TABLE I

Grain	Grind	Retained on Screen		
		325-mesh %	270-mesh %	100-mesh %
Soybeans	Hammermill .020" slots	31.8	27.0	10.3
		30.5	29.0	10.3
		31.0	29.0	10.9
		31.3	28.6	11.0
		30.9	29.0	......
	Ave.	31.1	28.5	10.6
Soybeans	Hammermill .027" holes	19.7	16.0	3.1
		18.4	16.6	3.2
		18.5	16.1	3.5
		18.3	16.9	3.6
		18.6	17.0	......
	Ave.	18.7	16.5	3.4
Soybeans	Attrition mill Position 2	33.0	31.4	25.1
		33.9	32.2	24.8
		33.6	33.3	25.6
		34.0	31.8	26.7
		33.0	31.8	......
	Ave.	33.5	32.1	25.6
Soybeans	Attrition mill Position 5	42.6	44.1	37.8
		42.0	43.9	37.2
		44.6	42.2	38.2
		43.6	43.5	36.3
		42.3	42.2	......
	Ave.	43.0	43.2	37.4
Soybeans	Attrition mill Position 15	64.9	61.2	55.5
		59.8	61.7	58.0
		62.8	61.9	57.8
		61.0	59.7	55.3
		61.2	61.5	......
	Ave.	61.9	61.2	56.6
Corn	Attrition mill Position 5	64.8	63.8	53.0
		64.7	63.3	52.9
		65.7	64.2	54.2
		66.1	63.2	53.7
		66.3	64.6	......
	Ave.	65.5	63.8	53.4
Corn	Hammermill 1/16" screen	61.0	59.0	40.6
		62.2	60.0	39.0
		62.1	59.8	39.7
		61.8	58.9	39.7
		62.4	59.9	......
	Ave.	61.9	59.5	39.8
Soybeans	Commercial	12.5	9.3	None
		12.3	9.6	
		11.8	9.2	
		11.7	8.7	
		11.6	9.2	
	Ave.	11.9	9.2	

scribed by Ross and Hardesty (2), and the attrition mill was a laboratory model commercially available. Of the 23 groups of data only four show a range greater than 2%, and, of these, three are on the same sample—the coarsest in the series. The hammermill used with the screen having the 0.027-inch round holes produced the finest grind, and the same mill with the slotted screen produced the next finest. The attrition mill at its finest setting (Position 2) produced essentially as much material passing the 325-mesh sieve as did the hammermill with the slotted screen but contained more material retained by the 100-mesh sieve. The progressive variation in particle size is shown very clearly for the three positions of the attrition mill. The difference between the corn and soybeans ground in the attrition mill at Position 5 presumably reflects the differences in the structure and hardness of the grain although no tests were made to determine if a given setting of the mill could be reproduced. The data in Table I show very definite differences between mills and between grinding conditions in each mill. The commercial soy flour was included for comparison.

The method has disadvantages. It requires a rather large volume of carbon tetrachloride although the amount lost per sample is not excessive. Further washing with an additional seven liters causes a continuing transfer of sample through the screen. Results are reported as a percentage of the original sample although the residue weighed contains less moisture and oil than the starting material. If the material retained by the screen were dried for one hour at 130°C. and analyzed for oil, results could be calculated to any desired basis. For the present purpose the effect of the small amount of residual oil and moisture was considered unimportant. It could be important however in other applications of the procedure. The change in size of particles treated with carbon tetrachloride is unknown.

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Extraction of Distillers' Dried Grains in a Soybean Solvent Extraction Plant

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DISTILLERS' dried grains are a by-product of the whiskey industry prepared by drying the slop remaining after the fermented grains have passed through the beer stills. The grains put into the fermentation and distillation process consist of about 75% corn, 15% barley, and 10% rye. The slop is reduced to 5% to 9% moisture by filtration, multi-effect evaporation, and rotary drying. In most cases all of the solid material in the slop is recovered. The principal use of the dried grains is as a constituent in dairy feeds.

