A Diverging Belt Screen for Farmer Stock Peanuts[1]

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ABSTRACT

Separating farmer stock (FS) peanut materials into more than two diameters with conventional belt screens requires more than one screen with different spacings between belts. A new type of belt screen (diverging belt) was developed which separates materials into six sizes. The effects of varying the diverging belt screen operational parameters on separating farmer stock peanuts (cv. Florunner), loose shelled kernels (LSK), and foreign materials (FM) were evaluated with three replications. The operational parameters for two of the replicates were six consecutive positions along the deck length (30.5, 20.3, 50.8, 50.8, 50.8 cm and riding the entire deck length); six belt speeds (101.6, 111.8, 122.1, 132.3, 142.6, and 152.4 cm/sec); and six material feed rates (MatFR) (0.9, 1.8, 2.7, 3.6, 4.5, and 5.4 Mg/hr). Deck lengths and belt speeds were the same for the third replicate but MatFRs of 1.4, 2.7, 4.1, 5.4, 6.8, and 8.2 Mg/hr were used to evaluate performance of the screen at higher flow rates. Materials were collected into six compartments according to where they fell through the screen. The amount of materials falling through the screen deck varied directly with screen deck length, belt speed, and material feed rate. Screen deck length had the greatest effect on the amount of materials falling through. The diverging belt screen provides an alternative for multi-separation of FS peanut materials based on diameter.

Key Words: *Arachis hypogaea* L., cleaning, foreign material, loose shelled kernels, LSK, separation, screening.

In the U.S., farmer stock (FS) peanuts are harvested, handled, shelled, and processed mechanically. Quality maintenance during mechanical procedures has recently come under close scrutiny by the peanut industry because of demands and competition of U.S. and world marketing of peanuts (1,5). During many mechanical procedures, loose shelled kernels (LSK) and foreign material (FM) are inadvertently generated or increased in FS peanuts diminishing quality and value. LSK are peanut kernels unintentionally removed from pods with a value at farmer marketing 80 to 90% less than kernels from intact pods. LSK have a higher aflatoxin risk and a higher rate of quality deterioration during storage than kernels in pods (3,4). FM are any materials other than peanut pods or LSK collected with peanuts during harvesting and processing and have no value. FM include materials such as dirt; rocks; plant parts such as stems (sticks), wild bur gherkin, pieces of citron, corn cobs, horse nettle, nutsedge tubers, and wood; metal parts dislodged from equipment; and glass (4). Attempts are made during harvesting and processing to remove LSK and FM from FS peanuts for quality improvement. Removal of all LSK or FM is difficult because some LSK and FM have physical properties similar to peanut pods. Various techniques are used for removing LSK and FM including screening which allows separation of materials based on diameter. Separating FS peanut material into three to four consecutive diameter sizes provides a coarse method for concentrating most LSK and FM into a small portion of peanuts and an initial step in separating LSK from FM. Mechanical screens accomplish material separation with surfaces or decks with openings which allow smaller diameter materials to fall through and larger diameter materials to ride over. Materials are conveyed across screen decks with some type of mechanical deck motion or with gravity.

Five types of screens are used in FS peanut processing: (a) stationary, (b) vibratory, (c) orbital, (d) rotating drum, and (e) parallel belt. An undesirable characteristic of operating types (a), (b), (c), and (d) is the requirement for periodic deck cleaning. Parallel belt screens are self-cleaning (1,2). However, parallel belt screens are used only on a limited basis in the peanut industry, probably because commercially available belt screens separate

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materials into only two sizes or diameters. Single screens other than parallel belt screens can be equipped to separate materials into more than two sizes utilizing either multiple decks per screen or decks with more than one diameter opening. Multiple separations with belt screens currently require multiple screens. Providing multiple separations with belt screens is generally more expensive than other types of screens.

The purpose of this research was to design and evaluate a belt screen with capability to separate farmer stock peanut materials into more than two diameters of materials. A multiple separation, self-cleaning belt screen could provide the industry with additional capabilities for quality improvement and maintenance during FS peanut processing.

