bilizing effect of the solvents was slowly overcome by the protein degradation caused by the heating, the net effect depending upon the length of the heating period.

In the case of lipoxidase all three solvents very effectively reduced the activity, methylene chloride showing the greatest effect. With urease the pattern was somewhat different. All three solvents caused an initial increase in activity probably due to an opening up of the protein molecules. Except in the case of the methylene chloride, this was then followed by a decrease in activity upon prolonged contact or heating. The effect of liopxidase activity is reflected in the commercial plant data shown in Table II.

Conclusions

As a result of this investigation it appears that if the relationship between the nutritional value of soybean oil meal and its protein glutelin fraction is confirmed for a wider range of processing conditions than those reported on by Evans and St. John (5), there then exists a simple, reliable, and reproducible analytical means of further relating nutritional value to plant processing conditions. For the range of processing conditions normally employed in plant practice, a maximum glutelin fraction percentage is consistently attained with the application of either dry or moist heat, beyond which additional heat treatment results in a decrease, completing a pattern with heating similar to that normally followed by the nutritional value of the meal. In all cases where moist heat was employed, the activity of both the urease and lipoxidase enzyme systems was reduced to a level satisfactory for feeding prior to the point where the maximum glutelin protein fraction was attained. This is in agreement with numerous poultry feeding tests relating feed value to processing conditions.

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Solvent Extraction of Oil From Cottonseed Prior to the Removal of Linters and Treatment of the Residue to Effect Separation of Meal, Hulls, and Linters[1]

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THE mechanical delinting of cottonseed is one of the most expensive operations in cottonseed processing. Even so, only about 80 to 90% of the linters on the seed are recovered. Linters are somewhat contaminated with hull particles, and some oil is lost with the hulls. With these apparent shortcomings of present processes as justification, research was conducted by the Texas Engineering Experiment Station to investigate the technical and economic feasibility of solvent extracting the oil from rolled whole seed and then separating the solids residue into meal, linters, and hulls.

Process

A process was developed which was considered to be technically feasible and can be carried out in the following steps starting with seed from storage: cleaning; cracking of the hulls to facilitate subsequent conditioning and rolling; conditioning by heating and moisture adjustment; rolling or flaking; solvent extraction of the oil, desolventizing of the extracted solids and of the oil; cooling the extracted solids; separating the solids into a protein or meal fraction with most of the lint still attached to the hulls; separating the hulls-lint fraction into hull bran and lint fiber.

A flow sheet of the process is shown in Figure 1 and is designated No. 1 Seed Process. A material balance for the process is given in Table I.

All of these operations can be carried out in standard equipment. Up to the stage of separation of the solvent-extracted solids into protein and hull fractions, the equipment is the same as that performing similar functions in commercial direct solvent or prepress-solvent extraction plants. Rolling is accomplished with standard one-pair-high flaking rolls. The separation of protein and hulls-lint is carried out by a combination of standard hull beaters, purifiers, and tailings beaters such as are used in the commercial separation of delinted cottonseed hulls and meats. The separation of the hulls-lint into lint fiber and hull bran is effected with commercial hull defibrating machines.

The last operation is the only one which was not investigated experimentally. No tests were made because the project was set up as only an exploratory investigation, and preparation of enough extracted seed for even one test on a commercial defibrating machine would have been costly with the small output

[1] A report of work done under a contract between the Cotton Research Committee of Texas and the U. S. Department of Agriculture and authorized by the Research and Marketing Act. The contract was supervised by the Southern Regional Research Laboratory of the Bureau of Agricultural and Industrial Chemistry. The paper was presented at the 43rd annual meeting, American Oil Chemists' Society, Houston, Texas, April 28-30, 1952.

TABLE I

Material Balance for 100 Pounds of Seed Entering Each Process
Letters designate points on flow sheet, Figure 1. Complete recovery of products is assumed.

Point	Product	Water	Oil	Meats[b]	Hulls[b]	Lint[b]	Total
		lb.	*lb.*	*lb.*	*lb.*	*lb.*	*lb.*
A	Seed to processes	8.40	17.20	34.66	29.97	9.77	100.00
B	First-cut linters from Meats and No. 2 Seed Process	0.14	N[a]	N	0.19	1.53	1.86
C	Second-cut linters from Meats Process	0.63	0.02	N	1.38	6.11	8.14
D	Hulls from Meats Process	3.12	0.18	0.51[c]	21.81	2.13	27.75
E	Meats to extractor	4.51	17.00	34.15	6.59	N	62.25
E	No. 1 Seed to extractor	8.40	17.20	34.66	29.97	9.77	100.00
E	No. 2 Seed to extractor	8.26	17.20	34.66	29.78	8.24	98.14
F	Oil from Meats Process	N	16.26	N	N	N	16.26
F	Oil from Seed Processes	N	16.44	N	N	N	16.44
G	Desolventized extracted meats (same as finished meal)	5.07	0.74	34.15	6.59	N	46.55
H	Desolventized seed, No. 1 Seed Process	8.89	0.76	34.66	29.97	9.77	84.05
H	Desolventized seed, No. 2 Seed Process	8.74	0.76	34.66	29.78	8.24	82.18
I	Protein fraction from Seed Processes	3.80	0.51	28.26	2.35	0.42	35.34
J	Hull fiber, No. 1 Seed	0.96	N	0.40	1.72	9.35	12.43
J	Hull fiber, No. 2 Seed	0.80	N	0.33	1.44	7.82	10.39
K	Hull bran, No. 1 Seed	4.13	0.25	6.00	25.90	N	36.28
K	Hull bran, No. 2 Seed	4.15	0.25	6.07	25.99	N	36.46
	43% protein meal after mixing with some of hull bran, No. 1 and No. 2 Seed Processes						39.47
	Hull bran remaining, No. 1 Seed Process						32.15
	Hull bran remaining, No. 2 Seed Process						32.32

