Sorting Peanuts by Pod Density to Improve Quality and Kernel Maturity Distribution and to Reduce Aflatoxin [1]

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ABSTRACT

Peanut maturity and several peanut quality factors are closely related. An examination of peanut physical properties revealed that by sorting farmer-stock peanuts into pod density classes before shelling, the maturity distributions within shelled-stock classes can be manipulated. An unsorted sample of farmer-stock peanut having an initial maturity distribution in No. 1 kernels of 66% immature, 23% mid-mature and 11% mature was sorted using a gravity separator into four pod-density fractions ranging from 98% immature and 2% mid-mature in the least dense fraction to 8% immature, 43% mid-mature and 49% mature in the most dense fraction. Along with improvements in maturity distributions, we also found that the higher test weight fractions (higher pod density) had less aflatoxin and a greater percentage of large kernels than did the low test weight fractions. Many density sorting devices were tested, including air columns, pod cleaners, and gravity tables. All of these devices were capable of sorting pods into maturity groups, but the gravity table was the most precise.

Key Words: Gravity table, cleaners, test weight.

In its natural habitat, peanut (*Arachis hypogaea* L.) is a perennial plant (Kvien and Ozias-Akins, 1991). However, in production agriculture, peanut is grown as an annual. The peanut plant will start the flowering process approximately 30 d after planting and continue to flower and set fruit in cycles, based on environmental conditions and fruit load, throughout the season. Due to this indeterminate fruiting pattern, fruit of different maturities will be harvested at the end of the growing season. Therefore, the raw product (peanuts in the hull) going to post-harvest processing will consist of a mixture of maturities.

The quality of harvested peanut is dependent upon several factors, including variety, growing conditions, post-harvest operations, and maturity of the crop at harvest. At the present time, the Hull-Scrape Method is used by many growers to predict when to dig peanuts for best yield (Williams and Drexler, 1981). This method has proved to be a valuable tool to improve the quality of farmer stock peanuts. However, even when peanut is dug and harvested at the optimum time, a certain percentage of the pods on the plant will still be immature.

Peanut products made from peanut lots which contain higher percentages of mature kernels are known to have longer shelf-life than those products made from immature kernels (Sanders *et al.*, 1989). Changes in starch, sugar, and lipid content occur with maturity (Pattee *et al.*, 1974). The longer shelf life of products made from mature kernels is in part due to changes in total lipid content and lipid characteristics that occur during the maturation process. Mature kernels have higher oleic to linoleic acid ratios, lower polar lipid and free fatty acid content, and an increased percentage of oil compared to immature kernels (Sanders, 1980a,b). Duke (1970) found that the density of freshly dug peanuts varied with maturity. The most dense pods were those with the higher moisture content.

Flavor of peanuts is also affected by maturity. Studies have established that mature peanuts have a more favorable sweet aromatic flavor pattern than immature peanuts. Peanuts which are immature are often described as having a fruity fermented flavor (Sanders *et al.*, 1987, 1989).

Methods that provide peanuts with lower aflatoxin concentrations has been a major thrust in the peanut industry over the past several decades. Research has indicated that mature peanuts are less likely to contain aflatoxin than immature peanuts (Hil *et al.*, 1981; Dorner *et al.*, 1989). Reducing the percentages of immature peanuts from within a lot should, therefore, reduce the risk of aflatoxin contamination.

Presently, the peanut industry sells shelled-stock peanut based on kernel size rather than maturity. This is partially because there has been no commercial method to sort peanuts by maturity. Size, within a cultivar, is partially correlated to maturity and therefore quality (Williams *et al.*, 1989). Large kernels are typically more mature and, therefore, generally of better quality than smaller kernels. However, since cultivars, environmental conditions and fruit load determine fruit (and therefore kernel) size, the correlation between kernel size and maturity is only partial and can change from lot to lot (Sanders, 1989). Therefore, the development of a sorting technique that would improve the maturity distribution within a market class should help the peanut industry improve the quality and uniformity of its products.

