Effects of Belt Screen Operational Settings on Separations of Farmers Stock Peanut Materials

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ABSTRACT

The effects of varying belt screen operational parameters on separating farmers stock peanuts (cv. Florunner), loose shelled kernels (LSK), and foreign materials (FM) were evaluated. The operational parameters evaluated were four screen deck lengths (40.6, 81.3, 121.9, and 162.6 cm); four belt spacings (0.87, 0.95, 1.03, and 1.11 cm); four belt speeds (81.3, 91.4, 101.6, and 111.8 cm/sec); and four feed rates (0.45, 0.91, 1.36, and 1.81 t/hr). The amount of materials falling through the screen varied directly with screen deck length and belt spacing. Screen deck length had the greatest effect on the amount of LSK, total FM, sticks from FM, dirt from FM, and rocks from FM falling through the screen. Belt speeds and material feed rates had less effect on the separations made than screen deck length and belt spacing.

Key Words: Screen, peanuts, foreign material, separation, cleaning, *Arachis hypogaea* L.

Peanut quality is a major issue in peanut marketing in the U.S. and international markets. An assessment of the amount of loose shelled kernels (LSK) and types and amounts of foreign materials (FM) are indicators used to determine the compositional quality during all phases of post harvest processing. LSK are kernels that have been shelled out of the pod by mechanical harvesting or handling operations. FM are any materials present other than in-shell peanuts and LSK. Until recently, FM were specified only by the quantity of materials (weight and count) present; however, many final processors and manufacturers of peanut products now categorize FM by type, and make stringent stipulations to suppliers relative to the materials found. Some processors also require that LSK not be included in their peanut supply because of the general low quality and aflatoxin risk often associated with this type of peanut kernel (2). Thus, technology for LSK and FM removal is becoming increasingly important.

Removal of FM from peanuts is attempted during essentially all harvesting, shelling, and manufacturing processes. If removed, LSK are separated primarily at the beginning of shelling. Research has shown, however, that peanut quality can be better maintained if LSK are removed prior to storage because of their susceptibility to insect damage and rapid rate of quality deterioration (3).

One common technique utilized in the separation of LSK and FM from peanuts is mechanical screening. Historically, vibrating screens have been used to make this separation in peanuts. Vibratory screens divide materials into two size categories by allowing smaller particles to fall through the perforations as materials flow across the screen. Although providing satisfactory separations, vibratory screens have two major disadvantages: (a) relatively low flow rates and (b) occasional blanking (perforations become clogged and material cannot fall through).

Recently, a different type of screening device was developed by the United States Department of Agriculture (USDA), Agricultural Research Service (ARS), South Atlantic Area (SAA), National Peanut Research Laboratory (NPRL), Dawson, GA, and the U.S. peanut industry. This device, commonly referred to as a belt screen, utilizes multiple, parallel belts (double-V or round) spaced at specific distances and rotating continuously on properly positioned sheaves thus providing a dynamic, self-cleaning deck for screening (Fig. 1). The belt screen overcomes the two major disadvantages of vibratory screening by providing a much higher capacity than conventional vibratory screens and avoiding blanking. Commercial versions of the belt screen are being used as stationary and portable cleaners and for sizing unshelled peanuts prior to shelling.

The operation of the screen was examined in the "Peanut Quality Enhancement Project" (PQEP) funded by both the U.S. peanut industry and USDA (1). Eight screens were installed at peanut buying points distributed across all U.S. peanut-producing areas. Most types of commercial peanuts were screened during the tests. The screens tested in the PQEP had fixed operational settings which were judged appropriate for each specific type of peanut being screened.

This study was conducted in the early stages of the development of the belt screen to provide an evaluation of the controllable adjustments of the belt screen on separations of peanuts, LSK, and foreign materials. The objective was to develop data on belt screen operation

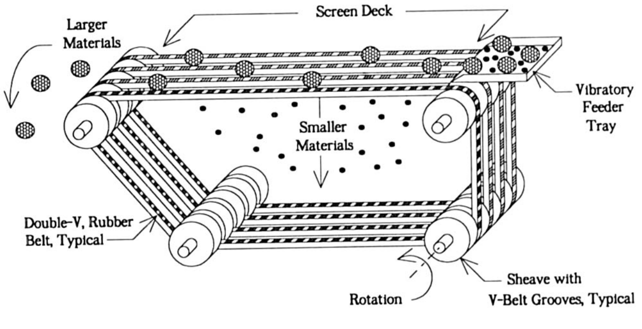

Fig. 1. Schematic of a belt screen.