Materials and Methods

The diverging belt screen deck (separation area) was 38.48 cm wide at the input end, 203.2 cm long, and 58.12 cm wide at the discharge end. The deck consisted of 20, 1.27-cm diameter, round belts spaced at specific distances with 10.16-cm diameter sheaves (Fig. 1). The sheave at the input end spaced adjacent belts with a 0.69-cm gap between belts. The gap between adjacent belts at the discharge end was 1.72 cm. During screen operation, the increasing gaps between belts allowed varying diameters of materials to fall through along the screen deck length (SDL). Five consecutive screen deck lengths were used as follows: one for material falling through the first 30.48 cm of deck length (SDL_1), another for the following 20.32 cm of deck length (SDL_2), three additional for each succeeding 50.8 cm of deck length (SDL_3, SDL_4, SDL_5) (Fig. 2). Side discharge chutes carried falling material to separate containers. A chute at the discharge end conveyed material riding over the deck to an additional container (SDL_6). Each sample screened was thus separated into six subsamples. The spacing between belts for the SDL_1 section of the deck was 0.69 cm at the input end and spread to 0.84 cm at the discharge end: 0.84 cm and 0.95 cm for SDL_2, 0.95 cm and 1.20 cm for SDL_3, 1.20 cm and 1.46 cm for SDL_4, 1.46 cm and 1.72 cm for SDL_5. Materials with diameters greater than 1.72 cm were captured as SDL_6.

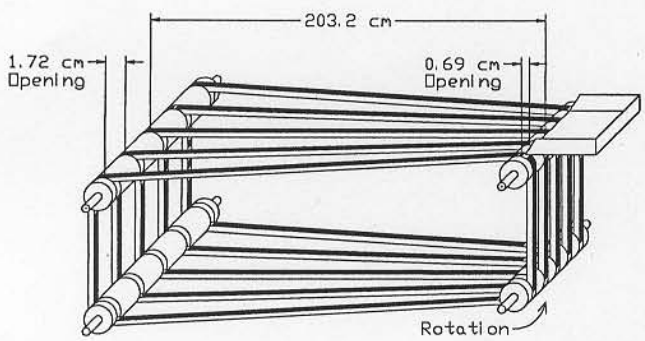

Fig. 1. Schematic of the diverging belt screen.

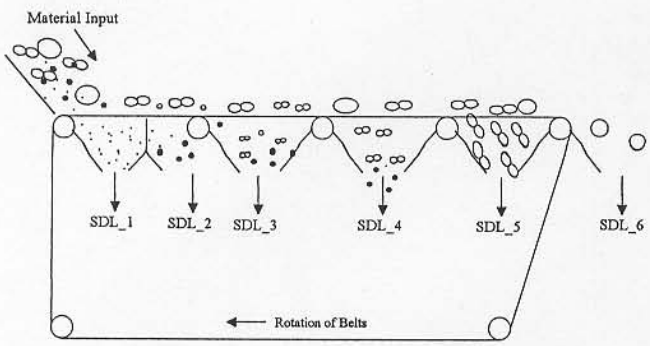

Fig. 2. Schematic of diverging belt screen operation.

The experimental design evaluated the effect of three independent variables on the diverging belt screen separation of farmer stock peanuts (cv. Florunner) including LSK and FM. Three replicates of the experiment were conducted. The independent variables and corresponding settings planned for the first two of the replicates included: (a) the six positions of SDL described above (SDL_1, SDL_2, SDL_3, SDL_4, SDL_5, and SDL_6); (b) six belt speeds (Bspd) of 101.6, 111.84, 122.08, 132.32, 142.56, and 152.4 cm/sec; and (c) six material feed rates (MatFR) of 0.91, 1.81, 2.72, 3.63, 4.54, and 5.44 Mg/hr. The SDLs and Bspd's were the same for the third replicate but MatFRs of 1.36, 2.72, 4.08, 5.44, 6.8, and 8.16 Mg/hr were planned to evaluate performance of the screen at higher flow rates. Tests were conducted with all combinations of Bspd's and MatFRs. SDL was not included as a factor in determining the combinations of independent variables to be run in the tests because the design of the diverging belt screen allowed collecting data for all six SDLs with any combination of Bspd and MatFR. A total of 36 samples were screened (six Bspd's × six MatFRs) for each replicate of the experiment. The combinations of Bspd's and MatFRs were tested in random order during each replicate of the experiment.