The objective of this paper was to develop a method in which peanuts could be sorted based on maturity. To develop this sorting method, we first measured the physical characteristics of peanut pods and kernels at all maturity stages. After determining which characteristics offered the most promise for an automated maturity sort, we evaluated several techniques to accomplish this sort. The characteristics measured and the methods evaluated along with their effects on peanut quality including kernel maturity distributions and aflatoxin concentration are presented in this paper.

[1]Equipment brands and manufacturers are given as information for the reader and not an endorsement to the exclusion of other products which may perform the same function.

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Materials and Methods

Pod Parameters. In 1992, Florunner plots grown in two locations, Tifton (Tifton loamy sand soil type; fine-loamy, siliceous, thermic Plinthic Kandiudult) and Plains (Greenville sandy clay loam soil type; clayey, kaolinitic, thermic Rhodic Kandiudult), GA, were harvested and cured, and a 500-pod subsample was collected from each site for physical measurements. Maximum dimensions of individual pods were determined by measuring the longest and widest points with dial calipers. Weights of individual pods were determined using an electronic balance. Pod volume was determined using a water displacement method. Pods were submerged into a graduated cylinder from which the displaced water flowed out a 65-mm tube taped into the side of the cylinder into a small beaker placed on an electronic scale. Volume of the pod was calculated from the weight of the displaced water assuming 1 mL = 1 g.

Individual pods were then hand shelled, and the basal and apical kernels were separated. Each kernel was weighed, sized on standard grading screens and classified as either Mature, Mid-mature, or Immature based on kernel testa characteristics (wrinkled testa - Immature; smooth testa - Mid-mature; pod "waffle like" indentations and color pattern on the testa - Mature) (Rucker *et al.*, 1994).

Kernel volume was determined on both the apical and basal kernel using the previously described water displacement method. Each kernel was then cut in half and a visual rating of lumen size made. Empty hulls were individually weighed and volume determined as before. Density of apical and basal kernels and hull were calculated using weight and volume measurements as with pod density.

After a data set with all pod, kernel and hull measurements was established, correlations between kernel maturity and each physical characteristic measured above were determined using the PROC CORR procedures of the SAS statistics package (SAS, 1985). Kernel maturity was compared to the variables of pod weight, pod length, pod width, pod volume, pod density, kernel weight, kernel size, kernel volume, kernel density, lumen size, hull weight, hull volume, and hull density to establish correlation coefficients. After determining a strong relationship between pod density and pod maturity, a regression curve was fit using the Table Curve v.1 software package (Jandel Scientific, AISN Software) using pod density and pod maturity variables from the data set.

Air Column. A variable air speed air column was used to test air flow rates needed to separate a random sample of peanut pods of various pod densities. The air column consisted of a variable speed squirrel cage blower which moved air through a 15-cm dia. clear acrylic tube approximately 1 m long. Hardware cloth was placed at the bottom of the tube to prevent material from falling into the blower. Air speed within the column was monitored using a 2000 series Dwyer magnetic differential pressure gauge (Dwyer Instruments, Inc., Michigan City, IN).

To test the air speed required to float pods of different densities, 150 pods were randomly selected from a farmer-stock warehouse at Farmers Fertilizer and Milling (Colquitt, GA). Pods were individually placed on the hardware cloth screen at the bottom of the acrylic tube. Air speed was gradually increased until the pod floated approximately 3 mm above the screen. Once the airspeed required to lift the pod was determined, pods were individually numbered and recorded with the required air speed.

Each numbered pod which floated in the airstream was then analyzed for physical characteristics. Pod weight and volume were measured as before. Pods were hand shelled after which apical and basal kernel maturity and size were determined as previously described. Pod density was calculated from weight and volume measurements. Regression analysis was used to determine relationships between air speed, pod maturity and pod density.