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which would assist the peanut industry in the correct design and operation of belt screens. An additional objective was to provide basic knowledge on the characteristics of belt screening which could be used in the separation of other materials or commodities.

Materials and Methods

The screen deck (separation area) consisted of double-V belts spaced at required specific distances with adjustable V-belt pulleys mounted on steel shafts (Fig. 1). The deck had 14 belts which provided 13 openings between the belts. The belts were positioned around the sheaves and driven with a variable speed, mechanical drive. Materials to be separated were fed onto the screen deck with an adjustable, vibratory tray. The belts carried materials larger than the spacings between the belts along the length and over the end of the deck. The openings between the belts allowed smaller materials to fall through, resulting in a separation based on particle diameter. The screen deck was 30.48 cm wide and 81.3 cm long. Three containers were provided for separately capturing material falling through the first and second halves of the deck (40.6-cm long sections) and material riding over the deck (three subsamples). Because the screen deck was not long enough to test the length in the experimental design, the material riding over the screen deck with the first pass was run over the deck again. The second pass allowed capturing two additional subsamples of material falling through and a subsample of material riding over the deck. Each sample screened was thus separated into five subsamples. Separations obtained from the second pass were probably not the exact separations that would have been obtained from the second half of a 162.6-cm length screen since the materials riding over the deck from the first pass had to be captured and then replaced onto the belts. However, the authors believe that the separations made would serve as acceptable approximations and data were analyzed as though samples were screened over a 162.6-cm length screen.

The experimental design evaluated the effect of four independent variables on belt screen separation of farmers stock peanuts (cv. Florunner) including LSK and FM. The independent variables and corresponding settings tested included (a) four screen deck lengths (SDL) of 40.6, 81.3, 121.9, and 162.6 cm; (b) four belt spacings (BSpa) of 0.87, 0.95, 1.03, and 1.11 cm; (c) four belt speeds (BSpd) of 81.3, 91.4, 101.6, and 111.8 cm/sec; and (d) four material feed rates (MatFR) of 0.45, 0.91, 1.36, and 1.81 t/hr. Tests were conducted with all combinations of belt speeds, belt spacings (distance between belts), and material feed rates. One replicate of the experiment is reported herein. 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 belt screen allowed collecting data for all four SDLs with any combination of BSpd, BSpa, and MatFR. A total of 64 samples were screened (four BSpd's x four BSpa's x four MatFR's) for the experiment. The combinations of BSpd, BSpa, and MatFR were tested in random order.

After harvest and a 2-3-mo storage period, a 225-kg lot of peanuts, including LSK and FM, was divided into 32, 6-8 kg-test samples for screening. Each test sample was then screened using a given set of operating parameters. After the first 32 treatments were completed, the separated materials were recombined and thoroughly mixed. The peanuts, including LSK and FM, were again separated into 32, 6-8-kg test samples for the remaining treatments.

The first step for screening a test sample was to set the screen operational parameters. Next, a test sample was placed into a hopper above the vibratory tray. The elapsed time for the sample to be fed onto the screen was measured. The materials falling through the screen were collected as two subsamples in containers positioned underneath. One container collected the materials falling through the first half of the screen deck length and the other the second half. The material riding the screen was collected also and then placed back into the hopper above the vibratory tray and metered at the same rate onto the screen again. The elapsed time for this portion of the original sample to be metered onto the screen was measured. At the end of the second run with the screen, two additional subsamples of the materials falling through the screen deck and the subsample of material riding over the deck also were collected. Each treatment thus yielded five subsamples for each sample screened. The materials in each subsample were then manually separated into peanut pods, LSK, and FM, and each fraction weighed. Weight percentage of each fraction was calculated for further analysis. Total FM was further divided into the following subfractions: sticks, rocks, and dirt. The percentage of the sample weight falling through the screen was calculated by adding weights of the various components from the subsamples collected underneath and dividing by the initial sample weight.

