Dehulling Cottonseed and Separating Kernels and Hulls: Comparison of Several Varieties of Seed[1]

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ABSTRACT

The proteinaceous components of cottonseed can be converted into several different forms for use in human food. All of them require nearly complete separation of kernels and hulls. In research on improving separation processes, eight multiton lots of cottonseed were processed through pilot size commercial-type dehulling and kernel-hull separating machinery. The machinery was operated to produce the cleanest separations possible. Each lot of seed was from a different variety of cotton. For six of the lots, seed were delinted to 2 levels of ca. 7.0 and 2.5% residual linters; and separate dehulling runs were made on seed of each level. Weak hulled seeds were the only lots showing any important differences in dehulling characteristics. They produced higher yields of coarse kernels than the other lots. In terms of nearly pure kernels, good results were obtained with all lots. Yields of kernels averaging 90% of the total kernels from each variety were concentrated into a product which contained less than 1.0% hulls. These products could be converted into meals of more than 55% protein and less than 3% crude fiber. With the addition of a specific gravity separator to the process, loose hulls in coarse kernels can be reduced to nearly zero.

INTRODUCTION

Although hulling of cottonseed and separation of kernels and hulls have been practiced in oil mills for many years, a search of the literature revealed only a small amount of quantitative data on these operations. The effects of varying moisture in seed on yields of coarse meats were nearly the only studies reported. Nothing was found on comparison of dehulling characteristics of different varieties of seed. Hardly any quantitative data were found on separating hulls and unhulled seed from kernels.

An earlier report on the present study presented detailed data on dehulling-separating one variety of seed (1). The present article compares results on eight different lots of seed, including the one reported earlier.

Reuther (2) used a 12 in. bar-type huller operating at 890 rpm to dehull a single lot of cottonseed ranging in moisture from 3.7-13.7%. Yields of coarse meats on a 6/64 in. round hole (6/64R) screen increased as moisture increased from 40% up to a maximum of 86%. The yield at 12.1% moisture was 77% (2). Mehta, et al., obtained similar trends with a bar huller (3).

Using an 8 in. disc huller, S.P. Clark (unpublished) found a rapid increase in yield of coarse kernels (on 6/64R) as moisture in seed was increased from 5 up to 10%. Between 10 and 13% moisture, yield was constant at ca. 90% of total kernels.

Lawhon compared seed pretreatments by dehulling with both laboratory (8 in. diameter) and pilot plant size (24 in. diameter) disc hullers. Yields of coarse kernels on 8/64 x 3/4 in. slotted holes ranged up to 87% for the former and to 68% for the latter. Pretreatment of seed by steaming produced yields of coarse kernels which were as good or better than yields from seed moistened and equilibrated to 11% moisture. Quality of kernels from steamed seed was superior to the kernels from moistened seed (4).

Surendranath compared dehulling with disc hullers having steel, wood, and carborundum discs. Results were similar from all types. Moisture levels in seed used were not reported (5).

Clark reported on dehulling with a 24 in. disc huller and on purifying coarse kernels with two different types of specific gravity separators. Using these separators, coarse kernels were produced which were essentially free of hulls (6).

EXPERIMENTAL PROCEDURES

Materials

Eight lots of cottonseed were processed. They are listed with their analytical data in Table I. The qualities of the seed can be judged from levels of free fatty acid in oil. Only four of the lots were part of the original research plan. These were DPL, Paymaster, Acala, and Coker 421. The others were processed for other purposes, and data were accumulated as by-products.

Rogers glandless I and II were two lots of an experimental variety dehulled to produce kernels for protein isolation. Unknown variety was from a gin in Brazos County, Texas. It was possibly of mixed varieties. It had been weather damaged, as is shown by the high free fatty acid content. DPL variety was DPL-16 planting seed procured from Delta and Pineland Co., Scott, Miss. Paymaster 111 seed was procured from Plains Cooperative Oil Mill, Lubbock, Texas. Acala was Acala SJ-1 planting seed from California Planting Cottonseed Distributors, Bakersfield, Calif.

Coker 421 was commercial planting seed from Coker Pedigreed Seed Co., Hartsville, S.C. It contained an unusually high level of loose kernels, as shown in Table I. Coker 711 was an experimental glandless variety from Coker Pedigreed Seed Co. It also contained more loose kernels than is normal.