Farmer Stock Cleaner. To test the feasibility of using commercially available pod cleaning devices to achieve density separation, four 200-kg samples of cleaned farmer-stock peanuts were obtained from both the heavy and light discharge of an LMC 8448 Cleaner (Lewis M. Carter Manufacturing Co., Inc., Donalsonville, GA) during a commercial run of a 1992 peanut lot. This device used positive and negative airflow through a louvered screen to achieve material separation. As pods passed over the louvered screen, dense pods fell through while the less dense pods and light foreign material were lifted in the air flow and passed over onto another set of screens. During this process, pods were separated into two density fractions, generally designated as light and heavy discharges. Three subsamples, each containing 100 pods from each 200-kg sample (heavy and light) were collected and hand shelled to analyze for kernel maturity.

Maturity Separation Using a Gravity Table. Preliminary studies using four farmer-stock lots of 1992 crop year cv. Florunner peanuts indicated that a gravity separator (LMC 401, Lewis Carter Manufacturing Co., Inc., Donalsonville, GA) could be used to achieve precise density separations. The test gravity separator had a 1 x 2 m deck with four discharge ports. The deck of the table consisted of a perforated, ripple bottomed screen through which air from a below-mounted fan flows. In-shell peanuts were loaded onto the deck and recirculated until a steady product flow with a uniform (within a discharge port) target test weight was achieved. Test weights were measured by placing a 4-L can in the discharge stream of each port. When four sequential test weights from the same port varied by <10%, steady state was assumed. After achieving a steady state, three subsamples of 100 each from the four discharge ports were collected and pod parameters analyzed for physical characteristics as previously described. Each pod was weighed, pod volume measured, and pod density calculated.

To determine the distribution of densities within a farmer-stock lot and associated kernel maturity distributions, a 1000 kg lot of 1993 crop year Florunner peanuts was separated by density using a gravity table into eight fractions. The selected farmer-stock test lot was composed of peanuts which were drought-stressed during the growing season. Density separation was accomplished by sequentially cutting the least dense fraction off the lower end of the machine to achieve a target test weight. Thus, a run involving eight test weight fractions required seven table cycles with the residual material of the seventh cycle providing the highest test weight number eight sample. Because density within a test lot was not equally distributed, adjustments to the gravity table were made to achieve a target test weight. Final sample test weights and distributions of test weights within the test lot were recorded.

Keeping each density fraction separate, pods were shelled and kernels sorted into market classes (Jumbos, Mediums, No. 1s, Splits and Oil Stock), and weights and kernel maturity distributions within each market class and density fraction were recorded.

Gravity Separation and Aflatoxin. After analysis of the initial 1000-kg lot mentioned above, an additional 1000-kg subsample of the same warehouse was obtained to determine the effect of segregating the least dense material on aflatoxin contamination. Although all peanuts in the warehouse had graded Seg. 1 (no visual *Aspergillus flavus* mold observed), these farmer-stock peanuts were known to contain significant levels of aflatoxin. After density segregating into two fractions, the 250-kg lot of low density and the 750-kg lot containing the most dense material were each shelled, sized into market classes, and eight 2-kg subsamples from each market class and density separation were tested for aflatoxin using an immunoassay (ViCam, Watertown, ME).

Results and Discussion

Pod Parameters. The peanut industry currently sorts shell-stock peanuts into market classes based on seed size using slotted screens. In general, the correlation between kernel size and kernel maturity was reasonably good (apical kernels, 0.56; basal kernels, 0.49) (Table 1). However, as did Williams *et al.* (1987), we found immature kernels in each screen size (Fig. 1).

Kernel density has been suggested as maturity related. However, our research found little relationship with apical kernel density to apical kernel maturity (correlation = 0.04). Basal kernel density to basal maturity correlation was also poor (-0.18) (Table 1). None of the physical properties measured on shelled kernels were highly correlated to kernel maturity (Table 1).

The parameter measured that correlated best with kernel maturity was pod density (0.62 for basal kernels and 0.59 for apical kernels) (Table 1). The change in pod density (cured pods) with kernel maturity is due to physiological processes that take place during the maturation of the peanut fruit. During development, peanut pod size is rapidly established. Young pods consist mostly of watery parenchymous tissue. Shortly after pod size is established, the hull forms a layer

Table 1. Correlation coefficients of Florunner peanut pod and seed parameters with apical and basal kernel maturities.