Results and Discussion

The performance of the belt screen was evaluated by deriving seven equations from the collected data to describe the effects of the independent variables on the amounts of the various types of materials falling through. A multiple variable, quadratic regression analysis (4) was used to generate these equations. The equations derived were of the following form:

$$\begin{aligned}
DV=IC &+ M_1 \times \mathrm{BSpa} + M_2 \times \mathrm{BSpa}^2 + M_3 \times \mathrm{BSpd} + M_4 \times \mathrm{Bspd}^2 \\
&+ M_5 \times \mathrm{MatFR} + M_6 \times \mathrm{MatFR}^2 + M_7 \times \mathrm{SDL} + M_8 \times \mathrm{SDL}^2 \\
&+ M_9(\mathrm{BSpa} \times \mathrm{BSpd}) + M_{10}(\mathrm{BSpa} \times \mathrm{MatFR}) + M_{11}(\mathrm{BSpa} \times \mathrm{SDL}) \\
&+ M_{12}(\mathrm{BSpd} \times \mathrm{MatFR}) + M_{13}(\mathrm{BSpd} \times \mathrm{SDL}) + M_{14}(\mathrm{MatFR} \times \mathrm{SDL}) \\
&+ M_{15}(\mathrm{BSpa} \times \mathrm{BSpd} \times \mathrm{MatFR}) + M_{16}(\mathrm{BSpa} \times \mathrm{MatFR} \times \mathrm{SDL}) \\
&+ M_{17}(\mathrm{BSpa} \times \mathrm{BSpd} \times \mathrm{SDL}) + M_{18}(\mathrm{BSpd} \times \mathrm{MatFR} \times \mathrm{SDL}) \\
&+ M_{19}(\mathrm{BSpa} \times \mathrm{BSpd} \times \mathrm{MatFR} \times \mathrm{SDL}); \qquad \text{[Eq. 1]}
\end{aligned}$$

where:

DV = Dependent Variable, i.e.,
% of sample weight falling through (SFT),
% of pod weight falling through (PodFT),
% of loose shelled kernel weight falling through (LSKFT),
% of foreign material weight falling through (FMFT),
% of stick weight falling through (StickFT),
% of dirt weight falling through (DirtFT), and
% of rock weight falling through (RockFT);
IC = intercept;
M_1 = multiplier for BSpa term;
M_2 = multiplier for BSpa^2 term;
M_3 = multiplier for BSpd term;
M_4 = multiplier for BSpd^2 term;
M_5 = multiplier for MatFR term;
M_6 = multiplier for MatFR^2 term;
M_7 = multiplier for SDL term;

M_8 = multiplier for SDL^2 term;
M_9 = multiplier for (BSpa x BSpd) term;
M_{10} = multiplier for (BSpa x MatFR) term;
M_{11} = multiplier for (BSpa x SDL) term;
M_{12} = multiplier for (BSpd x MatFR) term;
M_{13} = multiplier for (BSpd x SDL) term;
M_{14} = multiplier for (MatFR x SDL) term;
M_{15} = multiplier for (BSpa x BSpd x MatFR) term;
M_{16} = multiplier for (BSpa x MatFR x SDL) term;
M_{17} = multiplier for (BSpa x BSpd x SDL) term;
M_{18} = multiplier for (BSpd x MatFR x SDL) term;
M_{19} = multiplier for (BSpa x BSpd x MatFR x SDL) term.

Estimates of intercepts and multipliers for the equations for each dependent variable are presented in Table 1. The significance ($P \leq 0.05$) of the independent variable terms in each equation for the dependent variables is also presented (Table 1).

The correlation coefficient for the SFT equation was 0.730. Correlation coefficients for the other six equations were:

Dependent variable	Correlation coefficient
PodFT	0.967
LSKFT	0.959
FMFT	0.964
StickFT	0.975
DirtFT	0.905
RockFT	0.798

The SFT varied from 6.3 to 49.1% with an average of 21.9% and a standard deviation (SD) of 10.4% (Table 2). The prediction equation derived for SFT had no significance at the $P \leq 0.05$ level (Table 1); however, the equation does provide an estimator for SFT as evidenced by the 0.730 correlation coefficient. A comparison of the Type II Sums of Squares (SS) generated during the regression analysis for the SFT indicated that all independent variables and interactions had comparable influences on the prediction equation. Prediction equations derived for calculating the percentages of each type of material falling through the screen were found to be more reliable.