Equipment and Procedures

Seeds to be dehulled first were cleaned with a Bauer no. 199 seed cleaner. All lots of cleaned seeds then were given a first cut delinting with a Carver 176 saw linter. For all seeds except Rogers glandless, the degree of first cut delinting was considerably greater than is normally conducted in oil mills because removal of as much of the long fiber as possible was desired without excessive denuding of the seeds. Long fibers remaining on seeds tend to trap kernel particles and make clean separations of kernels and hulls more difficult to achieve. Excessively denuded seeds tend to pass through the separator screens and into the meats fractions.

After first cut delinting, the seeds were moistened to a level of ca. 11% moisture by spraying water on them as they were moved by screw conveyor to a holding bin. The purpose of moistening was to eliminate large moisture differences between lots. A level of 11% was selected because this was high enough that no drying of seeds would

[1]One of seven papers presented at the symposium, "Processing Methods for Oilseeds," AOCS Spring Meeting, New Orleans, April 1973.

TABLE I

Analyses on Seed Used in Dehulling-Separating Test Runs

Measurement	Variety of seed							
	Crop year 1970			Crop year 1971				
	Rogers I glandless	Rogers II glandless	Unknown glanded	DPL glanded	Paymaster glanded	Acala glanded	Coker 421 glanded	Coker 711 glandless
Moisture, %[a]	8.63	6.05	7.9	8.5	9.3	7.2	8.3	7.2
Loose kernels in seed, %[a]	---	---	---	---	---	---	3.1	1.1
Free fatty acid in oil, %	1.05	1.05	19.9	1.1	1.1	0.4	3.9	6.8
Oil, %[a]	16.36	16.35	19.71	21.61	19.79	19.90	22.49	19.91
Nitrogen, %[a]	3.23	3.32	4.30	3.62	3.80	---	3.36	3.45
Linters, %[a]	14.2	15.1	11.8	11.7	11.0	11.4	15.9	14.0
Wt 100 seed, g[a]	13.6	13.7	9.2	9.2	10.7	13.9	9.9	10.1
Hulls thickness—mean[b]	0.0138	0.0155	0.0114	0.0158	0.0124	0.0150	0.0136	0.0123
High linters seed dehulled:								
Moisture, %	8.9	7.5	9.0	11.5	12.0	11.5	11.3	11.3
Linters, %	11.7	11.0	6.4	7.3	7.2	6.6	6.7	7.0
Low linters seed dehulled:								
Moisture, %	---	---	10.8	9.9	11.8	10.7	10.9	11.7
Linters, %	---	---	2.6	2.4	2.6	2.7	4.0	3.1

[a]Analysis reported as % on as is moisture basis.

[b]Measurements made on hulls from low linters seed.

be necessary to bring all seed lots to the same level. In addition, previous dehulling work had established that in the range of 6-10%, moisture differences have relatively large effects upon results of dehulling as measured by yields of coarse kernels, whereas moisture differences between 10 and 12% have less effect (2 and S.P. Clark, unpublished data). Seeds of 11% moisture should produce similar yields to those which might be produced with steam pretreatment (4).

Moistened seeds were stored in a bin for three days before dehulling to equilibrate the moisture.

For all lots of seed, except Rogers glandless, unhulled seeds remaining after dehulling first cut delinted seeds were subjected to second cut delinting. The linter saws were resharpened each time before the second cut. Second cut seeds were remoistened and stored in a bin as before until time for dehulling.

First cut delinted seeds are designated in this report as high linters seed and second cut delinted seeds as low linters seed.

The two Coker varieties were dehulled somewhat during delinting. Therefore, they were recleaned with the Bauer cleaner after delinting to remove part of the loose kernels. This was done only after second cut delinting for Coker 421 and after both delinting cuts for Coker 711.

Rogers glandless seeds were dehulled to produce kernels for protein isolation; therefore, first cut delinting on these seeds was less than for the other lots, the seeds were not moistened, and no second cut delinting and dehulling of second cut delinted seeds were conducted.

Dehulling-separating tests were conducted with Carver pilot plant dehulling machinery in the Oilseed Products Laboratory, Texas A&M University. Figure 1 is a flowsheet of the installation. All of these machines were of the standard design and size used in oil mills, except the widths were somewhat less. The huller was 24 in. wide with rotating cylinder 18 in. in diameter. Huller-shaker and purifier were 36 in. wide. Hull and seed separator was 48 in. wide.