	Apical maturity	Basal maturity
Pod density	0.59[a]	0.62
	0.01	0.01
Apical kernel screen size	0.56	0.50
	0.01	0.01
Apical kernel weight	0.55	0.49
	0.01	0.01
Pod weight	0.52	0.48
	0.01	0.01
Pod volume	0.50	0.43
	0.01	0.01
Apical kernel volume	0.50	0.43
	0.01	0.01
Basal kernel weight	0.49	0.51
	0.01	0.01
Basal kernel screen size	0.47	0.49
	0.01	0.01
Basal kernel volume	0.44	0.44
	0.01	0.01
Apical lumen rating	0.38	0.35
	0.01	0.01
Basal lumen rating	0.37	0.36
	0.01	0.01
Pod width	0.14	0.12
	0.01	0.01
Pod length	0.14	0.11
	0.01	0.01
Basal kernel density	-0.11	-0.18
	0.01	0.01
Apical kernel density	0.04	0.02
	0.27	0.50

[a]Top number in each cell is the correlation coefficient. Numbers close to 1 or -1 are highly correlated. Bottom number in each cell is the probability. If probability is less than 0.01 but not 0, it was rounded to 0.01.

of schlerenchymous tissue approximately six cells thick. This layer gives the peanut hull its rigid structure. Shortly after the layer is established, kernels begin to enlarge and develop. Like the pod, the young seed rapidly enlarges and is composed mostly of water. As seed development continues, solids begin accumulating in the seed, replacing water. By the time the seed reaches full maturity, kernel moisture has deceased significantly.

At the end of the growing season, peanut plants are inverted in the field and cured in the sun for a period of approximately 3 d. During this field curing process, very immature pods (ones without an established schlerenchlmous layer) lose most of their weight by water reduction and shrink considerably in size. When harvested, the combine will leave these "pops" in the field. Harvested pods are placed in curing wagons for further curing and moisture reduction. Immature pods having an established schlerenchymous layer will retain their size during the curing process. However, watery kernels inside immature pods will lose size and weight. Immediately after digging, mature kernels are approximately 28% water, compared to 47% water for immature kernels (Rucker *et al.*, 1994). Mature kernels also have fully expanded to completely fill the pod cavity. Therefore, after curing, pods containing mature kernels have a significantly greater density. When

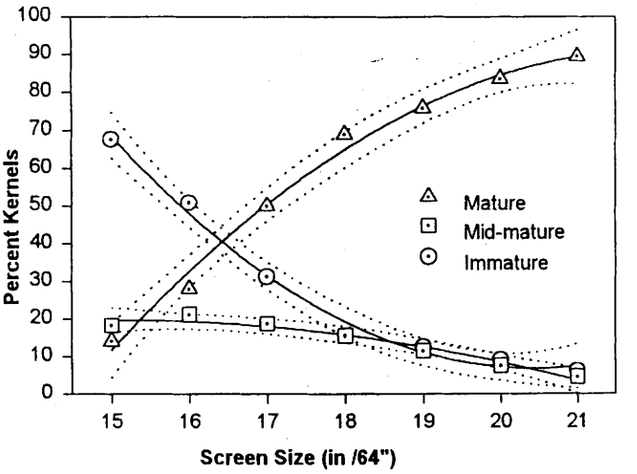

Fig. 1. Maturity distribution of Florunner peanut by seed size. Five location average. 95% confidence intervals shown.

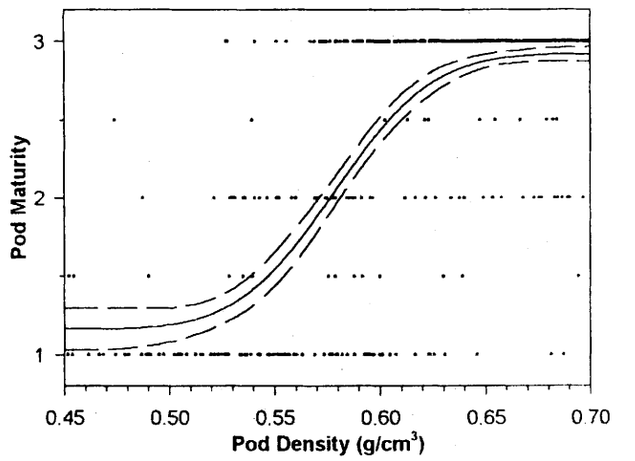

Fig. 2. Regression analysis between kernel maturity and pod density (g/cm³) of cured farmer-stock Florunner peanuts. Pod maturity of 1=immature, 2=mid-mature, and 3=mature. 95% confidence interval shown. R^2=.59.