The PodFT varied from 5.5 to 48.3% with an average of 23.7% and a SD of 14.4% (Table 2) and was significantly affected by BSpa and SDL at the $P \leq 0.05$ level (Table 1). PodFT was directly proportional to BSpa and SDL. Also, the Type II SS from the regression indicated that BSpa had about twice the influence on PodFT as SDL. Data for the remaining dependent variables were similar yielding equations with varying influences of the independent variables.

Minimums, maximums, means and standard deviations of LSKFT, FMFT, StickFT, DirtFT, and RockFT are presented also in Table 2. The LSKFT, FMFT, StickFT, DirtFT, and RockFT were influenced more by SDL than BSpa, BSpd, or MatFR. The sum of the Type II SS for the SDL terms accounted for approximately 77% of the total Type II SS from the LSKFT equation regression; 76.7% for the FMFT regression; 97.6% for the StickFT regression; 72.9% for the DirtFT regression; and 64.5% for the RockFT regression. Because of the major influence of SDL on LSKFT, FMFT, StickFT, DirtFT, and RockFT, average values of BSpa (0.99 cm), BSpd (96.525 cm/sec), and MatFR (1.1325 t/hr) were

Table 1. Derived multipliers for the independent variable terms of prediction equations describing the percentage of each dependent variable falling through the screen.

	Dependent variable equation multipliers						
	SFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT
IC	-114.6081	162.4351	-260.1180	-252.2163	28.6485	-4.7111	-353.9370
M_1	-20.6890	-327.9715*	436.0884*	388.2367*	-31.8257	0.1510	564.9129
M_2	125.7416	177.2871*	-84.9082*	-66.8857	24.1678	48.6096	-111.1780
M_3	2.6714	-0.3624	1.8669	2.2699	0.5909	1.1804	2.5785
M_4	-0.0036	0.0019	0.0016	0.0039	0.0015	0.0040	0.0066
M_5	169.1982	-7.1637	231.6336*	315.9123*	94.0622	129.3592	246.1789
M_6	-1.4026	-1.2435	-2.6909*	-1.9427	-3.0577*	-3.8780	-2.0173
M_7	-0.4591	-0.2844	1.6484	1.9930	0.8405	1.0357	-0.4118
M_8	-0.0003	-0.0005*	-0.0018*	-0.0022*	-0.0031*	-0.0011*	-0.0015*
M_9	-2.0959	0.0190	-2.3424*	-2.9276*	-0.6824	-1.5834	-3.7720
M_{10}	-179.4383	15.2491	-235.8929*	-315.7395*	-87.5244	-106.1703	-237.9239
M_{11}	0.5672	0.4745	-1.2281	-1.2589	0.2320	-0.3198	0.8291
M_{12}	-1.8629	0.1349	-2.1621*	-3.1698*	-0.9989	-0.8718	-2.4295
M_{13}	0.0034	-0.0039	-0.0098	-0.0163	-0.0031	-0.0097	0.0060
M_{14}	0.2904	-0.2723	-1.0460	-1.8415	-0.3701	-0.6176	0.1683
M_{15}	1.9602	-0.1879	2.2027*	3.1160*	0.8279	0.7112	2.3483
M_{16}	-0.2832	0.3186	1.0996	1.8549	0.3422	0.5582	-0.0796
M_{17}	-0.0032	0.0046	0.0107	0.0158	0.0017	0.0076	-0.0054
M_{18}	-0.0031	0.0034	0.0096	0.0189	0.0043	0.0041	-0.0012
M_{19}	0.0030	-0.0041	-0.0098	-0.0186	-0.0034	-0.0034	0.0006

*Significant at $P \leq 0.05$ level.

Table 2. Minimums, maximums, means, and standard deviations of the dependent variables (% of material category which fell through the screen).