[a] "N" designates negligible amount.
[b] Quantities listed in meats, hulls, and lint columns are pure materials, oil and moisture free.
[c] This quantity of meats is equivalent to protein loss not accountable by hulls and lint when using the figure of 94% recoverable protein, (3) p. 121.

of the extraction equipment available. However hull defibrating has been practiced in the cottonseed industry for many years; therefore the question did not appear to be whether lint fiber could be produced from the hulls-lint material, but only what quality could be produced.

A previous publication (1) by the authors described a test method which was used in this study to evaluate the effect of processing conditions on the extractability of the oil from the seed.

From the experimental work about 0.010 inch was found to be as thin as seed could be rolled without excessive breaking up of the hulls and consequent difficulty in separating the solid products. At this thickness the residual oil was reduced by solvent extraction to less than 1.5% on an oil and moisture free pure meats basis. It was found that the protein in the extracted residue should not be hardened by denaturing during desolventizing, otherwise separation of the protein and hulls-lint was difficult.

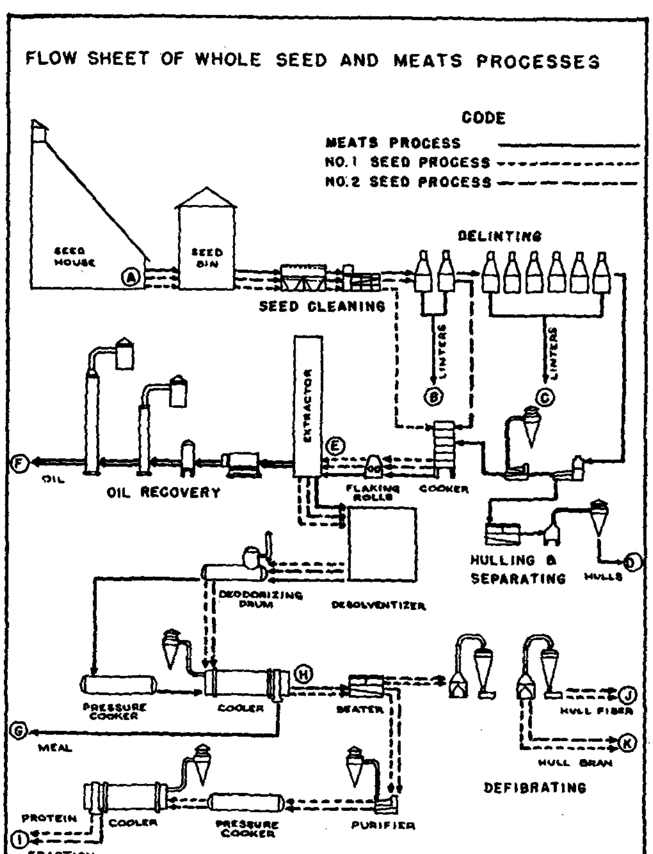

FIG. 1.

A number of tests was run to compare the direct solvent extraction of flaked cottonseed meats and rolled whole seed. The residual oil in rolled seed, calculated to the same basis as meats, was usually slightly lower than the residual oil in meats rolled to the same thickness and extracted in the same manner. The capacity of an extractor was lower when operating on rolled seed than on meats because of the lower bulk density of seed and the greater weight of solids which must be passed through the extractor. The more open character of rolled seed, which allowed solvent to percolate more rapidly through it, partially compensated for the lower bulk density and greater weight of solids. Considering all of these factors, the capacity of a percolation type of extractor was estimated to be only about one-half as great on seed as on meats.

The quality of oil and meal from seed was equal to the quality from meats except that the bleach color of oil from seed was a little higher than that from meats.

Economic Analysis

A cost analysis of the new process was made to determine its economic feasibility in comparison with the direct solvent extraction of flaked cottonseed meats. In this phase of the work a third process was included in the study which was the same as the undelinted seed process except a 37-pound per ton cut of linters was removed from the seed before rolling.