After harvest and a 2-mo minimum storage period, approximately 1800 kg of FS peanuts, including LSK and FM, were screened during each replicate of 36 tests. Samples (approximately 50 kg) were screened for each combination of Bspd and MatFr. Peanuts were supplied to the screen from an adjustable vibratory feeder which had been calibrated prior to the experiment to provide the approximate MatFR and sample size.

The first step in screening a sample was to set the screen and vibratory feeder operational parameters. Next, screen belts rotation was started. Then, the vibratory feeder was activated and operated for the prescribed period of time. The materials falling through along the length of the deck and materials riding over were collected into six containers as subsamples. Each subsample was weighed and bagged for later evaluation. After the 36 samples of a replicate were screened, the subsamples were manually separated into peanut pods, LSK, and FM, and weighed. The FM was further separated into the following categories: sticks, rocks, dirt, hulls, and miscellaneous materials (Mis_FM). Weight percentage of each fraction was calculated for further analysis. The percentages of the subsamples separated from each sample were calculated using the sum of subsample weights as the initial sample weight.

Results and Discussion

A comparison of the average compositions of samples of FS peanuts used for the three replicates of the experiment is shown in Table 1. The average percent of pods in samples of replicate one averaged significantly higher ($P \leq 0.05$) than percent of pods in samples of replicates

two (0.61% higher) and three (0.99% higher) (Table 1). Average LSKs in samples of replicate one were significantly lower ($P \leq 0.05$) than LSKs in samples of replicates two and three (about 1.5% lower). Average FM in samples from all replicates were significantly different ($P \leq 0.05$); however, differences in the average FM content were less than 0.9%. Since differences in average compositions of the samples for the replicates were small, all data collected during screening the samples were combined for performance evaluation of the diverging belt screen.

Average compositions of samples for the three replicates are presented in Table 2. The average FM for the experimental samples ranged from 0.20 to 0.82% lower than the yearly (1985-1994) average grade factor for FM for runner-type peanuts (7). LSKs were 1.03 to 1.44% lower (7). The differences in FM and LSK were probably not of sufficient magnitude to influence predictable separations that could be expected with the diverging belt screen on average quality, runner-type FS peanuts.

Quadratic equations were derived from the data to describe the effects of the independent variables on the performance of the diverging belt screen in separating the FS peanut material. A multiple variable, quadratic regression analysis was used to generate these equations (6). The equations derived were of the following form:

$$DV = IC + (M_1 \times Bspd) + (M_2 \times Bspd^2) + (M_3 \times MatFR) + (M_4 \times MatFR^2) + (M_5 \times SDL) + (M_6 \times BSDL^2) + (M_7 \times Bspd \times MatFR) + (M_8 \times Bspd \times SDL) + (M_9 \times Mat\ FR \times SDL) + (M_{10} \times Bspd \times MatFR \times SDL); \quad [Eq.\ 1]$$

where:

DV = Dependent variable, i.e.,
- % of sample weight falling through (SamFT),
- % of pod weight falling through (PodFT),
- % of LSK weight falling through (LSKFT),
- % of FM weight falling through (FMFT),
- % of stick weight falling through (StickFT),
- % of dirt weight falling through (DirtFT),
- % of rock weight falling through (RockFT),
- % of miscellaneous FM weight falling through (Mis_FMFT);

IC = intercept;
M_1 = multiplier for the Bspd term;
M_2 = multiplier for the $Bspd^2$ term;
M_3 = multiplier for the MatFR term;
M_4 = multiplier for the $MatFR^2$ term;
M_5 = multiplier for the SDL term;
M_6 = multiplier for the SDL^2 term;
M_7 = multiplier for the (Bspd × MatFR);
M_8 = multiplier for the (Bspd × SDL);
M_9 = multiplier for the (MatFR × SDL);
M_{10} = multiplier for the (Bspd × MatFR × SDL).