averaged over three locations, we measured statistically significant changes in mean pod density for pods which contained immature kernels (0.54 g/cm³), mid-mature kernels (0.62 g/cm³) and mature kernels (0.69 g/cm³).

The density differences in cured farmer stock is in contrast to that in freshly dug green peanuts. Duke (1970) found that most immature peanuts had in-shell densities of 0.95 g/cm³ while the most mature "green" peanut densities were below 0.85 g/cm³. This reversal of the density- maturity relationship is due to the maturity related differences in moisture content and subsequent water loss during curing.

Regression of pod maturity and pod density (Fig. 2) showed that as pod density increased, kernel maturity increased. In our study, pods with a density <0.54 g/cm³ contain mostly immature kernels, and pods with densities >0.65 g/cm³ contained mostly mature kernels. Although within a given range of pod density it is possible to have kernels of more than one maturity, the majority of kernels

within a density are of the same maturity. Therefore, within limits, it is possible to sort pods based on in-shell density to achieve a desired maturity distribution.

Sorting Pods by Density. Many methods are used to density sort, including gravity tables, fluidized beds and air columns. Because of the approximately 28% difference in pod density between immature (average 0.54 g/cm^3) and mature pods (0.69 g/cm^3), many density sorting methods are available and can be modified to accomplish a peanut pod maturity sort. The peanut shelling industry currently uses farmer stock cleaners, gravity tables and fluidized bed devices to remove foreign material and unshelled pods from shelled kernels based on product density. We tested three of these devices: a farmer stock cleaner, a gravity table, and a simple air column device.

Air Column. The air flow rate at which pods of different maturities began to float was positively correlated with pod density (Fig. 3). Pod densities of 0.54 g/cm^3 or less (pods containing immature kernels) floated at an airspeed of 7.8 m/sec or less. As airspeed increased, the percentage of pods containing mature kernels in the air stream increased (Fig. 4). By varying airspeed, the average density and the distribution of densities (and therefore maturities) of the floating and nonfloating fractions can be changed (Fig. 4).

Farmer-Stock Cleaner. When pods obtained from the light discharge of an LMC 8448 cleaner were shelled, 41% of the kernels were immature, 35% mid-mature, and only 24% mature. Kernels shelled from pods of the heavy discharge were more mature with only 16% of the kernels being immature, 38% mid-mature, and 46% mature. Because air speeds can be changed, this cleaner has the potential to customize output based on product requirements. By adjusting air and vibration speeds, flow rates and other settings and by sequencing this cleaner with additional secondary cleaners or other density sorting devices, the quality, speed, and degree of maturity separation can be manipulated.

Maturity Separation Using a Gravity Table. The gravity separator used in these experiments (LMC 401) had four discharge ports, allowing a single pass removal of pods in four density fractions. The mean density of pods collected from several trials with 1992 farmer-stock peanuts from the four discharge ports of the gravity separator (1-4) were 0.41, 0.62, 0.68, and 0.69 g/cm^3, respectively. Different separator settings, cultivars, and/or growing conditions would result in different mean pod density discharges. Therefore, the maturity distribution within a farmer-stock peanut lot can be manipulated using this device by seperating based on pod density. For example, an unsorted subsample of farmer-stock peanut was shelled and determined to have an initial maturity distribution of No. 1 kernels of 66% immature, 23% mid-mature, and 11% mature. After placing another sample from the same farmer-stock peanuts on the gravity separator and collecting and shelling the discharge from the four discharge ports, maturity distributions in the No. 1s ranged from 98% immature and 0% mature (fraction 1 - least dense) to 8% immature and 48% mature (fraction 4 - most dense).

