EXPERIMENTAL HULLING-SEPARATING OF KERNELS AND HULLS FROM HIGH OIL CONTENT SUNFLOWER SEED

By

S.P. Clark, P.J. Wan and S.W. Matlock
Food Protein Research and Development Center
Texas A&M University
College Station, Texas 77843

Abstract

A flowsheet was developed and tested for separating hulled sunflower seed into nearly pure kernels and hull fractions. Pilot plant size equipment was employed to produce material balances for three lots of seed. Design of the flowsheet was based on the principles of 1) sizing of seed to remove small seed before hulling in order to minimize passage of unhulled seed through the first separating screen following the huller; and 2) use of specific gravity separators to separate loose kernels from hulls. Sizing rejected about 27% of the cleaned seed from two different lots. One lot was processed without sizing. Kernel fractions were produced from sized seed which contained 1.2 and 2.1% residual hulls, compared with 3.7% hulls from unsized seed. The results from sized seed were on the border line of acceptability if light color in defatted flour were desired. Kernel contents of the hulls fraction ranged from 0.9 to 1.8%.

Introduction

Hulling seed and separating kernels and hulls usually are considered together for any kind of seed. However, hulling and separating are separate operations. For one kind of seed, the same operating techniques usually can be applied to the product from any type of hulling machine. Usually not all seed are hulled during a single pass through a huller, and the separating process requires separation of unhulled or partially hulled seed as well as kernels and hulls. The unhulled seed may then be recycled to the same huller or to a different huller.

Our investigation of hulling of sunflower seed was conducted as a separate study and it is being reported separately. This paper describes a process developed to separate hulled sunflower kernels and hulls, with application here only to so-called "high oil content or oilseed cultivars", as contrasted with "low oil content confectionary cultivars".

A similar separation process was described by Defromont (1972), applied to an oil mill operation.

Oilseed cultivars are known for their greater difficulty of hulling, because the hull is thinner and is more tightly attached to the kernel than for confectionary seed (Popova, 1968).

Materials and Methods

Two lots of sunflower seed were employed. Both were called oilseed cultivars. The first lot was of unknown and possibly mixed cultivars, grown in the northern U.S. and designated "Northern". The oil content was 46.8%, moisture free basis. The second lot was planting seed from Growers Seed Co., Lubbock Texas, designated "Growers 380". It was grown in West Texas. The oil content was 39.3%, moisture free basis.

The flowsheet (Figure 1) shows the processing steps employed for experimental separating. This also is the flowsheet proposed for a continuous hulling-separating process.

The seed was cleaned and sized on a Bauer No. 199 cottonseed cleaner (step 1). This machine has two shaker trays, 0.91 m wide by 3.05 m long. Each tray can be equipped with a perforated metal sash having holes of different sizes and shapes. Round holes were employed for sunflower seed. Hole sizes for screens are designated in millimeters as 9.5 R for round or 1.0 S for square holes.

Hulling and separating machinery, one-half commercial size, designed primarily for cottonseed, was used for hulling and separating in steps 3, 4a, 4b, 5 and 9. This machinery was manufactured by Murray-Carver Co., Dallas, Texas. The huller consisted of a rotating cylinder with longitudinal bars, which operated in close proximity to 5 stationary bars mounted on a concave member. The square edged bars were mounted to protrude approximately 3.2 mm from the surfaces of the cylinder and the concave. Seed hulls were broken by the square corners on the bars, either by impact or by shearing. The distance between cylinder and concave was adjustable, and for hulling sunflower seed, a single, realtively wide spacing was used. Because of the wide spacing, most hulling was judged to be by impact.

A shaker screen was positioned to receive seed discharging from the huller (steps 4a, 4b). The two 0.91 by 3.05 m trays were dressed with perforated metal sash which could be changed to suit the separation being made. A second similar shaker screen (purifier) was also used for sizing kernels (step 4c). Also employed for this purpose was a vibrating screen with 76 cm diameter round trays and woven wire screen (step 4d).