Only one variable on the huller was changed from variety to variety and that was the clearance between the cylinder and concave. This was regulated to give a recycle rate from the hull and seed separator back to the huller falling within the range of 15-20% of the recycle plus the fresh feed. This percentage reflected general oil mill practice.

The huller-shaker and purifier were both double-deck shaker screens with pneumatic aspiration of the ends of the trays, as indicated in Figure 1.

The hull and seed separator was an air classifier of the vertical air column type in which hulls of lower density were aspirated off, leaving undehulled seed and kernels of higher density, which discharged from the bottom.

The screens employed in all machines were of perforated sheet metal. The sizes of the lower screens on the huller-shaker and on the purifier were 8/64R and 6/64R, except for short screens under the aspiration nozzles which were slotted. The only screen changed in any of the machines during this work was the top screen on the huller-shaker. Screens were selected to retain as many unhulled seed and hulls as possible while allowing most of the dehulled kernels to pass through. Both round and slotted hole screens were employed.

The nine products produced by the machinery are indicated by underlined names in Figure 1. Throughout this article, the term meats is used to designate a fraction or a product which contains some hull material either as loose hulls or as undehulled seed (UHS). When kernels is used it means pure, hull-free kernels.

The dehulling characteristics of seed were evaluated by running the machinery as it would be run in a continuous processing operation in an oil mill. After 30-120 min of initial operation during which adjustments were made in settings on the machines and equilibrium of flows were attained, a period of operation was commenced during which no changes were made and a constant feed rate was maintained. Data were recorded, and continual sampling of all fractions was conducted. This period of operation usually was ca. 60 min long. The machinery was started and

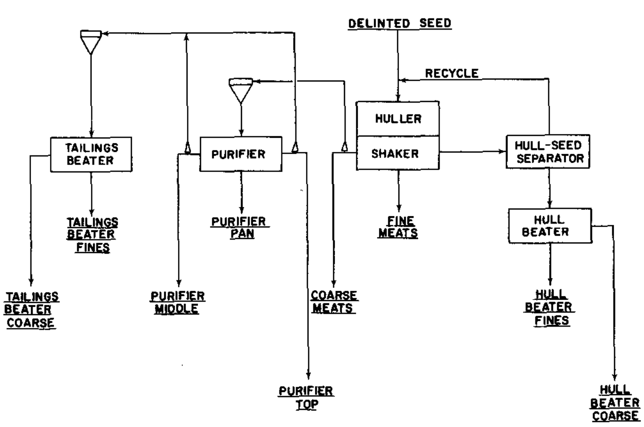

FIG. 1. Flowsheet of Carver dehulling-separating process in Oilseeds Products Laboratory.

TABLE II

Percentages of Kernel Particles Larger than 6/64 in. Round in Combined Meats Fractions from Dehulling-Separating Tests[a]

Seed variety	High linters seed, %	Low linters seed, %	Mean, %	Statistical significance[b] 5% level	1% level
Rogers Ia	77.6	---	77.0	C	C
Rogers Ib	76.5	---			
Rogers II	77.2	---	---		
Unknown	79.7	76.5	77.7	C	C
DPL	91.5	87.5	89.5	B	B
Acala	88.2	90.9	89.6	B	B
Paymaster	92.1	92.2	92.1	B	A,B
Coker 711	94.1	92.0	93.0	A,B	A,B
Coker 421	96.6	97.4	97.0	A	A

[a]Meats fractions are coarse meats, fine meats, all purifier fractions, and hull beater fines.

[b]Varieties having the same letters are not significantly different while those with different letters are different.

stopped while full of material. At the end of the run, all products were weighed. After analysis of samples, a material balance was calculated by type and particle size of material. The feed rate to the huller was ca. 25 lb/min, so each data run was made on ca. 1500 lb of seed, not including the seed required for adjustments on the machinery.

During the initial period, settings on the separating machinery were made by observation of the composition of products. The objective was to make the cleanest separations possible between kernels and hulls. Clean separations in some products necessarily resulted in less clean separations in other products. The balance achieved was strictly a subjective matter.

The fine meats fraction had passed through an 8/64R screen. However, the kernel particles in this fraction larger than 6/64R could be salvaged in nearly pure form when the fine meats were rescreened over the purifier. Such rescreening was done on the fine meats fractions and also on the hull beater fines fractions for every run, and material balances were calculated for these rescreenings.