	Dependent variable						
	SFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT
Min	6.3	5.5	93.6	88.4	83.9	93.9	64.5
Max	49.1	48.3	99.8	98.3	99.5	100.0	99.0
Mean	21.9	23.7	97.9	93.4	93.9	99.8	84.9
SD	10.4	14.4	1.3	2.2	3.7	0.9	7.2

substituted into (Eq. 1) for LSKFT, FMFT, StickFT, DirtFT, and RockFT. Equations of the form:

$$LSKFT = IC + M_1 \times SDL + M_2 \times SDL^2 \qquad [Eq. 2]$$

were obtained. Coefficients for these equations are given in Table 3 and curves developed from the equations are presented in Fig. 2. The LSKFT, FMFT, StickFT, RockFT, and DirtFT increased with increases in SDL. The LSKFT equation (Eq. 2) predicted that the largest amount of LSK expected to fall through the screen (99.1%) required a 153-cm SDL; the largest FMFT (94%), a 163-cm SDL; the largest StickFT (93.9%), a 163-cm SDL; the largest RockFT (85.4%), a 163-cm SDL; and the largest DirtFT (100%), a 153-cm SDL. These curves and equations indicate that the longest SDL tested was required to separate the maximum amounts of LSKFT, FMFT, StickFT, RockFT, and DirtFT.

Table 3. Derived multipliers for independent variable terms of equations describing the effects of SDL on LSKFT, FMFT, StickFT, DirtFT, and RockFT [reduction of (Eq. 1) substituting average values for BSpa, BSpd, and MatFR].

	Dependent variable equation multipliers				
	LSKFT	FMFT	StickFT	DirtFT	RockFT
IC	56.464	34.090	11.695	47.319	44.532
M_1	0.556	0.726	1.008	0.518	0.501
M_2	0.002	0.002	0.003	0.001	0.002

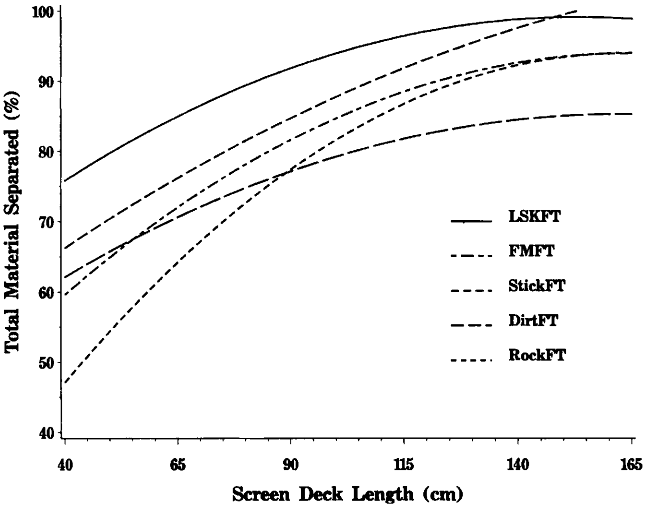

Fig. 2. Effect of screen deck length (SDL) on the separation of materials.

Because of physical limitations, the SDL would not normally be adjusted during operation, i.e., the screen would have a fixed length. Because the longest SDL tested was required for maximum separation of LSKFT, FMFT, StickFT, RockFT, and DirtFT, the prediction equations (Table 1) were reduced by substituting 162.56-cm for SDL. Equations of the form:

$$DV = IC + M_1 \times BSpa + M_2 \times BSpa^2 + M_3 \times BSpd + M_4 \times Bspd^2 + M_5 \times MatFR + M_6 \times MatFR^2 + M_9(BSpa \times BSpd) + M_{10}(BSpa \times MatFR) + M_{12}(BSpd \times MatFR) + M_{15}(BSpa \times BSpd \times MatFR); \qquad [Eq. 3]$$

were obtained. These equations (Table 4) were utilized to generate a data set predicting values for each dependent variable for all combinations of BSpa, BSpd, and MatFR tested (4 x 4 x 4 = 64 values for each dependent variable). Minimums, maximums, means, and standard deviations for each dependent variable were determined from the data set and are presented in Table 5. The data set and equations also were used to generate two-dimensional graphs (quadratic curves) for the dependent variables significantly effected by BSpa, BSpd, or MatFR as indicated in Table 4. These curves for PodFT, LSKFT, FMFT, and StickFT are presented in Figs. 3-6, respectively. No curves are shown for SFT, DirtFT, and RockFT. The effects of BSpa, BSpd, or MatFR on SFT were not significant at the $P \leq 0.05$ level (Table 4).