Estimates of intercepts and multipliers for the equations for each dependent variable are presented in Table 3. Also presented in Table 3 are the significance ($P \leq 0.05$) of the independent variable terms in each equation along with correlation coefficients for the derived equations.

Equations derived for SamFT, PodFT, and DirtFT had only one independent variable which was significant at the $P \leq 0.05$ level (Table 3). SamFT varied from 95.1 to 99.9% with an average of 98.9% and a standard deviation (SD) of 1.14% (Table 4) and was significantly affected by SDL (Table 3). Similarly, PodFT varied from 95.42 to 99.96% with an average of 99.08% and a SD of 1.04% (Table 4), and was significantly affected by SDL (Table 3). DirtFT varied from 89.6 to 100% with an average of 99.3% and a standard deviation (SD) of 1.59% (Table 4), and was significantly affected by Bspd (Table

Table 1. Comparison of the average sample compositions of farmer stock peanuts used in the three replications of the experiment evaluating performance of the diverging belt screen.

Material	Replicate	Mean[a]	Min.	Max.	S.D.
		%	%	%	
Pods	1	94.22 a	79.37	97.14	3.04
	2	93.61 b	88.60	95.39	1.44
	3	93.23 b	89.13	95.74	1.72
LSK	1	1.70 b	0.58	5.67	1.01
	2	3.18 a	1.56	7.08	0.95
	3	3.17 a	1.89	5.31	0.88
FM	1	4.08 a	2.21	14.96	2.18
	2	3.21 c	2.21	7.04	0.88
	3	3.59 b	1.61	7.76	1.37
Sticks	1	1.12 b	0.55	4.44	0.61
	2	0.69 c	0.48	0.97	0.12
	3	1.73 a	0.84	3.55	0.52
Dirt	1	0.93 a	0.09	4.74	1.08
	2	0.45 b	0.20	1.68	0.31
	3	0.28 c	0.04	1.88	0.38
Rocks	1	0.48 a	0.09	2.23	0.42
	2	0.32 b	0.09	0.75	0.15
	3	0.07 c	0	0.67	0.11
Hulls	1	1.53 b	0.91	5.51	0.74
	2	1.73 a	1.15	3.93	0.50
	3	1.45 b	0.62	3.45	0.66
Mis_FM	1	0.02 b	0.003	0.08	0.02
	2	0.02 b	0.003	0.08	0.02
	3	0.07 a	0.02	0.50	0.08

[a]Means in a column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2. Average sample composition of farmer stock peanut material used during the experiment.

Material	Mean[a]	Min.	Max.	S.D.
	%	%	%	
Pods	93.70	79.37	97.14	2.23
LSK	2.67	0.58	7.08	1.18
FM	3.63	1.61	14.96	1.62
Sticks	1.18	0.48	4.44	0.63
Dirt	0.56	0.04	4.74	0.74
Rocks	0.29	0	2.23	0.32
Hulls	1.57	0.62	5.51	0.65
Mis_FM	0.04	0.003	0.50	0.0

Table 3. Derived multipliers and correlation coefficients for independent variable terms for equations describing the percentage of each dependent variable separated by the screen.