Some of the kernel fractions were processed with a laboratory size specific gravity separator to measure the degree of further purification of kernels which could be achieved by this machine. The machine used was a model V 135a separator manufactured by Triple/S Dynamics, Dallas, Texas.

Analysis of samples of meats fractions was performed by first separating them into fractions of the following sizes: on 8/64R, through 8/64R on 6/64R, through 6/64R on 14 mesh (woven wire) screen, through 14 mesh on 20 mesh, through 20 mesh (pan). Hull content of sizes on 6/64R and larger was determined by hand picking. Hull content of smaller meats fractions was calculated from moisture and nitrogen analyses of these fractions. The kernel content of predominantly hull fractions also was calculated using moisture and nitrogen analyses.

RESULTS AND DISCUSSION

Dehulling

Results are presented first on dehulling as distinguished from overall separation of kernels and hulls which is affected by degree of kernel breakage during dehulling, as well as by separation parameters. Yields of coarse kernels in terms of percentages of total kernels in combined meats fractions, which were retained on 6/64R screens, were the principal statistics selected to express the dehulling characteristics of the seed. These data for the eight lots of seed processed are shown in Table II for both high and low linters levels. Two data runs were conducted on Rogers I seed, and the results are designated Rogers Ia and Ib.

A statistical analysis of variance was calculated for the data in Table II. The dehulling data on high linters and low linters seed were considered to be replicates in this measurement. No reason is apparent why residual linters on seed should affect dehulling. Values in Table II were not correlated with linters level, and the mean square between linters levels in the analysis of variance was only slightly above the residual mean square. Rogers Ia and Ib were replicates. Rogers II is shown in the table for comparison, but it was not included in the mean for Rogers.

The statistical significances of differences among means were determined by Duncan's Multiple Range Test (7). Means having the same letter in the column heated statistical significance are not significantly different from each other but are different from means with different letters.

Usually cottonseeds are not dehulled to any important extent during ginning of the seed or during delinting. For example, Acala seeds cleaned before delinting were found to have 0.1% and 0.2% loose kernels in seed after first and second cut delinting, respectively. Conversely, Coker seeds were dehulled to considerable degrees even during first cut delinting. When delinting to 7.6% residual linters, samples of delinted seeds showed 16% loose kernels for Coker 421 and 4% for Coker 711. Dehulling of seed during second cut delinting for Coker 421 was estimated to be 25% of the seed going to the linter.

Separation of means in Table II shows the two Coker varieties not to be significantly different from each other. Coker 421 is different from all other varieties. Coker 711, Paymaster, Acala, and DPL are not significantly different from each other; but they are different from Unknown and Rogers. Unknown and Rogers are not different from each other but are different from all the rest.

The Coker 421 may be different from the others in dehulling characteristics because of weak hulls. Weak hulls does not seem to be thin hulls. The average thicknesses of hulls, as shown in Table I, ranged from 0.0114-0.0155 in. The Coker varieties did not have the thinnest hulls. The dehulling which occurred with Coker varieties during delinting also points up the hull weakness on these seed.

Rogers seed (Table II) is believed to have given significantly lower yields of coarse kernels because it was dehulled at lower moisture levels. Unknown was of the same moisture range as all of the others except Rogers. Presumably the exceptionally low quality of these seeds (19.9% free fatty acid in oil) resulted in these seeds giving dehulling results comparable with seeds of lower moisture.

Reuther reported yields of coarse meats on 6/64 round hole screen to be 77% at 12.1% moisture in seed (2). The present study obtained yields of ca. 90% at average

TABLE III

Distribution of Kernels in Products and Composition of Products from Dehulling-Separating: Mean Values for Five Varieties of Cottonseed[a]

Product and component	Kernel distribution, percent[b]		Composition, percent	
	Mean	Standard deviation	Mean	Standard deviation
From high linters seed				
Low fiber meats	90.5	3.0		
Kernels			99.79	0.08
Hulls, loose			0.17	0.09
Hulls from unhulled seed			0.04	0.04
Total			100.00	
High fiber meats	7.8	3.2		
Kernels			70.5	6.2
Hulls			29.5	6.2
Combined meats	98.3	1.0		
Kernels			96.6	1.3
Hulls			3.4	1.3
Hulls product				
Kernels			2.9	1.9
Hulls	1.7	1.0	97.1	1.9
Oil[c]			1.6	1.0
From low linters seed				
Low fiber meats	90.1	4.3		
Kernels			99.16	0.54
Hulls, loose			0.34	0.41
Hulls from unhulled seed			0.50	0.21
Total			100.00	
High fiber meats	9.4	4.4		
Kernels			52.6	6.8
Hulls			47.4	6.8
Combined meats	99.5	0.3		
Kernels			91.4	4.0
Hulls			8.6	4.0
Hulls product	0.5	0.3		
Kernels			1.2	0.7
Hulls			98.8	0.7
Oil			0.9	0.5

[a]DPL 16, Acala SJ-1, Paymaster 111, Coker 711, Coker 421.