An air column type air classifier, called a "hull and seed separator", was used to separate some of the hulls from mixtures of hulls, unhulled seed and kernels (step 5). The unhulled seed and kernels were then recycled to the huller. Hulls aspirated from this separator were rescreened in a revolving screen hull beater to salvage small kernel particles (step 9).

More complete separations of kernels and hulls (steps 6,7,8) were made with a 56 cm long deck, model V 135A specific gravity separator manufactured by Triple/S Dynamics, Dallas, Texas. Three fractions were taken from this separator which were called "unders", "mids" (middle), and "overs". Unders were rich in kernels; overs were rich in hulls; and middles were mixtures of kernels and hulls. In a continuous process mids would be recycled to the huller or to some other earlier process step.

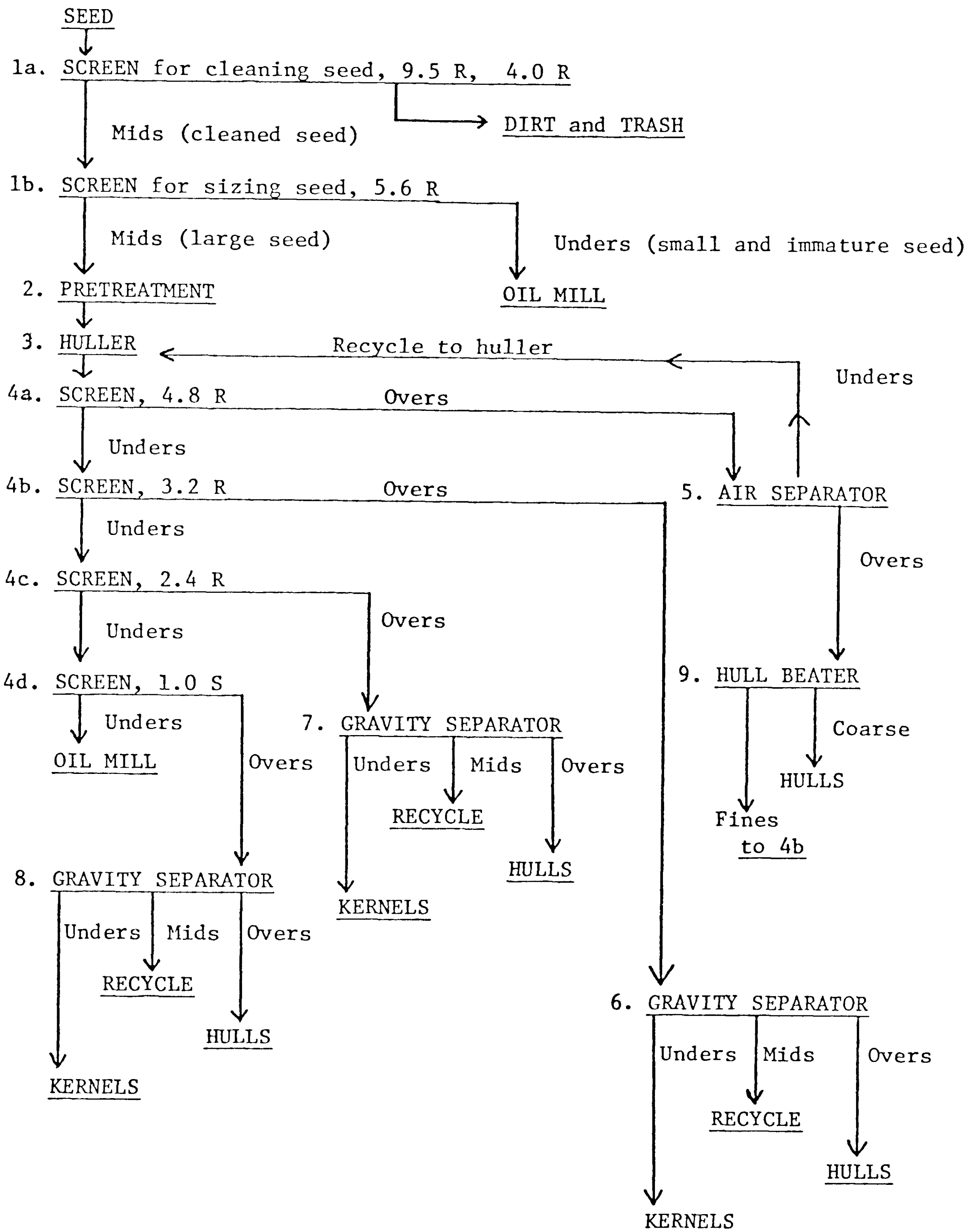

FIGURE 1. Flowchart for processing sunflower seed.

Results and Discussion

Development of Flowsheet

When the Murray-Carver hulling-separating machinery is operated on cottonseed, hull and kernel separation is achieved by screens and by aspiration of loose hulls from kernels. Aspiration can be done quite effectively without pulling off many kernel particles with the hulls. When unsized sunflower seed were passed through this machinery, attempts to separate unhulled seed from coarse kernels by screens, and hulls from kernels by aspiration were ineffective. These results indicated that small seed needed to be separated from larger seed before hulling so that each size fraction could be processed separately. Experiments in the hulling phase of the present investigation showed that small seed were more difficult to hull than large seed and this likewise indicated that seed should be sized before hulling.

Preliminary separating experiments with the Carver machinery also showed that removal of sunflower hulls from kernels by aspiration has only limited application because sunflower seed kernels are too easily picked up along with hulls. Some other principle of separation was needed, and specific gravity separation was selected. Therefore, makeup of the flowsheet was based on these two principles: sizing of seed to minimize passage of unhulled seed through the first separating screen after the huller (step 4a); and use of specific gravity separators to separate loose kernels and hulls. This flowsheet was constructed with the objective of producing maximum yields of low hull content kernels for use in manufacture of defatted flour.