Independent variable multiplier	Dependent variable								
	SamFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT	HullFT	Mis_FMFT
IC	-13.7912	-15.2090	52.6758	-6.0265	15.5788	-63.9432	32.6171	45.0757	-48.6187
M_1	0.0757	0.0427	0.0056	0.7044	0.0759	1.8637*	0.0593	0.1021	0.8492
M_2	-0.0005	-0.0003	-0.0024*	-0.0034*	-0.0004	-0.0075*	-0.0015	-0.0018	-0.0036
M_3	-0.6480	0.0535	-9.2304*	-8.1704*	-6.2271*	-1.7246	-9.4427	-12.8687*	-5.7469
M_4	-0.0975	-0.1031	-0.0098	-0.2611*	0.0430	0.1253	1.0825*	-0.0714	0.4299*
M_5	0.3795*	0.3695*	0.6029*	0.4044*	0.4981*	0.2750	0.2712	0.4323*	0.6583*
M_6	0.0013*	0.0015*	-0.0030*	-0.0006*	0.0001	-0.0003	-0.0011*	-0.0014*	0.0004
M_7	0.0098	0.0057	0.0647*	0.0502*	0.0010	0.0142	0.0073	0.0756*	0.0142
M_8	-0.0003	-0.0004	0.0033*	0.0007	-0.0004	0.0003	0.0026	0.0017*	-0.0027
M_9	-0.0043	-0.0077	0.0528*	0.0359	-0.0028	0.0061	0.0515	0.0611*	-0.0117
M_{10}	0	0	-0.0004*	-0.0003	0	-0.0001	-0.0005	-0.0004*	0.0001
R[a]	0.97	0.97	0.98	0.94	0.97	0.70	0.67	0.96	0.79

*Significant at the $P \leq 0.05$ level.

[a]Correlation coefficient for the derived equation.

Table 4. Minimums, maximums, means, and standard deviations of the percent of the dependent variables which fell through the screen.

	Dependent variable								
	SamFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT	HullFT	Mis_FMFT
	%								
Min.	95.09	95.42	98.54	77.63	61.18	89.62	0	95.14	11.64
Max.	99.89	99.96	100.00	99.15	99.95	100.00	100.00	100.00	100.00
Mean	98.89	99.08	99.82	92.90	90.46	99.33	76.24	99.01	68.03
S.D.	1.14	1.04	0.27	5.58	10.27	1.59	23.11	1.04	26.29

3). Equations for the remaining dependent variables had more than one significant independent variable.

The LSKFT was significantly affected at the $P \leq 0.05$ level by Bspd, MatFR, SDL, and interactions between the three (Table 3). A comparison of the Type II Sums of Squares (SS) generated during the regression analysis for the LSKFT indicated that SDL had a much higher influence on the prediction equation than the other independent variables. SDL terms accounted for approximately 90.2% of the total Type II SS from the LSKFT equation regression: Bspd, 0.4%; MatFR, 2.0%; and interactions between independent variables, 7.4%. FMFT also was significantly affected at the $P \leq 0.05$ level by Bspd, MatFR, and SDL. Type II SS for this regression also indicated that SDL had a greater influence on FMFT than Bspd or MatFR (i.e., SDL, 46.1%; Bspd, 9.7%; MatFR, 27.4%; and interactions 16.8%). StickFT, RockFT, HullFT, and Mis_FMFT were influenced at the $P \leq 0.05$ level by SDL and MatFR. SDL terms accounted for approximately 81.2% of the total Type II SS from the StickFT equation regression and MatFR, 17.8%. MatFR terms accounted for approximately 68.3% of the total Type II SS from the RockFT equation regression and SDL, 22.1%. SDL terms accounted for approximately 67.2% of the total Type II SS from the HullFT equation regression and MatFR, 13.4%. SDL terms accounted for approximately 46.1% of the total Type II SS from the Mis_FMFT equation regression and MatFR, 32.3%.

Within the range of values used for Bspd and MatFR, SDL was the major factor influencing separation of the FS peanut material with the diverging belt screen. Separation data was therefore averaged by SDL to provide an overview of average performance of the screen.