[b]Distribution of total kernels in seed into products from dehulling-separating.

[c]Calculated percentage of oil in hulls product based upon oil in kernel-free hulls, kernel content, and oil in kernels.

moisture of 11.3% and speed of 615 rpm. These results suggest that greater yields of coarse kernels than 90% might be obtained at lower speeds than 615 rpm.

Separating

The principal methods for removing hulls and UHS from kernels are: screening, aspiration, specific gravity separator, and picking with electronic sorters. Only the last method is highly effective on undehulled seed, and this is costly to do so. Therefore, one of the principal considerations in processing should be prevention of UHS from getting into the kernel fractions.

In the Carver system, the top tray of the huller-shaker is the point where the primary separation is made between loose kernels and UHS. A secondary point of separation is on the purifier.

Some of the factors affecting separation of kernels from UHS on the top screen of the huller-shaker are size of openings in the screen, depth of material on the screen (which is a function of feed rate and amount of linters on seed), and percentage of undersized seed. If the screen openings are large enough and the screen is not heavily loaded, nearly all of the kernels will pass through but also some UHS will pass through, the amount depending upon the size of the seed in relation to the size of openings and the amount of residual linters on the seed. Denuded seed will pass through much more easily than fuzzy seed. If the screen openings are smaller, less UHS will pass through but also more kernels will go over the screen and into the hull and seed separator.

Most of the large kernels going into the hull and seed separator will recycle back to the huller where some will be degraded into the fine meats fraction. (In one test, coarse kernels alone from DPL seed were recycled back to the huller. From these, 82% went into coarse meats and 18% into fine meats.)

Screen analyses on delinted seed before dehulling-separating runs were used as guides to the selection of screen sizes to employ on the huller-shaker. However, observation of the UHS showing up in coarse meats or of kernels in UHS and hulls going to the hull and seed separator during the adjustment period were always necessary as check on screen selection; and frequently screens were changed before the data runs were made. Complete exclusion of UHS from coarse meats was not possible without throwing considerable quantities of kernels into the hulls and UHS. Therefore, selection of screen size was always a judgment matter of balancing one tendency against the other.

Considerable variation in UHS in coarse meats from the various runs was experienced. However, the variations were considered to be dependent upon the factors described rather than upon varietal differences in the seed.

Under low fiber meats, Table III shows the quantities of hulls in this product divided between loose hulls and hulls from unhulled seed. This comparison was made for high and low linters seed from the five principal seed varieties.

The figures show UHS were much larger sources of hulls in low linters seed than in high linters seed. Also in low

TABLE IV

Composition of Subfractions and Material Balance for Processing of Purifier Top and Purifier Middle Fractions with Specific Gravity Separator

	Composition, %			Wt, lb			
Subfractions	Kernels	Hulls	UHS	Kernels	Hulls	UHS	Total
Purifier top fraction from high linters Acala seed							
Accepts	99.65	0.00	0.35	59.19	0.00	0.21	59.4
Middle	96.41	0.08	3.51	37.50	0.03	1.37	38.9
Rejects	73.90	18.37	7.73	1.26	0.31	0.13	1.7
Total[a]	97.95	0.34	1.71	97.95	0.34	1.71	100.0
Purifier middle fraction from high linters Acala seed							
Accepts	100.00	0.00	0	94.90	0.00	0	94.9
Middle	99.63	0.37	0	3.49	0.01	0	3.5
Rejects	83.70	16.3	0	1.34	0.26	0	1.6
Total[a]	99.73	0.27	0	99.73	0.27	0	100.0

[a]Composition of feed was assumed to be same as total.

linters seed, UHS were larger sources of hulls than were loose hulls.

Considering that one of the purposes of this work was to demonstrate the purity of products which could be expected in commercial installations, overall evaluation of dehulling-separating was made by comparing the composition of four hypothetical products for each run.

