CONDITIONING SHRIVELED SOYBEAN SEED PART I. VARIATION IN PHYSICAL PROPERTIES

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ABSTRACT

This study was conducted to determine the effectiveness of various cleaning and upgrading equipment in removing shrivelled seeds from drought-damaged soybean seedlots. The conditioning line, consisting of an air-screen cleaner, spirals and a gravity table, successfully improved quality, but at the cost of a high number of discards. Shrivelled seeds removed during conditioning were significantly lower in seed weight, seed volume, and bulk density that the normal seeds. **KEYWORDS.** Soybean conditioning, Drought damage.

INTRODUCTION

A recent study by Taylor (1989) ranked the 1988 drought in the American Midwest as the fourth most devastating, in terms of yield, within the last 100 years. South American countries such as Brazil, Argentina, and Uruguay also faced great production losses due to a combination of low precipitation levels and high temperatures. In addition to a greatly reduced yield, large percentages of shriveled seeds were produced. This research was initiated to assist seed producers in conditioning seedlots containing shriveled soybean seeds.

The goal of any seed conditioning operation is to maximize the quality of clean seed and to minimize the amount of discard. A seed conditioner often faces the challenge of balancing the quality aspect with the amount of discard, especially in seedlots that are difficult to condition. Additionally, seed conditioners need to maintain a high capacity during operation and to produce a final product with an acceptable appearance. Conditioning shriveled soybean seedlots from the 1988 crop presented such a challenge.

The specific objectives of this study were to:

- Determine the effectiveness of various cleaning and upgrading equipment in removing shriveled seeds from soybean seedlots.
- Determine changes in physical and physiological seed properties at various stages in conditioning.

This article discusses the variation in the physical properties of shriveled soybean seeds during conditioning. A subsequent article deals with the correlation between physical properties and physiological quality parameters.

LITERATURE REVIEW

After harvesting, seeds are conditioned to upgrade their quality by removal of contaminants (weed seeds and damaged or deteriorated crop seeds). Conditioning machines exploit differences in physical properties between desirable seed and contaminants. The most important physical differences are size, shape, and density (Thomson, 1979).

Seed conditioning can be broadly divided into two major operations: 1) basic cleaning, and 2) seed upgrading. In many lots, the basic cleaning process removes all the contaminants separable by a simple combination of air blast and screens (Thomson, 1979). In some instances, however, the physical properties of contaminants are too close to those of desirable seed to allow separation. Thus, machines such as spiral separators and gravity tables, which perform precise separations by a specific physical characteristic, are necessary. These upgrading machines have been studied, in depth, by Harmond et al. (1968), Gregg et al. (1970), Brandenburg (1977), Thomson (1979), and others.

Misra et al. (1985) conducted experiments to determine the change in soybean seed quality at various stages in conditioning. The air-screen cleaner removed practically all impurities present in the seedlots and also improved germination percentage by 0.8%. The spiral separator did not improve germination significantly but was effective in removing misshapen seeds. The gravity table removed splits and also improved the germination percentage

In an experiment with soybean seeds, Gaul et al. (1986) found that the light fraction from the gravity table was lower in bulk density and was more brittle than the remaining seed fractions. No significant differences in specific gravity among the various fractions, however, were found. The authors attributed this finding to the high correlation between seed weight and seed volume.

In a field study, Green et al. (1965) found that wrinkled, shriveled, and green soybeans were more frequently produced when earlier planting dates had been employed and when higher temperatures were present during maturation. Seedlots containing a greater number of severely shriveled seed had lower laboratory germination and field emergence percentages.

Misra (1983) used an air-screen cleaner, spiral separator, and gravity table to separate shriveled black nightshade berries from soybean seedlots. The air-screen cleaner

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removed over 95% of the shriveled nightshade berries. For seeding purposes, the remaining seedlot was conditioned through the spiral separator and gravity table. An aspirator was attempted after the spiral separator, but it did not provide any appreciable improvement for removing shriveled nightshade berries. In a conditioning plant, Londgen et al. (1974) reported that attempts to remove shriveled seeds from sugar-beet by using vibrating screens, air columns, and rubber rolls were unsuccessful.

Baudet (1987) investigated five sizes of seed corn conditioned through two types of gravity tables (pressure and suction types). The gravity table was effective in separating different fractions (heavy, medium heavy, medium light, and light) of seed corn along the discharge edge. The fractions from the high side were heavier, larger, and better performing in germination and cold tests than the fractions from the low side.