Figure 5 shows the relative density distributions within a lot of drought stressed Florunner which was partitioned into eight density fractions based on test weight. Test

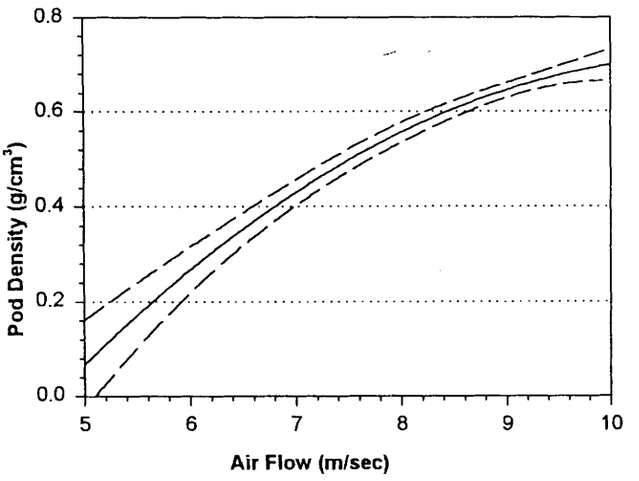

Fig. 3. Regression analysis between pod density (g/cm^3) and air flow (m/sec) required to float Florunner peanut pods. 95% confidence interval shown. R^2=.58.

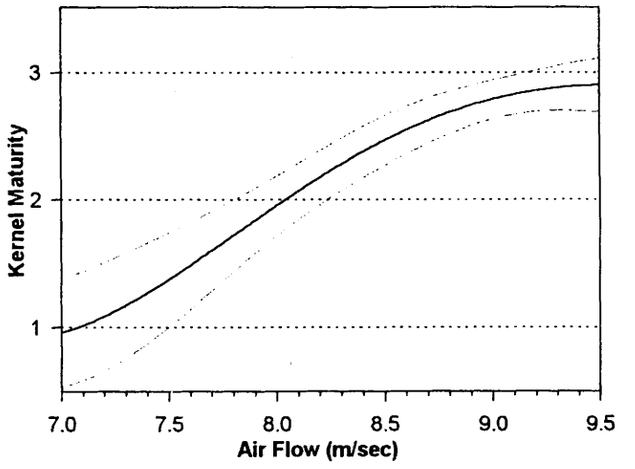

Fig. 4. Regression analysis between kernel maturity and air flow (m/sec) required to float Florunner peanut pods. Kernel maturity of 1=immature, 2=mid-mature, and 3=mature. 95% confidence interval shown. R^2=.55.

weight is a handy density related method often used in other crops to set price and measure quality. Approximately 25% of this farmer-stock lot had a test weight of 275 kg/m^3 or less. As test weight increased the composition of the density fraction changed, moving from 4 to 42 kg of mediums per 100 kg of farmer stock as the test weight increased from 200 to 410 kg/m^3, respectively (Fig. 6). Grade also changed significantly, rising from 18 to 80% sound mature kernels + sound splits (SMK+SS) as test weight increased from 200 to 410 kg/m^3. Maturity also increased with increasing test weight, with the percentage mature medium class kernels increasing from 35% in the 200 kg/m^3 test weight fraction to 80% mature in the 410 kg/m^3 fraction (Fig. 7).

Gravity Table Separation and Aflatoxin. The water-stressed Florunner lot mentioned above was chosen because it was known to be aflatoxin contaminated. Since past research has determined mature kernels to be less