The flowsheet shows small seed streams from step 1, and unders from step 4d going to OIL MILL. As an alternative, small seed might be subjected to a separate hulling-separating process with a 4.0 R screen at step 4a. However, probably such an additional process would not be economically feasible. One could not afford to discard the small seed, and therefore conventional oil milling might be the best way to utilize these seed. Likewise, kernels and hulls too small for separating, coming from step 4d, would be utilized best in an oil mill.

Step 2, pretreatment of seed, was placed in the flowsheet because experimental trials on hulling showed that some pretreatments would improve hulling, however, no pretreatments were employed in the present work.

Screening steps 4b, 4c and 4d were added because specific gravity separators function more effectively on narrow ranges of particle sizes. The four screening steps theoretically could be combined into one machine of proper design and for that reason were designated 4a,b,c,d.

Experimental Separations

In the experimental work, steps 1, 6, 7 and 8 were performed separately. Steps 3, 4a, 4b, 5 and 9 were performed continuously on two batches of Growers seed of about 907 kg each. This continuous operation included recycling of hull beater (step 9) fines back to screen 4b. On the Northern seed, steps 3, 4a, 4b, 5 and 9 were performed continuously on about 163 kg of seed, but with recycle back to the huller conducted as separate, batch-wise operations.

TABLE 1. Screen analyses of Northern and Growers 380 sunflower seed.[a]

Screen size: diam. of round holes, mm	Remaining on screens			
	Northern seed		Growers seed	
	Weight %	Cumulative	Weight %	Cumulative
7.9	0.49	0.49	0.11	0.11
7.1	2.95	3.44	0.68	0.79
6.4	12.99	16.43	7.02	7.81
5.6	30.43	46.86	36.49	44.30
4.8	35.98	82.84	35.75	80.05
4.0	14.20	97.04	12.66	92.71
3.2	2.97	100.00	5.27	97.98
2.4			2.02	100.00

[a] With foreign matter removed but before sizing. Screen analysis by hand shaking on 30 cm square testing screens.