Spilde (1989) studied the effects of seed size and weight of barley and hard red spring wheat on market traits. Seeds were separated by size and weight through a precision grader and a gravity table, respectively. In both barley and wheat, seed size was correlated with yield, whereas seed weight did not present a similar trend. Larger and heavier seeds had less moisture content than smaller and lighter seeds. The author considered this finding economically advantageous because drying costs could be reduced.

An early study by Snyder (1905) provided evidence that chemical composition percentages of wheat, oats, and barley were related to seed weight. Heavier wheat grains had greater percentages of nitrogen, phosphoric acid, and potash than did lighter grains. Similar results were found for oats and barley.

The literature concerning the effects of seed size on growth and on other aspects of many crops is extensive. Many investigators (Burris et al., 1971; Singh and Makne, 1985; Black, 1957) have reported a positive correlation between seed size and seedling vigor and yield. Other studies (Singh et al., 1972; Johnson and Luedders, 1974), however, showed no correlation between seed size and seedling performance.

Materials and Methods

Five uncleaned soybean seedlots, each a different proprietary variety, were obtained from commercial sources in the state of Iowa. The moisture percentages were 10.1, 11.2, 9.7, 10.0, and 9.2 (wet basis) for lots 1, 2, 3, 4, and 5, respectively. Table 1 shows the initial physical characteristics of each seedlot.

Each seedlot was divided into two sublots. Soybean seeds from each sublot were first conveyed to the cleaner bin by a Hance Model 110GH bucket elevator (fig. 1) and then passed through a Model H-434A Crippen air-screen cleaner. Good soybean seeds from the air-screen cleaner were conveyed by a Mitchel gentle bucket elevator and then passed through an AMOS (AG-Machinery & Safety, Inc.) Model No. 100 spiral separator. The remaining good seeds from the spiral separator were transported to the gravity bin and finally sorted into three fractions by an Oliver Model 50 gravity table equipped with a 10-mesh wire screen deck (fig. 1).

TABLE 1. Initial quality properties of each soybean seedlot*

Seed Lot	Shrivelled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Term. vel./ (m/s)
1	38 a	717.0c	12.02bc	9.66c	8.94bc
2	29 ab	723.9bc	11.18c	9.32c	8.72c
3	16 bc	754.9a	16.17a	13.23 a	9.22ab
4	16 bc	723.4bc	12.71b	10.74 b	8.72c
5	5 c	724.2b	15.58a	12.82 a	9.38a

* Means not followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

Preliminary tests were conducted using a few bags of soybeans to determine optimum equipment adjustments for each seedlot. Seeds were recycled through each machine until the most appropriate adjustments were obtained. The seeds used during the preliminary tests were discarded and not utilized subsequently in the experiment.

Samples were collected initially, after each conditioning operation, and also from the discard sections of each machine as shown in figure 1. The sample collection points were: Initial, screenings that passed through the first sifting screen of the air-screen cleaner (CS1), screenings that passed through the second sifting screen of the air-screen cleaner (CS2), bottom air lifting of the airscreen cleaner (CL), good seeds after the air-screen cleaner (AC), discard from the spiral separator (SD), and three fractions of the gravity table: gravity discard (GD), gravity middle (GM), and final. Each sample of approximately 1 kg was taken by moving a container several times across the stream flow.

Seeds were visually examined and recorded for shriveled seed percentage. Bulk density was obtained by calculating the ratio of weight to volume using the standard test weight apparatus and following the procedure described in the USDA Grain Inspection Handbook (USDA, 1980). The weight of one hundred seeds was obtained in a Mettler PE 160 scale to the nearest 0.001 g. Seed volume was measured on a stereo pycnometer using helium gas (Quantachrome Corp., 1985). Samples used for volume determinations were weighed and divided by their