The dried grains contain 9% to 10% oil, which originally was in the germ of the grains put into process. Naturally the oil consists largely of corn oil since this grain constitutes the bulk of those used.

During July, 1938, a submerged marc type extraction plant was completed and put in operation on distillers' dried grains (3). Later however the entire project was abandoned, and the plant was moved to Chile for use on another oil-bearing material (1). Since that time there have been considerable improvements in methods of extraction and solvents used. Also the feed markets have come to accept extracted meal to a much greater extent than in the earlier days of solvent extraction. More recently, laboratory and pilot plant studies have been made on the extraction of dried brewers' grains, but in this case the oil recovered was not of edible quality (2).

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It was the purpose of this work to determine if distillers' dried grains could be processed satisfactorily in a soybean solvent extraction plant and, if so, to determine optimum operating conditions. A further purpose was to obtain sufficient quantities of the oil and extracted grains for evaluation.

Plant Operation and Experimental Results

The flow sheet for processing soybeans in the solvent extraction plant of the Owensboro Grain Company is shown in Figure 1. The plant employs a basket type extractor and uses commercial hexane for solvent. It is designed to handle 100 tons of soybeans per 24-hour day. Several soybean plants throughout the United States use essentially this same process and equipment.

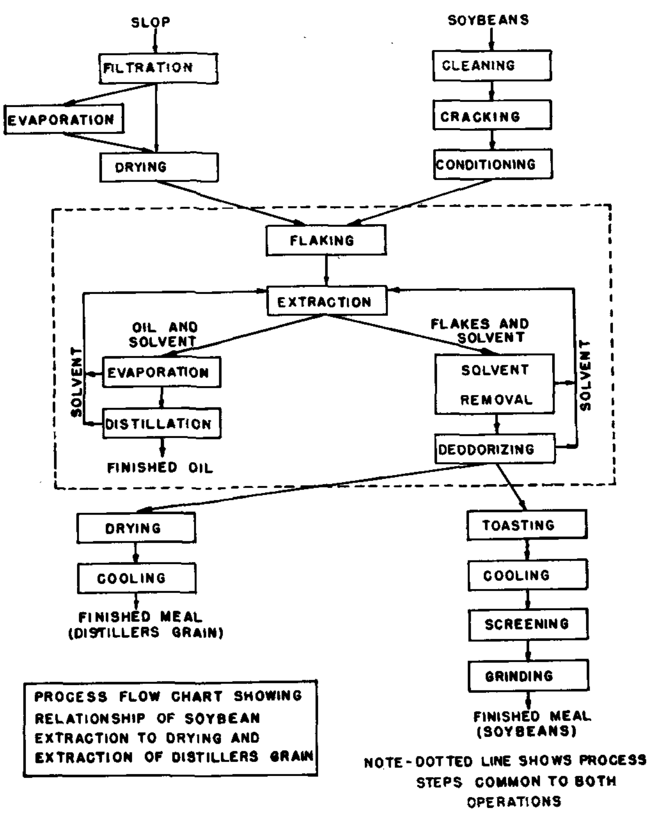

FIG. 1. Flow chart showing comparison of soybean solvent extraction process to drying and extraction of distillers' grains.

The distillers' dried grains were put through all the existing soybean channels including unloading at the rail dump and handling through the grain elevator. From the day storage bin the dried grains were fed to process over the grain cleaner and into the automatic dump scale. Air through the cleaner was reduced to a minimum, and the scale was set to dump 300 lb. instead of the usual 600 lb. of soybeans.

Rate of flow of grains to process was controlled by the feeder on the cracking rolls. These rolls were spaced so the distillers' grains would pass through without grinding but close enough to crack any soybeans present in the stream. Temperature and moisture were adjusted in the bean heater to correspond to best flaking conditions. These were found to be 140° to 160° F. and 12.5% to 13.0% moisture.