The curve and data scatters in Fig. 3 show that PodFT increased with BSpa. PodFT was not significantly influenced by BSpd or MatFR. Although LSKFT was significantly affected by BSpa and MatFR (Table 4), the influences were not as easily detected visually as with other comparable combinations of curves because of interactions between the independent variables (Fig. 4). The curves for FMFT (Fig. 5) show that amount falling through increased with BSpa and decreased with MatFR. BSpd had little influence on FMFT. The amount of StickFT decreased as MatFR increased (Fig. 6). Changes in BSpa and BSpd produced little change in StickFT. The ranges tested for BSpa, BSpd, and MatFR had little effect on DirtFT. Essentially all DirtFT was removed with the total SDL used with any combination of BSpa, BSpd, and MatFR. The ranges tested for BSpa, BSpd, and MatFR also had little effect on RockFT.

Pre-operational determination of key parameters in belt screen performance depends upon both desired separations and size distributions of materials to be screened. The data presented show varying amounts of components of farmers stock peanut material falling through the belt screen dependent upon settings of operational parameters. The amount of material falling through the screen varied directly with screen deck length and belt spacing. Screen deck length had the greatest effect on the amount of LSK, total FM, sticks from FM, dirt from FM, and rocks from FM falling through the screen. Belt speeds and material feed rates had less effect on the separations made than screen deck

Table 4. Derived multipliers for independent variable terms for equations describing the percentage of each dependent variable falling through the screen (reduction of Table 1 equations substituting 162.56 cm as SDL).

	Equation term multipliers						
	SFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT
IC	-197.9040	103.1520	-40.0790	13.7030	83.6920	133.7690	-461.4620
M_1	71.5110	-250.8340*	236.4430*	183.5830*	5.8900	-51.8410	699.6930
M_2	125.7420	177.2870*	-84.9080*	-66.8860	24.1680	48.6100	-111.1780
M_3	3.2275	-0.9940	0.2693	-0.3871	0.0914	-0.3977	3.5469
M_4	-0.0036	0.0019	0.0016	0.0039	0.0015	0.0040	0.0066
M_5	216.4120	-51.4280	61.5980*	16.5590*	33.9040	28.9560	273.5430
M_6	1.4026	-1.2436	-2.6909*	-1.9427	-3.0577*	-3.8780	-2.0173
M_9	-2.6113	0.7723	-0.5954*	-0.3614*	-0.4059	-0.3434	-4.6537
M_{10}	-225.4740	67.0460	-57.1430*	-14.2100*	-31.9030	-15.4340	250.8570
M_{12}	-2.3729	0.6836	-0.5953*	-0.0961*	-0.3006	-0.2063	-2.6269
M_{15}	2.4557	-0.8526	0.6166*	0.0923*	0.2833	0.1574	2.4468

*Significant at $P \leq 0.05$ level.

Table 5. Minimums, maximums, means, and standard deviations for the dependent variables calculated with the prediction equations utilizing the BSpa, Bspd, and MatFR values used in the experiment.

	Dependent variable						
	SFT	PodFT	LSKFT	FMFT	StickFT	DirtFT	RockFT
Min	5.94	3.84	94.48	89.99	86.87	98.57	72.51
Max	36.90	48.76	100.00	96.96	99.96	100.00	90.95
Mean	21.83	23.63	97.56	93.67	93.41	99.82	84.49
SD	7.84	14.83	1.48	1.69	3.52	0.39	3.14

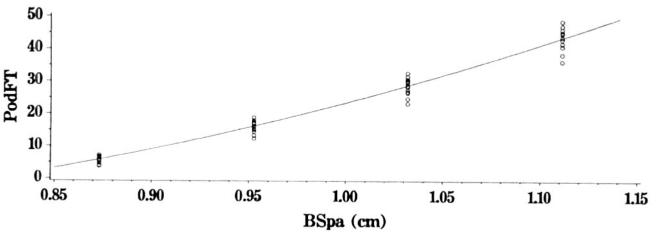

Fig. 3. Effects of BSpa on pods falling through the screen.