TABLE 2. Compositions and material balances for all products from uncleaned seed, with hulling-separating of cleaned and sized seed. Basis: 100 kg uncleaned, unsized Northern seed.

Product and source[a]	Composition		Material Balance			
	Kernels %	Hulls %	Kernels kg	Hulls kg	FM kg	Total kg
Cleaning and sizing seed						
Large foreign matter	-	-	-	-	0.53	0.53
Small foreign matter	-	-	-	-	6.09	6.09
Extra large seed	71.00	29.00	0.32	0.13	-	0.45
Small seed	74.00	26.00	19.28	6.78	-	26.06
Subtotal			19.64	6.91	6.62	33.13
Hulling-separating sized seed						
Purified kernels (6.7.8)	97.88	2.12	39.15[b]	0.85[b]	-	40.00
Purified hulls (9)	0.00	100.00	0.00	1.50	-	1.50
Hulls requiring purification (6.7.8)	35.16	64.84	5.44	10.03	-	15.47
Mixture of fine K&H (4d)	81.00	19.00	8.02	1.88	-	9.90
Subtotal			52.61	14.26	-	66.87
Total			72.25	21.17	6.62	100.00

[a] Source is given by step number in parentheses.

[b] Conversion of unhulled seed to kernels and hulls was made by assuming these partially hulled seed were 20% hulls.

TABLE 3. Compositions and material balances for all products from uncleaned seed, with hulling-separating of cleaned and sized seed. Basis: 100 kg of uncleaned Growers seed.

Product and source[a]	Composition Kernels %	Composition Hulls %	Material Balance Kernels kg	Material Balance Hulls kg	Material Balance FM kg	Material Balance Total kg
Cleaning and Sizing Seed						
Large foreign matter					0.02	0.02
Small foreign matter					1.07	1.07
Large seed	72.00	28.00	0.14	0.05		0.19
Small seed	72.40	27.60	19.71	7.51		27.22
Subtotal			19.85	7.56	1.09	28.50
Hulling-Separating Sized Seed						
Kernels (6,7,8)[c]	98.85	1.15	48.82	0.51		44.33
Hulls (6,7,8,9)	1.79	98.21	0.31	16.97		17.28
Mids (6.7.8)[b,c]	82.39	17.61	3.55	0.76		4.31
Mixture of fine K&H (4d)	76.50	23.50	4.27	1.31		5.58
Subtotal			51.95	19.55		71.50
Total			71.80	27.11	1.09	100.00

[a] Source is given by step number in parentheses.

[b] Mids would be recycled to the process.

[c] Conversion of unhulled seed to kernels and hulls was made by assuming these partially hulled seed were 20% hulls.

TABLE 4. Compositions and material balances for all products from uncleaned seed, with hulling-separating of cleaned but unsized seed. Basis: 100 kg of uncleaned Growers seed.

Product and Source[a]	Composition Kernels %	Hulls %	FM %	Material balance Kernels kg	Hulls kg	FM kg	Total kg
Cleaning seed (no sizing)							
Large FM						0.00	0.00
Small FM						0.48	0.48
Extra large seed	72.00	28.00		0.07	0.03		0.10
Small seed	72.40	27.60		1.27	0.49		1.76
Subtotal				1.34	0.52	0.48	2.34
Hulling-separating unsized seed							
Kernels (6,7,8)[c]	96.15	3.69	0.16	63.58	2.44	0.11	66.13
Hulls (6,7,8,9)	0.89	98.50	0.61	0.19	21.12	0.13	21.44
Mids (6,7,8)[b,c]	59.68	31.62	8.70	1.45	0.81	0.21	2.47
Mixture of fine K&H (4d)	75.00	25.00		5.72	1.90		7.62
Subtotal				70.94	26.27	0.45	97.66
Total				72.28	26.79	0.93	100.00

[a] Source given by step numbers in parentheses.

[b] Mids would be recycled to the process.