Flaking proved to be one of the most difficult operations. The grains contained enough hulls to require high pressure between the rolls to thin the flakes. At most levels of operation it was not possible to reduce the flakes to thicknesses corresponding to soybean operation. The flake thickness was 0.009 to 0.012 in. for most of the run. However it was found during the latter part of the run that thinning the flakes below 0.009 in. did not materially improve extraction results. It is estimated that about twice the present roll capacity would be required to thin the flakes to 0.006 to 0.008 in. for full operation.

On the extraction side of the plant flakes were handled in the same manner as soybean flakes with virtually no changes in equipment or operation. The extractor speed was varied between 15 and 29 baskets per hour, depending on the tonnage load (34 baskets per hour is normal for 100-ton operation on soybeans). The temperature of both the solvent and miscella (oil-solvent solution) to the extractor was regulated at 140° F. Sparging steam to the deodorizers was controlled at 300 lb. per hour instead of the usual 400 to 500 lb. per hour in order to avoid forcing dust into the meal desolventizer condenser.

Full miscella (20% to 25% oil) from the extractor was filtered and sent to the pre-evaporator where sufficient hexane was evaporated to give a solution boiling at 200 to 210° F. at atmospheric pressure. In the vacuum stripping column the pot temperature was regulated at 230° to 240° F. with 22 to 24 in. mercury vacuum. Sparging steam was fed to the bottom of the column at the rate of 110 lb. per hour. The finished oil was pumped directly outside and loaded into 55-gal. drums.

All condenser water temperatures, the solvent vapor recovery system, and other auxiliary equipment in the extraction section of the plant were operated in the same manner as for soybeans. The extracted flakes were sent to the toaster at 220 to 230° F. Only a small amount of water from the Roto-Clone was added to the flakes in the mixer, and this was to prevent excessive dusting. The toaster was used only as a drier since the distillers' grains did not lose color with extraction. The temperature of the flakes leaving the toaster was 235° to 245° F.

Conveying the dry extracted flakes limited the rate of output of the plant to the equivalent of 91 tons per day. While operating at this rate, the bucket elevator between the toaster and cooler choked down on two occasions. Even though the tonnage was subsequently kept below this figure, it is entirely possible that by changing the speed and discharge of this elevator it could have been made to handle more material.

After cooling, the flakes were screened twice over 14-mesh RoBall screens and the tailings put through a hammer mill grinder. The finished meal was stored in the outside day storage bin at 7% to 10% moisture. The bin was emptied at the end of the run, and the meal was loaded into railroad cars through the bagging and handling facilities for soybean meal.

The plant was run for about 26 hours without difficulty except for the choking down of the bucket elevator mentioned above. During this time 130,780 lb. of grain were processed, and several experiments were made to determine the effect of operating variables on extractions results. The operating time was consumed as follows: 1. about seven hours for starting the plant and establishing a flow of material through the equipment, 2. three hours for determining the maximum operating tonnage for the plant, 3. 12 hours for operating at three different solvent ratios: a) below 1.10, b) about 1.10, c) above 1.10, and d) four hours at very low tonnage to determine the effect of thinner flakes and increased time for extraction. Data for the entire run are tabulated in Table I.