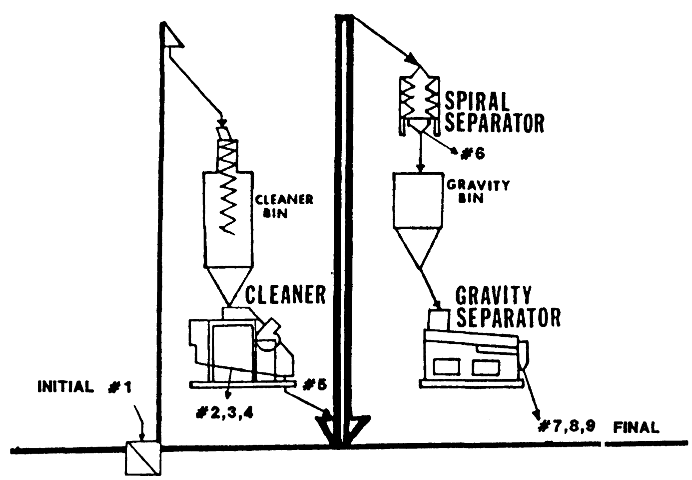

Figure 1–Conditioning equipment sequence and sample collection points # 1: Initial; #2: Screenings that passed through the first sifting screen (CS1) of the air-screen cleaner; #3: Screenings that passed through the second sifting screen (CS2) of the air-screen cleaner; #4: Bottom air lifting (CL) of the air-screen cleaner; #5: Good seeds after the air-screen cleaner (AC); #6: Discards from the spiral separator (SD); #7: Gravity discard (GD); #8: Gravity middle (GM); and #9: Final.

TABLE 2. Physical properties of seedlot 1 conditioned through the air-screen, spiral separator, and gravity table*

Condition Step	Shriveled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Kernel Density (g/cm^3)	Terminal Velocity (m/s)
Initial	38 d	717.0 cd	12.02 d	9.66 d	1.24 a	8.94 bc
CS1	98 a	672.6 f	7.72 g	6.30 g	1.23 a	7.96 d
CS2	73 bc	710.6 d	10.27 f	8.34 f	1.23 a	8.77 c
CL	91 ab	697.2 e	11.24 e	9.04 e	1.24 a	8.82 c
AC	18 ef	749.8 a	13.82 c	11.08 c	1.25 a	9.57 a
SD	66 c	725.3 bc	14.80 ab	11.90 ab	1.24 a	8.92 c
GD	29 de	732.2 b	14.10 bc	11.28 bc	1.25 a	9.28 ab
GM	7 f	749.7 a	15.00 a	12.00 a	1.25 a	9.34 a
Final	4 f	753.4 a	15.31 a	12.26 a	1.25 a	9.59 a
Overall change						
(Initial - Final)	-34.0	36.3	3.29	2.60	0.01	0.73

* Means followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

respective volumes to obtain kernel density. Terminal velocity was measured by placing individual kernels in a vertical air stream and adjusting the air flow by regulating voltage to the fan by a variable transformer until the seed remained suspended.

Data analysis was performed by the Statistical Analysis System (SAS) using a three-way factorial experimental design. Seedlots, replications, and conditioning steps were the factors. A standard analysis of variance procedures was used to analyze sources of variability and statistical significance. Correlations between physical and physiological properties were obtained by the "CORR" procedure of the Statistical Analysis System.

Results and Discussion

The physical quality for all seedlots was greatly improved by conditioning procedures (Tables 2-6). For seedlots 1, 2, and 4, the final sample contained a significantly reduced percentage of shriveled seeds (Tables 2, 3, and 5). Bulk density, seed weight, seed volume, and terminal velocity were also significantly improved. Seedlots 3 and 5 showed improvements in physical properties after conditioning, but the improvements were not statistically significant at the 0.05 level of confidence (Tables 4 and 6). This is due to the higher initial quality of these seedlots. Seedlot 3 had the greatest initial values of bulk density, seed weight, and seed volume (Table 1). Seedlot 5 had the least amount of shriveled seeds initially and had the highest value in terminal velocity (Table 1).

Kernel density did not show significant change at various stages in conditioning for all seedlots (Tables 2-6). This is explained by the high correlation between seed weight and seed volume (Table 7). This finding is in agreement with that of Gaul et al. (1986). The percentage of shriveled seeds was negatively correlated with seed weight and seed volume (Table 7). McDonald (1985) found similar results and stated that plants under environmental stress during filling period decrease their growth rate, thus producing small-sized soybean seeds. Bulk density presented positive correlations with seed weight and seed volume (Table 7). Baudet (1987) working with seed corn, and Gregg (1969) sorting cottonseed in a gravity table, found similar relations. Terminal velocity had a strong positive correlation with seed weight and seed volume (Table 7). Cundiff (1979) and Hawk et al. (1966) also found heavy and large seeds associated with high terminal velocities.