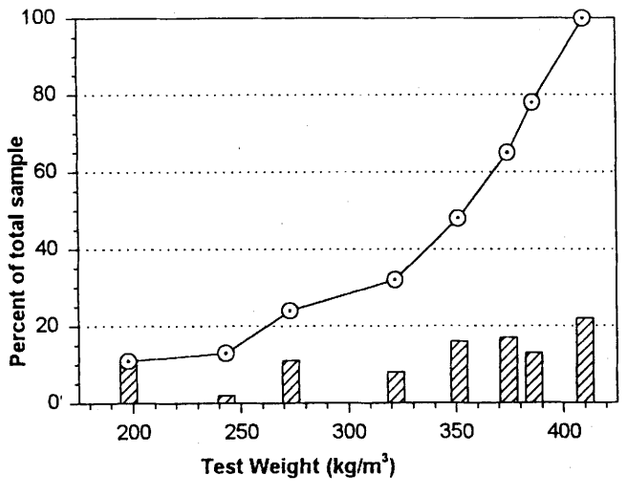

Fig. 5. Distribution of farmer-stock into test weight categories (bar graph) and cumulative percent of sample (line graph). Water stressed Florunner peanut.

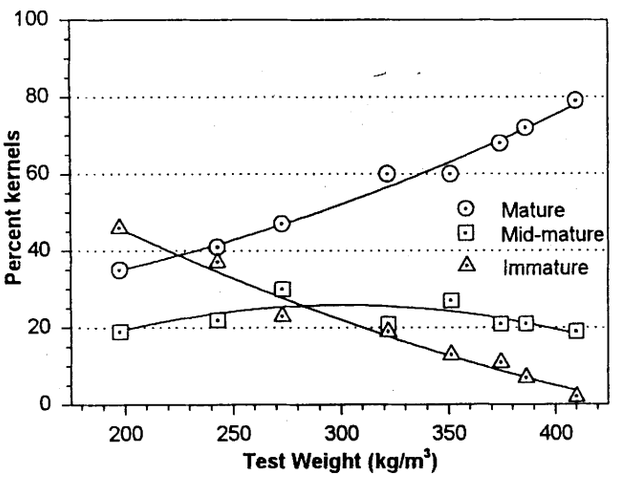

Fig. 7. Effect of in-shell test weight on maturity distribution of shelled-stock kernels. Water- stressed "medium" runners.

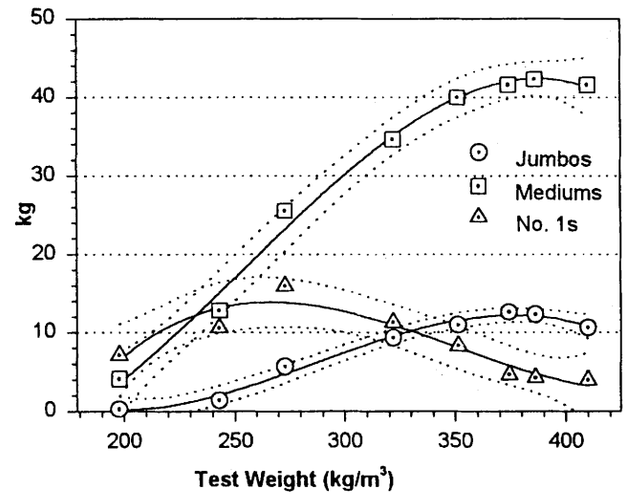

Fig. 6. Composition of shelled-stock (jumbos, mediums and no. 1s) per 100 kg of farmer-stock by test weight. Water stressed Florunner. 95% confidence interval shown.

susceptible to aflatoxin contamination than immature kernels (Hill *et al.*, 1981; Dorner *et al.*, 1989), it seemed reasonable that a preshelling density sort might also impact aflatoxin. Preliminary data indicated that the risk in this Florunner lot seemed to be mainly in the portion of the lot having a test weight of 275 kg/m³ or less. This portion comprised approximately 25% of the total lot. Therefore, the gravity separator was adjusted to achieve a 25% (least dense) to 75% (greater density) split. Grades (SMK+SS) for the least-dense (25%) and most-dense fractions were 60 and 73%, respectively. The market class composition of the most dense fraction was significantly skewed to the larger kernels when compared to the least dense fraction (Table 2).