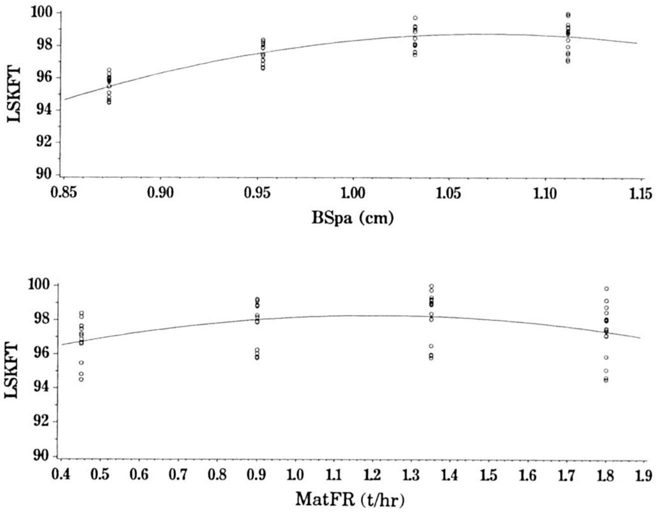

Fig. 4. Effects of BSpa and MatFR on LSK falling through the screen.

length and belt spacing.

The data presented here describe a range of separations obtained from one population of peanut material. Similar separations could probably be made with most farmers stock peanut material, if testing was done to select proper settings for screen deck length, belt spacing, belt speed, and material feed rate.

The controlling factor limiting the removal of foreign material from farmers stock peanuts with belt screens is probably the amount of pods removed with the loose shelled kernels and foreign materials. Subsequent separation of pods, loose shelled kernels, and foreign material, is difficult and requires additional separating techniques such as aspiration and specific gravity separation. Combinations of screens may provide a usable solution for removal of certain materials from farmers stock peanuts which could then be subsequently cleaned at lower flow rates to improve the efficiency of conventional cleaners.

Use of belt screens for improving the quality of farmers stock peanuts is feasible but will require adjustment of parameters controlling machine operation for desired separations of materials. Belt screens offer a nonblanking, high-capacity alternative to vibratory screens for screening farmers stock peanut materials.

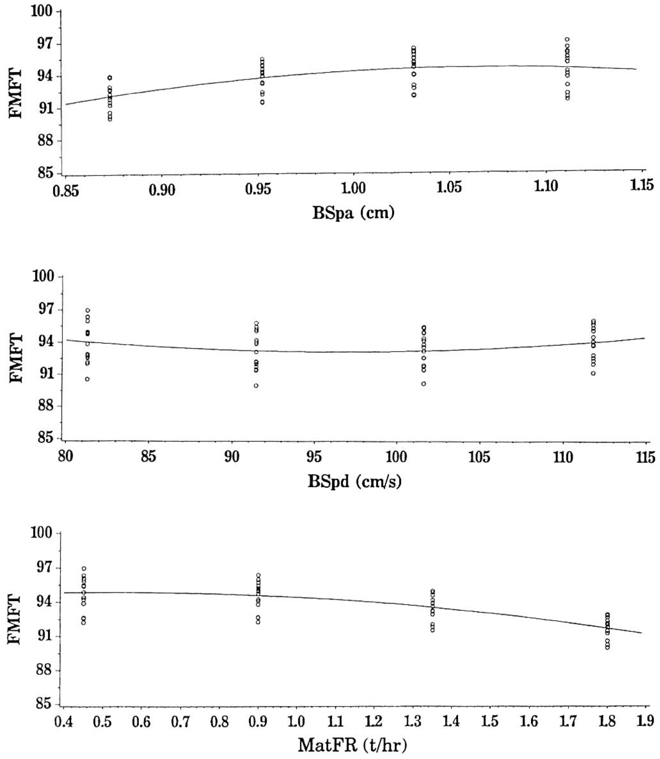

Fig. 5. Effects of BSpa, BSpd, and MatFR on FM falling through the screen.

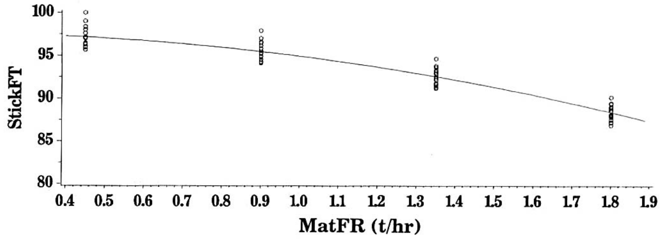

Fig. 6. Effects of MatFR on sticks falling through the screen.

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