Unusually high amounts of discard were recorded for all seedlots (Table 8), except for seedlot 5. Such discards, however, were necessary because seedlots 1, 2, 3, and 4 initially contained 16 to 38% shriveled seeds. The screenings through screen 1 (CS1) and through screen 2 (CS2) of the air-screen cleaner, for example, contained high percentages of shriveled soybeans (fig. 2). This

TABLE 3. Physical properties of seedlot 2 conditioned through the air-screen, spiral separator, and gravity table*

Condition Step	Shriveled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Kernel Density (g/cm^3)	Terminal Velocity (m/s)
Initial	29 c	723.9 d	11.18 b	9.32 b	1.20 b	8.72 bc
CS1	95 a	694.0 e	7.09 d	5.71 d	1.24 a	7.82 d
CS2	90 a	666.1 f	8.02 cd	6.48 cd	1.24 ab	8.05 d
CL	64 b	696.6 e	9.20 c	7.44 c	1.24 ab	8.38 cd
AC	12 cde	740.4 bc	12.91 a	10.38 ab	1.23 ab	8.95 abc
SD	22 cd	739.2 bc	12.69 ab	10.40 ab	1.22 ab	8.76 bc
GD	16 cde	731.6 cd	12.68 ab	10.29 ab	1.21 ab	8.63 bc
GM	7 de	744.8 ab	13.43 a	11.21 a	1.20 ab	9.12 ab
Final	4 e	753.0 a	13.89 a	11.41 a	1.22 ab	9.36 a
Overall change						
(Initial - Final)	-25.0	29.10	2.71	2.09	0.02	0.69

* Means followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

TABLE 4. Physical properties of seedlot 3 conditioned through the air-screen, spiral separator, and gravity table*

Condition Step	Shriveled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Kernel Density (g/cm^3)	Terminal Velocity (m/s)
Initial	16 d	754.9 ab	16.17 ab	13.23 ab	1.22 a	9.22 b
CS1	100 a	653.6 e	7.27 d	5.94 d	1.22 a	7.29 e
CS2	75 b	728.8 d	7.92 d	6.60 d	1.20 ab	7.83 d
CL	50 c	726.8 d	9.00 d	7.96 d	1.14 b	8.29 c
AC	6 d	755.0 ab	13.99 bc	11.41 bc	1.22 a	9.34 ab
SD	12 d	746.7 bc	12.67 c	10.41 c	1.22 a	8.37 c
GD	16 d	736.8 cd	13.63 bc	11.18 bc	1.22 a	9.22 b
GM	4 d	749.4 ab	15.94 ab	13.05 ab	1.22 a	9.35 ab
Final	3 d	758.4 a	17.46 a	14.67 a	1.19 ab	9.55 a
Overall change (Initial - Final)	-13.0	3.5	1.29	1.44	-0.03	0.48

* Means followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

TABLE 5. Physical properties of seedlot 4 conditioned through the air-screen, spiral separator, and gravity table*

Condition Step	Shriveled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Kernel Density (g/cm^3)	Terminal Velocity (m/s)
Initial	16 e	723.4 bc	12.71 bc	10.74 b	1.18 a	8.72 bc
CS1	90 a	699.0 d	9.30 de	7.67 cd	1.21 a	7.69 e
CS2	32 c	717.9 c	8.99 e	7.50 d	1.20 a	8.03 de
CL	44 b	701.7 d	10.30 de	8.88 cd	1.17 a	8.26 d
AC	10 f	726.8 b	13.79 b	11.40 b	1.21 a	8.92 b
SD	16 e	724.6 b	11.01 cd	9.09 c	1.21 a	8.37 cd
GD	23 d	701.1 d	12.93 b	10.90 b	1.19 a	8.78 b
GM	10 f	725.8 b	16.66 a	13.70 a	1.21 a	9.09 ab
Final	4 g	745.2 a	16.33 a	13.50 a	1.22 a	9.32 a
Overall change (Initial - Final)	-12.0	21.80	4.16	2.76	0.04	0.73

* Means followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

TABLE 6. Physical properties of seedlot 5 conditioned through the air-screen, spiral separator, and gravity table*