These products could be made by combining, in appropriate combinations, the nine fractions of the material balance and the fractions from rescreening fine meats and hull beater fines over the purifier. In some cases the purifier top fractions were assumed to be processed over a specific gravity separator or to be recycled back through the huller to lower the contribution of hulls by that fraction. All of the extra operations, such as rescreening fine meats, would be practical to do in an actual oil mill, and combination of fractions into two or three products would be feasible. Thus, the compositions of the products were hypothetical only in the sense that they were calculated values and were not actually made experimentally.

The four products were called low fiber meats, high fiber meats, combined meats, and hulls. In general, low fiber meats contained all of the low hull content, coarse meat fractions; and high fiber meats the remainder of the predominantly meats fractions. Combined meats were a combination of the low and high fiber meats. Hulls contained the combined hull fractions.

Table III shows the mean and standard deviation for hull and kernel content of the four hypothetical products for both linters levels for five seed varieties. Data from only five varieties were averaged because these were the ones which were comparable for separation. The other three lots of seed were of different moisture, linters level, or quality. The data show that, in low fiber meats, products which are low in hull content can be produced from high linters seed. Once again variations in the values shown are considered to be due primarily to machinery settings and not to differences in seed. Somewhat lower values of hulls could have been produced by stronger aspiration of the huller-shaker and the purifier. However, this would have put more kernels over into the tailings beater which would have increased kernels in hulls.

If low fiber meats were to be used for animal feed, the purities shown in Table III are probably good enough. If low fiber meats were to be used for nuts, flour, or protein isolates, they probably would need to be purified further by specific gravity separation and electric sorting.

The sum of low fiber meats, high fiber meats, and hulls includes all of the products of dehulling-separating. Combined meats are the sum of low and high fiber meats. Any of these meat products might pass on into animal feed after oil extraction. Table V shows the composition of animal feeds which could be made from all of the three meats products.

Table III also shows the distribution of total kernels in seed into the hypothetical products. One of the principal comparisons of interest is between kernels in hulls for high and low linters seed. Values for the former are more than twice as great as the latter. This reflects the more difficult separation between kernels and hulls in the hull and seed separator and in the beaters when high linters seed are being processed. Somewhat better results than the average of those shown for high linters seed are believed to be possible with the use of larger openings in beater screens.

The data in Table IV show that loose hulls in coarse kernels can be reduced to nearly zero by further processing meats fractions with specific gravity separators. In these examples, the separator fractions called accepts were completely free of loose hulls for both purifier top and purifier middle. For purifier top, the separator also achieved some lessening of UHS in the accepts. The middle fraction also was much lower in loose hulls but higher in UHS than in the feed material. Combined accept and middle fractions would be much lower in loose hulls and some lower in UHS than in feed. Similar results to those in Table IV were obtained on coarse meats fraction.

These data indicate that specific gravity separators should be process steps following the primary separating machinery whenever coarse kernels completely free of loose hulls are desired (UHS must be excluded or removed by electronic sorting).

Table V shows the calculated composition of meals which could be produced from the three meats products. High quality (high protein, low crude fiber) meals could be produced from low fiber meats from both high and low linters seed. For both linters levels, high fiber meats would produce meal below present 41% protein meal. Meals from combined meats would be higher in quality from high linters seed than from low linters seed.

Removal of loose hulls from coarse meats fractions

TABLE V

Calculated Compositions of Meals which Could Be Made from Hypothetical Meats Products[a]

	Protein		Crude fiber	
Meats products	Mean	Standard deviation	Mean	Standard deviation
High linters seed				
From low fiber meats	56.1	1.7	2.3	0.1
From high fiber meats	29.5	5.7	19.3	3.2
From combined meats	52.8	0.6	4.5	0.9
Low linters seed				
From low fiber meats	55.6	1.7	2.8	0.3
From high fiber meats	23.3	3.8	27.4	2.6
From combined meats	49.1	2.5	7.6	2.3

[a]Based upon 10% combined moisture and oil in meals, 2.2% crude fiber in hull-free meal, and 45% crude fiber in hulls.

would allow meal of less than 3.3% crude fiber to be produced from combined meats from high linters seed. This would not be possible for low linters seed unless UHS in coarse meats were reduced drastically.

Removal of hulls from meats smaller than 6/64R by specific gravity separator was unsuccessful. At present these small particles probably have no better use than in animal feed, after oil removal.

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