These three processes are compared on the flowsheet of Figure 1 and the material balance of Table I and are designated "Meats Process," "No. 1 Seed Process," and "No. 2 Seed Process." The undelinted seed process is "No. 1 Seed Process." Some of the values in Table I were determined by analyses of materials produced experimentally while the balance were calculated with the aid of reasonable assumptions.

A summary of the total investment and yearly costs for the three processes is shown in Table II while the

TABLE II

Summary of Total Investment and Yearly Costs for the Three Processes

No.	Cost Item	Meats Investment	Process Yearly Charges	No. 1 Seed Investment	Process Yearly Charges	No. 2 Seed Investment	Process Yearly Charges
1	Machinery[a]	$560,651	$ 28,033	$622,263	$ 31,113	$658,157	$ 32,908
2	Machinery depreciation[b]		56,065		62,226		65,816
3	Machinery maintenance		16,800		14,838		16,063
4	Buildings[a]	88,160	4,408	102,640	5,132	106,160	5,308
5	Building depreciation[c]		4,408		5,132		5,308
6	Building maintenance[d]		1,763		2,053		2,123
7	Taxes[e]		13,625		15,223		15,051
8	Insurance[f]		11,679		13,048		13,758
9	Steam		11,400		16,350		16,350
10	Water		4,740		6,270		6,270
11	Electrical power		16,800		22,140		21,810
12	Solvent loss		15,300		20,400		20,400
13	Labor		55,584		41,688		41,688
		$648,811	$240,605	$724,903	$255,613	$764,317	$262,853
Partial cost per ton for 30,000 tons processed per year[g]			$8.02		$8.52		$8.76
Increased cost of processing by Seed Processes compared with Meats Process, dollars per ton			....		$0.50		$0.74

[a] Interest rate on investment was taken as 5%.
[b] Machinery depreciation rate: 10%.
[c] Building depreciation rate: 5%.
[d] Building maintenance rate: 2%.
[e] Tax rate: $30 per $1,000. on 70% of items 1, 4.
[f] Insurance rate: $20 per $1,000, on 90% of items 1, 4.
[g] These costs include principally the items which are different among the three processes. Many items which are approximately the same were not considered in this cost estimate; therefore, the increased costs of processing by the Seed Processes are the significant figures.

monetary returns for the products are given in Table III. Most operating costs were estimated to be higher and the return for the products was less for the undelinted seed process so the net return per ton was about $3.90 less for this seed process in comparison with the meats process. This seed process is not economically feasible on the comparison basis used.

For the seed process in which a first cut of lint is removed, the net return per ton of seed was estimated to be only $0.32 less than for the meats process. This difference is too small to be significant, and this alternate seed process could be expected to compete on approximately equal terms with the meats process.

The details of this research were published in 1951 as a bulletin of the Texas Engineering Experiment Station (2). A recalculation of the cost analysis was made after the bulletin was published, using more accurate and complete cost data. This recalculation narrowed the difference between the meats and seed processes in plant investment costs and in net return per ton of seed. But the changes were not great enough to alter the conclusions.

TABLE III

Monetary Return on Products Per Ton of Seed Processed

Product	Price per pound	Meats Process	No. 1 Seed Process	No. 2 Seed Process
Oil	$0.10	$32.52	$32.88	$32.88
Meal, 43% protein	0.0315	29.34	24.88	24.88
First-cut linters	0.12	4.46	....	4.46
Second-cut linters	0.0175	2.86	....	....
Hull fiber[a]	0.0175	....	4.14	3.46
Hulls	0.004	2.22	....	....
Hull bran	0.0094	....	6.06	....
Hull bran	0.0095	....	....	6.14
Total return per ton of seed		$71.40	$67.96	$71.82
Increased return on products by Seed Processes compared with Meats Process, dollars per ton of seed		....	—$ 3.44	$ 0.42
Increased cost of processing by Seed Processes compared with Meats Process, dollars per ton of seed (from Table II)		....	$ 0.50	$ 0.74
Decreased net return per ton of seed by Seed Processes compared with Meats Process		....	$ 3.94	$0.32

[a] Five per cent of the hull fiber was assumed to have been lost in the defibrating operation and the return on hull fiber is lessened by a corresponding amount.

Cottonseed hulls with most of the lint attached to them is a product which is not produced by present cottonseed processes. There are at least two ways in which this product could be utilized. One is conversion into hull bran and a product similar to cotton linters. Calculations for the cost analysis were based on this method. The other way of utilizing the hulls-lint product would be to develop uses for this material without further expensive processing. No work at all was done to investigate possibilities along this line. Such an investigation should be included in any future work.

Summary

The results of the work which has been described can be summarized as follows:

a) A new, workable process has been developed using standard oil mill machinery, which can process cottonseed into oil, meal, linters, and a new product.

b) The economic position of the new process depends upon the use made of the new product; in the version of the new process investigated by this study, the new process competes on about equal terms with existing processes.

c) Although the new process does not give immediate promise of additional profits to cottonseed processors, another possibility for new products from cottonseed has been explored which might become important in the future if the present demands for second cut linters and hulls should decline.

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