TABLE I

Extraction Data

Conditions under observation	Hour	Grains to process		Solvent ratio	Flake thick. (x 0.001")	Final meal	
		T/24 hrs.	% Moist.			% Oil	% Moist.
Plant Start-up	1	50	—	—	—	—	—
	2	65	—	1.68	15–18	—	—
	3	50	16.5	1.91	12–17	4.0	—
	4	40	16.4	1.78	9–11	6.2	8.6
	5	61	14.0	0.95	9–10	1.8	8.6
	6	67	12.8	1.03	10–12	0.8	11.4
	7	72	12.8	1.07	10–12	1.6	9.7
Maximum tonnage	8	91	12.8	1.07	12–14	0.9	6.2
	9	72	13.5	1.07	11–12	1.3	8.9
	10	57	12.7	1.11	11–12	1.3	7.5
Solvent ratio below 1.10	11	54	12.7	0.95	9	1.2	8.6
	12	61	12.9	0.95	9–10	1.5	8.4
	13	66	12.3	0.89	9–10	1.1	8.5
	14	61	12.5	0.95	9–10	1.7	9.0
	15	66	12.5	0.89	9–10	2.1	8.8
Solvent ratio about 1.10	16	61	13.1	1.05	9–10	1.3	8.9
	17	66	12.8	1.09	9	1.5	9.0
	18	66	12.7	1.09	9	0.8	8.9
	19	66	13.2	1.09	9	0.8	9.6
Solvent ratio above 1.10	20	82	11.9	1.24	11–12	0.13	8.0
	21	57	13.1	1.34	10–11	0.3	9.1
	22	57	13.2	1.01	10–11	1.2	8.8
Reduced tonnage thinner flakes	23	54	13.5	1.19	8–9	0.7	10.1
	24	47	12.9	1.10	7–9	0.7	10.0
	25	47	13.3	1.10	8–9	1.2	10.2
	26	36	—	—	—	1.8	—

The information from the operation and experimental results may be summarized as follows:

1. It was possible to process distillers' dried grains in the 100-ton capacity soybean extraction plant at 40 to 85 tons per day without significant changes in the existing process.
2. The extraction capacity of the plant was not reached. The limiting factors to additional tonnage were the conveying equipment and the flaking rolls.
3. Extraction results during the early part of the run were very poor, emphasizing the importance of uniform operation and proper adjustment of operating variables.
4. Extraction of the grains improved with an increase in solvent ratio. The optimum ratio for continuous operation probably corresponds very closely with the 1.10 lb. hexane per lb. grain processed generally used for soybeans.
5. There was no significant improvement in extraction results when flakes were reduced below 0.009 in. thick and the holding time in the extractor was increased.
6. The oil produced from 130,780 lb. of the dried grains was 11,358 lb., equivalent to 8.68% over-all yield.
7. With continuous uniform operation it should be possible to extract the grains in a basket type extraction plant to the equivalent of 0.5% residual oil in the finished meal.

Meal and Oil Analyses

The analyses of composite samples of the distillers' dried grains before and after extraction are given in Table II.

TABLE II

Analysis of Distillers' Dried Grains Before and After Extraction

	Before extraction	After extraction
Ash (%)	2.04	2.04
Crude fiber (%)	9.83	10.6
Crude fat (%)	9.18	1.05
Moisture (%)	5.35	7.50
N.F.E. (%)	44.9	47.0
Protein (%)	28.7	31.8

Extraction of the grains yields a meal of higher protein content that should be superior to the original grains for some types of feeding. There is some controversy as to the effect of lowering the fat content of dairy rations on milk and butterfat production (2). In most cases the amount of distillers' dried grains in the ration is a relatively small percentage of the total so any reduction in its fat content would show up as a much smaller reduction in the entire ration.

The oil extracted from the grains was classed as of edible quality and showed the analysis given in Table III.

TABLE III

Analysis of Oil Extracted from Distillers' Dried Grains

Unsaponifiable (%)	2.22
Iodine number	125.5
Saponification value	187.7
Free fatty acids (%)	7.8
Refined color (1" column)	8.2
Refined and bleached color (4% S.F.)	6.6
Refining loss (laboratory cup, %)	26.4

The analysis indicates the oil is similar to corn oil in most respects except for a higher color and refining loss. These two factors might limit the amount of the extracted oil that could be used by any one processor of edible oils.

Conclusion

The processing of distillers' dried grains in existing basket type soybean solvent extraction plants, or new plants built expressly for the grains, is practical from the standpoint of mechanical operation and extraction results. As shown in Figure 1, not all the steps in the soybean process are necessary for processing the distillers' dried grains. Extracted oil from the grains is similar to corn oil except for its higher color and refining loss. The extracted grains are higher in protein than the original grains which should increase the value for certain types of feed. The lower fat content should not significantly alter the value as a part of dairy rations.

Acknowledgments

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