µg kg^{-1} (Table 2). Thus the larger the size of discoloured spots higher was the aflatoxin level. When the aflatoxin-affected kernels were split open the white mycelium with greenish sporulation of the *A. flavus* was visible in most of the kernels, but the same was absent in the kernels that developed burnt spots during roasting (Fig. 2). The blanched kernel with small dark brown spots had aflatoxin in the range of 4.97-40.08 µg kg^{-1} and the kernels with burnt spots had 0.04-0.33 µg kg^{-1}. The aflatoxin content in the good grade kernels after blanching ranged from 1.30-9.94 µg kg^{-1}. However, the kernels that

Table 2. Aflatoxin content in the different grades of blanched groundnut

Samples	Aflatoxin B_1 (ìg kg^{-1})	
	Range*	Mean**
Good grade HPS lot after blanching	1.30-9.94	3.31
Blanched kernels without spots	0.00-0.68	0.33
Blanched kernel with large dark brown spots	879.74-1015.18	954.17
Blanched kernel with small dark brown spots	4.97-40.08	13.04
Blanched kernels with burnt spots	0.04-0.33	0.06

*Range of aflatoxin in 10 samples
**Mean of 10 samples taken from different lots (one sample from each lot)

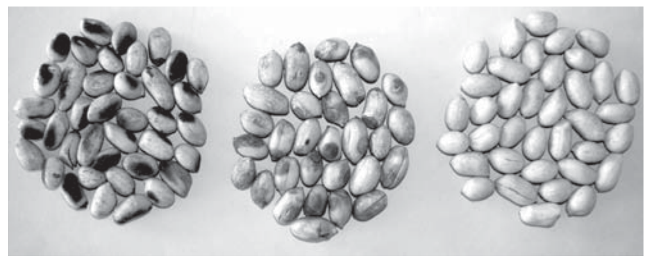

Fig. 1. Blanched kernels: a. Kernels with burnt spots, b. Kernels affected by aflatoxins showing typical dark brown spots, c. Good grade

Fig. 2. Blanched kernels split open: good (top 2 rows), aflatoxin affected (middle 2 rows), and kernels with burnt spots (bottom 2 rows)

were free from any discolouration or spots had aflatoxin 0.0-0.68 µg kg^{-1}. It could thus be noted that aflatoxin content in good grade kernels after blanching ranged from 1.30-9.94 µg kg^{-1}, but the blanched kernel with large dark brown spots derived from the same lot had aflatoxin ranging from 879.74-1015.18 µg kg^{-1}. This shows a heterogeneous and skewed distribution of aflatoxin contaminated kernels in the lot. The colour sorting process effectively isolated and concentrated the majority of aflatoxin-contaminated kernels into separate fractions, which if rejected renders the finished product free from aflatoxins, that further strengthens the hypothesis of Cole (2). Also, it was evident that the unblanched groundnut lots, both the bulk and the good grade HPS lot, had higher aflatoxins (100.0-193.5 and 3.3-29.9 µg kg^{-1}, respectively) than the blanched good grade HPS lot (1.30-9.94 µg kg^{-1}) (Table 1 and 2). It showed that blanching reduced the aflatoxins loads, which corroborate to the earlier finding of Paulsen *et al.* (8) who observed that the unblanched kernels contained higher levels of aflatoxin than those that blanched fully.

The study conclusively proved that the blanching used in conjunction with manual and electronic sorting indeed is very effective in eliminating aflatoxin-contaminated kernels. A sequential sorting of bulk groundnuts being practiced by a few Indian industries using mechanical screening, electronic eye sorting followed by manual sorting of discoloured kernels is a good measure to get rid of aflatoxins in the final product. Hence, it is suggested that the groundnut industries involved in processing and value addition should invariably follow the sequential sorting procedures to ensure supply of aflatoxin free groundnut to consumers.

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