[c] Conversion of unhulled seed to kernels and hulls was made by assuming these partially hulled seed were 20% hulls.

For two of the three batches tested, seed was first cleaned in one pass over the cleaner dressed with 9.5 mm round hole screen on the top tray and 4.0 R on the bottom tray. Large trash and a few large seed passed over the 9.5 R screen while small foreign matter and a few small seed passed through the 4.0 R screen.

A screen size of 4.8 R was arbitrarily selected for the screen following the huller (designated 4a on the flowsheet). Therefore all seed smaller than this size were desired to be separated from the larger seed before hulling. As shown by the screen analyses of Northern and Growers seed in Table 1, about 20% of the original seed were smaller than 4.8 R.

Use of 5.6 R screens was found to be necessary in sizing seed because 4.8 R screens required an excessive number of passes of seed over the smaller screen in order to reduce small seed remaining in large seed below an arbitrarily established 5%. For example, with Growers seed, after 6 passes over 4.8 R the large seed fraction still contained 7% of seed smaller than 4.8 R. A seventh pass over 5.6 R screens was necessary. When 5.6 R was used for sizing Northern seed, after only 3 passes the large seed contained 2% small seed. On a second batch of Growers seed, cleaning and sizing conducted simultaneously over 5.6 R screens lowered small seed in large seed to 3.5%, in two passes.

Tables 2 to 4 show the compositions of streams and material balances for cleaning and sizing and for separating steps. Compositions and material balances for kernel products are shown in Tables 5 to 7.

Cleaning and sizing combined removed 33.13 and 28.5% of the original seed from two batches (Tables 2 and 3), whereas cleaning alone removed 2.34% of the third batch (Table 4). Results of sizing Northern and Growers seed were closely similar, with 26 and 27% of the original seed going into the small seed fractions. On the two Growers seed trials, two passes over 5.6 R for cleaning and sizing removed approximately twice as much foreign matter as one pass over 4.0 R for cleaning only. The foreign matter remaining in seed after only one cleaning pass was included in the product streams from separating (Tables 4,7).

Hulling conditions employed were a cylinder speed of 770 rpm, feed rates of about 14 kg per minute, and recycle from the air separator amounting to about 36% of the sum of feed plus recycle. This recycle rate was rather high compared with a normal commercial recycle rate of about 20% for cottonseed. It was employed in an attempt to maximize production of large kernels. The effect on material balances of lower recycle is not known, but probably lower recycle would decrease the fraction going to step 6 and increase the smaller particle fractions.

An estimate of 20% hulls in partially hulled seed was used to calculate hull and kernel equivalents in Tables 2-4. This figure was lower than the percentage of hulls in whole seed removed during sizing (Tables 2-4) and reflected the fact that partially hulled seed were not completely covered. Kernel products streams from all three gravity separators were combined for Tables 2-4. Resulting products contained 2.1, 1.15 and 3.7% hulls for the trials. The high value of 3.7% for the unsized Growers seed, compared to 1.15% for sized seed, demonstrates the improvement which is possible through sizing.

TABLE 5. Compositions and weights of kernel products. Basis: 100 kg of sized Northern seed.

Product source[b]	Composition Kernels %	Composition Hulls %	Composition UHS %	Weights[a] Kernels kg	Weights[a] Hulls kg	Weights[a] UHS kg	Weights[a] Total kg
Gravity Sep., (6)	92.88	0.93	6.19	30.04	0.03	2.00	32.34
Gravity Sep., (7)	97.04	1.51	1.45	19.54	0.30	0.29	20.13
Gravity Sep., (8)	95.00	2.00	3.00	6.97	0.15	0.22	7.34
Total	94.55	1.25	4.20	56.55	0.75	2.51	59.81

[a] Foreign matter was of negligible amounts and is not shown.

[b] Source given by step numbers in parentheses.

TABLE 6. Compositions and weights of kernel products. Basis: 100 kg of sized Growers seed.