Average separations of the various components of the FS peanut materials by the diverging belt screen are shown in Table 5. Only 3.93% of the sample average was separated by SDL_1 and SDL_2 combined. However, 58.41% of the LSK and 39.25% of the FM were separated by SDL_1 and SDL_2. Seventy-seven percent of the FS materials were separated by SDL_4 and SDL_5. SDL_4 and SDL_5 separated 80.51% of the pods, 13.44% of the

Table 5. Average separations of FS peanuts collected from the consecutive positions of screen deck length during performance evaluations of the diverging belt screen.

FS peanut material	Consecutive position					
	SDL_1	SDL_2	SDL_3	SDL_4	SDL_5	SDL_6
	%					
Sample	2.38	1.55	17.96	56.23	20.77	1.11
Pods	0.23	0.69	17.65	58.89	21.62	0.92
LSK	36.80	21.61	27.96	10.74	2.70	0.18
FM	29.60	9.65	19.48	20.86	13.32	7.10
Sticks	14.15	6.96	21.87	26.96	20.52	9.54
Dirt	61.15	6.07	10.80	12.90	8.42	0.67
Rocks	20.50	10.95	20.85	12.34	11.59	23.76
Hulls	33.83	13.81	21.57	21.27	8.52	0.99
Mis_FM	3.36	4.67	17.02	24.86	18.12	31.97

LSK, and 34.18% of the FM. Average compositions of the six SDLs are presented in Table 6. Comparing data in Tables 2 and 6 show that average separations made by the diverging belt screen are different from the original average composition. For instance, the average composition of SDL_5 was 3.1% higher in pods, 2.37% lower in LSK, and 0.83% lower in FM than the original composition. The data shown in Tables 2, 5, and 6 indicate that the diverging belt screen has the capability to separate or concentrate various components of FS peanuts. Separations made probably could be used to facilitate further FS peanut separation in subsequent processing.

Table 6. Average composition of the FS peanut materials collected at the six positions of deck length from the diverging belt screen deck.

FS peanut material	Consecutive position					
	SDL_1	SDL_2	SDL_3	SDL_4	SDL_5	SDL_6
	%					
Pods	14.4	41.8	88.7	98.0	96.8	72.2
LSK	52.1	42.4	7.1	0.6	0.3	0.5
FM	33.5	15.8	4.2	1.4	2.8	27.3
Sticks	7.2	4.3	1.9	0.7	1.8	22.6
Dirt	7.6	0.8	0.1	0.03	0.1	0.2
Rocks	0.6	0.5	0.1	0.01	0.1	1.2
Hulls	18.0	10.0	2.2	0.7	0.7	1.4
Mis_FM	0.1	0.2	0.1	0.02	0.1	1.9

Summary and Conclusions

The diverging belt screen can be used to separate FS peanut components into categories with different diameter ranges. The data presented show varying amounts of components of farmers stock peanut material falling through the screen depend upon settings of operational parameters. The amount of material falling through the screen varied directly with screen deck length, i.e, opening between belts; belt speed; and material feed rate. Screen deck length had the greatest effect on the amount of sample weight, pods, LSK, total FM, sticks from FM, hulls from FM, and miscellaneous FM falling through the screen. Material feed rate had the next most influencing effect. Belt speed had the least effect on the separations made.

The data presented here describe separations obtained from three populations of peanut material with small differences in compositions. Similar separations probably could be made with most farmer stock peanut material, although higher rates of some types of FM could possibly decrease the accuracy of diameter separations made.

The controlling factor limiting the removal of FM from farmers stock peanuts with the diverging belt screen is probably the amount of pods removed with the LSK and FM. Although multiple separations are made based on diameter, subsequent separation of pods, LSK, and FM is difficult and requires additional separating techniques such as aspiration and specific gravity separation. The diverging belt screen does provide a usable solution for removal of certain materials from farmers stock peanuts which could then be cleaned subsequently at lower flow rates to improve the efficiency of conventional cleaners.

Use of the diverging belt screen for improving the quality of farmers stock peanuts is feasible but will require management of machine operation for desired separations of materials. As with parallel belt screens, the diverging belt screen offers a nonblanking alternative to vibratory screens for screening farmers stock peanut materials.

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