Condition Step	Shriveled Seeds (%)	Bulk Density (km/m^3)	Weight (g/100 seeds)	Volume (cm^3/100 seeds)	Kernel Density (g/cm^3)	Terminal Velocity (m/s)
Initial	5 de	724.2 a	15.58 b	12.82 bc	1.21 ab	9.38 abc
CS1	96 a	485.8 b	9.18 d	7.54 d	1.22 ab	7.58 d
CS2	10 cd	723.2 a	9.53 cd	8.14 d	1.17 b	7.69 d
CL	37 b	690.4 a	12.21 c	10.31 cd	1.18 ab	8.27 cd
AC	2 e	741.1 a	16.40 b	13.76 ab	1.19 ab	9.32 abc
SD	12 c	736.9 a	16.32 b	13.32 bc	1.22 a	9.01 bc
GD	9 cd	727.6 a	16.33 b	14.79 ab	1.21 ab	9.15 abc
GM	3 e	740.3 a	19.64 a	16.02 ab	1.23 a	9.87 ab
Final	2 e	745.4 a	20.21 a	16.65 a	1.21 ab	10.32 a
Overall change (Initial - Final)	-3.0	21.20	4.63	3.83	0.00	0.98

* Means followed by the same letter in a column are not statistically different ($p < 0.05$) according to the T-test.

TABLE 7. Correlations among physical properties of soybean seeds conditioned by the air-screen cleaner, spiral separator, and gravity table

	Bulk Density	Weight	Volume	Kernel Density	Terminal Velocity
Shriveled seeds	-0.69*	-0.78*	-0.79*	0.16	-0.73*
Bulk density		0.54*	0.53*	0.01	0.63*
Weight			0.99*	0.10	0.90*
Volume				0.01	0.88*
Kernel density					0.24

* $p < 0.01$.

finding indicates the importance of proper screen selection. Screening alone, however, was not sufficient for removing shriveled soybeans to the point that the seedlot was marketable. The percentage of shriveled soybeans in air liftings from the cleaner (CL) was also high following the screening operation (fig. 2). This finding indicates the importance of proper air adjustment in the air-screen cleaner for the production of a quality product. Even after the air-screen cleaner, all seedlots except lot 5 contained some shriveled soybeans and needed to be cleaned by the spiral separator and gravity table for further removal of shriveled soybeans to meet marketing standards.

Conclusions

The following conclusions were obtained from this study.

The conditioning line, consisting of an air-screen cleaner, spiral separator, and gravity table, successfully removed shriveled seeds. The air-screen cleaner removed about 50% of the shriveled soybean seeds. For seedlots with great initial amounts of shriveled seeds, additional upgrading equipment was necessary. After the air-screen cleaner, the spiral separator removed most of the remaining shriveled seeds. Following the spiral separator, the gravity table was able to provide a finishing separation.

The final product was distinctly improved in appearance and physical properties. The improve-ment in quality, however, was obtained at the cost of high amounts of discards.

TABLE 8. Percentage of discard from the air-screen cleaner, spiral separator, and gravity table

Sample Point	Seedlot 1	2	3	4	5
Air-screen Cleaner					
CS1	10.60	18.63	2.00	7.69	4.42
CS2	22.24	1.08	2.76	10.77	2.43
CL	5.01	4.27	6.88	5.63	1.35
Spiral Separator					
SD	8.23	9.00	10.31	20.67	1.86
Gravity Table					
GD	19.23	26.05	18.60	17.63	14.58
Total	65.31	59.03	40.55	62.39	24.63

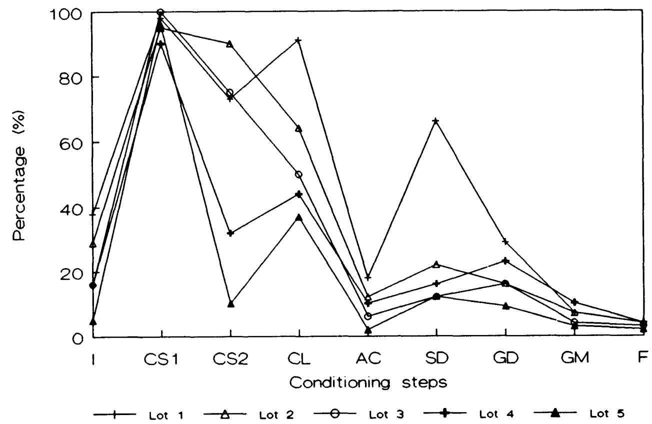

Figure 2-Shriveled seed percentages at various stages in conditioning.

Shriveled seeds removed from soybean lots during conditioning procedures were significantly lower in seed weight, seed volume, and bulk density than normal seeds.

A trend of increase in weight, size, and bulk density was observed from the low to the high discharge end of the gravity table.

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