Product Source	Composition Kernels %	Composition Hulls %	Composition UHS %	Weights[a] Kernels kg	Weights[a] Hulls kg	Weights[a] UHS kg	Weights[a] Total kg
Gravity Sep., (6)	95.47	0.51	4.02	46.94	0.25	1.98	49.17
Gravity Sep., (7)	98.66	0.37	0.97	9.80	0.04	0.10	9.94
Gravity Sep., (8)	99.34	0.44	0.22	2.87	0.01	0.01	2.89
Total	96.18	0.48	3.34	59.61	0.30	2.09	62.00

[a] Foreign matter was of negligible amounts.

TABLE 7. Compositions and weights of kernel products. Basis: 100 kg of cleaned but unsized Growers seed.

Product and Source	Kernels %	Hulls %	UHS %	FM %	Total %
	Composition				
Gravity sep., (6)	80.85	0.21	18.91	0.12	100.0
Gravity sep., (7)	91.94	0.29	7.55	0.22	100.0
Gravity sep., (8)	91.80	2.11	5.39	0.70	100.0
Subtotal	82.40	0.25	17.19	0.16	100.0
	Weights				
	kg	kg	kg	kg	kg
Gravity sep., (6)	47.07	0.07	11.01	0.07	58.22
Gravity sep., (7)	4.95	0.01	0.41	0.01	5.38
Gravity sep., (8)	3.78	0.09	0.22	0.03	4.12
Total	55.80	0.17	11.64	0.11	67.72

TABLE 8. Weights of hull fractions from Growers seed. Basis: 100 kg of cleaned unsized seed.

Products and Source	Kernels kg	Hulls kg	UHS kg	FM kg	Total kg
Hulls from (9)	0.00	3.35	0.00	-	3.35
Hulls from (6)	0.00	11.24	0.05	0.07	11.36
Hulls from (7)	0.03	1.43	0.00	0.02	1.48
Hulls from (8)	0.11	1.80	0.02	0.04	1.97
Total					18.61

Even in the best separating result of the three trials (sized Growers seed) the kernel product from step 6 contained 4% unhulled seed, whereas the kernel products from steps 7 and 8 contained much less unhulled seed. This suggests that one way to lower hull content in kernels would be to reduce the particle size of kernels enough that all kernels pass through screen 4b. Step 6 would be eliminated and all kernels would then go to steps 7 and 8 for separation of hulls. Such a reduction of kernel size probably would increase the unders from 4d, and this would be a disadvantage.

This separation work has identified factors requiring attention in order to maximize yield of kernel products and minimize hull content. In the future, perhaps better huller settings and pretreatments can be found which will allow kernels lower in hull content to be produced.

Decrease of residual hull in kernels is especially desirable. Unpublished work has shown that color of defatted sunflower seed flour is acceptable until unhulled seed content exceeds approximately 3-4% or 0.9 to 1.1% hulls. The better combined kernels fractions produced in this work (Tables 5 and 6) contained 4.2 and 3.3% unhulled seed or 2.1 and 1.1% hulls (Tables 2 and 3). These results are on the borderline of acceptability for color.

In the trial with Northern seed, no mids fractions were produced from the specific gravity separators. Instead, the hulls containing some kernels and unhulled seed were combined and called "hulls requiring purification" (Table 2). In the trials with Growers seed, mids were produced which would be recycled; this resulted in hulls streams which contained 1.79 and 0.89% kernels (Tables 3 and 4). These are not considered to be excessive kernel losses.

Separations for Oil Mill Purposes

Sunflower seed processed in oil mills may have part of the hulls removed or the seed may be processed with no hulls removed. Table 8 showing the material balances on hulls in processing cleaned but unsized Growers seed, may be helpful in selecting a flowsheet for partial hull removal. These data show that use of only a hull and seed separator, followed by a hull beater (steps 5 and 9) would not remove many hulls, and the gravity separator in step 6 would be necessary. Increased hull removal by the hull and seed separator might be achieved, but at the risk of increased loss of kernels in hulls.

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