Aflatoxin risk was also skewed, where the least dense fraction contained aflatoxin concentrations of 109, 37, 50, 33, 126, and 800 ppb and the most dense fraction contained aflatoxin concentrations of 1, 19, 4, 1, 35, and 194 ppb in the Jumbo, Medium, No. 1, Splits, Oil-Stock, and damaged kernels categories, respectively (Table 2). The 109 value for the less dense Jumbos resulted from a single sample measuring 868 ppb. Although these results indicate that a pre-shelling density sort might be useful in the management of aflatoxin contaminated peanut lots, additional trials, to maximize the usefulness of this tool, are needed to better characterize the aflatoxin-contaminated kernels in each density fraction.

Table 2. Distribution of weight (%) and aflatoxin concentration (ppb) by market class within each density fraction.

Market class	Run 1			
	Light fraction (26%)		Heavy fraction (74%)	
	%	ppb	%	ppb
Hulls	32	-	24	-
Oil Stock	18	126	3	35
No. 1s	17	50	5	4
Mediums	22	37	40	19
Jumbos	5	109	14	1
Splits	6	33	14	1
Damage	-	800	-	194

Summary

An in-shell peanut density sort can be used to partition peanut kernels into many possible maturity related segregations. The separation will allow the user to better manage farmer-stock lots to achieve higher quality and lower aflatoxin risk. Although three devices (air columns, pod-cleaners, and gravity tables) were tested for their ability to separate peanut kernels into maturity classes based on pod density, it is reasonable to expect that other fluidized-bed and non-fluidized-bed density sorting devices could be used to achieve a peanut kernel maturity sort. In-shell test weights can be used to set and test equipment. Visual inspections of kernel testa characteristics can be used to determine maturity distribution improvements.

The use of a pre-shelling density sort in combination with the current seed-size-based market classes should significantly improve the user's ability to manage peanut lots for quality.

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Literature Cited

1. Dorner, J.W., R.J. Cole, T.H. Sanders, and P.D. Blankenship. 1989. Interrelationship of kernel water activity, soil temperature, maturity, and phytoalexin production in preharvest aflatoxin contamination of drought-stressed peanut. Mycopathologia 105:117-128.
2. Hill, R.A., P.D. Blankenship, R.J. Cole, T.H. Sanders, J.W. Kirksey, and R.L. Greene. 1981. Influence of soil temperature and moisture on microflora, aflatoxin concentration, maturity and damage in peanuts. Proc. Amer. Peanut Res. Educ. Soc. 13:61 (abstr.).
3. Kvien, C.K., and P. Ozias-Akins. 1991. Lack of monocarpic senescence in Florunner peanut. Peanut Sci. 18:86-90.
4. Pattee, H.E., E.B. Johns, J.A. Singleton, and T.H. Sanders. 1974. Composition changes of peanut fruit during maturation. Peanut Sci. 1:57-63.
5. Rucker, K.S., C. K. Kvien, G. Vellidis, N. S. Hill, and J. K. Sharpe. 1994. A visual method of determining maturity of shelled peanuts. Peanut Sci. 21:143-146.
6. Sanders, T.H. 1980a. Effects of variety and maturity on lipid class composition of peanut oil. J. Amer. Oil Chem. Soc. 57:8-11.
7. Sanders, T.H. 1980b. Fatty acid composition of lipid classes in oils from peanuts differing in variety and maturity. J. Amer. Oil Chem. Soc. 57:12-15.
8. Sanders, T.H. 1989. Maturity distributions in commercially sized Florunner peanuts. Peanut Sci. 16:91-95.
9. Sanders, T.H., J.R. Vercelloti, and G.V. Civille. 1987. Flavor-maturity relationships of Florunner peanuts. Proc. Amer. Peanut Res. Educ. Soc. 19:42 (abstr.).
10. Sanders, T.H., J.R. Vercelloti, K.L. Crippen, and G.V. Civille. 1989. Effects of maturity on roast and descriptive flavor of peanuts. J. Food Sci. 54:475-477.
11. Williams, E.J., and J.S. Drexler. 1981. A non-destructive method for determing pod maturity. Peanut Sci. 8:134-141.
12. Williams, E.J., G.O. Ware, J.Y. Lai, and J.S. Drexler. 1989. Effect of pod maturity and plant age on pod and seed size distributions of Florunner peanuts. Peanut Sci. 14:79-83.

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