Integrated Processing of Peanut for the Separation of Major Constituents

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IN THE PRESENT-DAY METHODS of processing oil seeds the oil and cake are obtained by treating the seed in a screw-press and/or a solvent-extraction unit. The cake is generally used for livestock feed and fertilizer. To a limited extent it is also further processed to isolate the protein and obtain a carbohydrate meal as a by-product. Extensive work has been reported on the properties of the protein in the peanut meal as influenced by various processing conditions. It has been shown that high temperature and pressure employed during the mechanical expression of oil adversely affect the quality of the protein (2). Where a protein with minimum denaturation is required the meal is obtained by low-temperature solvent-extraction.

Heat degradation of the protein occurs also in the collagen during the degreasing of bones for the manufacture of glue. To avoid this degradation Chayen and Ashworth have developed an "impulse rendering" process (1). It is reported that this process removes the fat with minimum damage to the structure of the nonfat-matter in the raw material and thus makes possible the manufacture of high-class glue protein. Practical difficulties have been encountered in the application of this technique to vegetable oil seeds.

In view of the growing importance of vegetable proteins for enrichment of food and for industrial uses, attempts have been made to develop new methods for the recovery of oil and protein from the oilseeds, wherein high temperature and pressure are avoided. In some of these, dispersion of the oilseed in water has been used to effect a separation of the oil and protein from each other and from the other constituents. Sugarman has patented a process for the simultaneous extraction of oil and protein from peanuts and other oil-bearing materials, wherein the kernel is ground with water under optimum condi-

tions of pH and temperature and the dispersion is separated into an oil-rich emulsion, a protein solution, and residual solids (4). The protein is obtained by acid precipitation from the solution and the oil is obtained by demulsifying the emulsion. The present paper reports the results of the work conducted in these laboratories on the development of an integrated process for the processing of peanut. The process is similar in principle to those just described; it aims at the extraction of oil and protein at low temperature and also the separation of these constituents in a single process.

Experimental

Laboratory Trials

Laboratory work was carried out according to the process outlined in Figure 1. Clean decuticled peanut

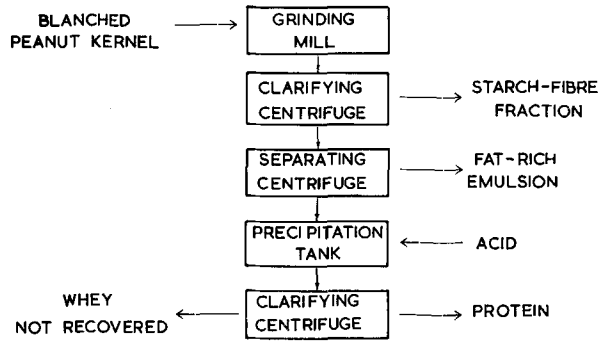

FIG. 1. Flow sheet of the laboratory process.

kernel [moisture 4.2%, oil 46.2%, protein (N × 6.25) 30.2%] was pasted in a mikropulverizer to peanut-butter consistency. The paste was then dispersed in seven parts of water, and the pH adjusted to 7.0. The dispersion was clarified in the hollow bowl of a Westfalia multipurpose laboratory centrifuge, yielding the starch-fiber fraction. The fat was then separated from the clarified dispersion by using the separator bowl of the same centrifuge. The fat was obtained as an oil-in-water type of emulsion with 35% moisture, similar to the cream from milk. This emulsion had to be frozen or dehydrated to recover the peanut oil from it. After the separation of fat the dispersion was acidified to pH 4.5–5.0 to precipitate the protein, which was removed by centrifuging and then dried. The whey, containing soluble sugars, nitrogenous constituents, and minerals, was not recovered.

Table I gives the distribution of oil and protein in the different fractions obtained in the process. The results show that, while the total oil present in the peanut kernel is accounted for in the different fractions, the protein balance is not obtained. This is partly due to the losses of nitrogen in the whey and in a protein fraction sedimented in the centrifuge bowl during the separation of the fatty fraction from the emulsion.

TABLE I
Distribution of Oil and Protein
Moisture in Peanut Kernel 4.2%

	Quantity	Oil	Protein
	(g.)	(g.)	(g.)
Kernel	2,000	924	604
Starch fiber fraction	412	50	154
Protein fraction	350	30	304
Fat-rich emulsion	1,344	832	27

The solids obtained as the starch-fiber fraction during the clarification step were found to contain a large amount of fat and protein. It was observed that, if the kernel were ground in the presence of water to get a dispersion directly, the loss of fat and protein in the suspended solids was considerably reduced (Table II).

At this stage the process was still not satisfactory as all the fat was obtained in the form of a fairly stable emulsion which had to be further processed for the recovery of the oil. It was therefore considered desirable to defat the kernel partially before making the dispersion in water. This defatting was conveniently done without the use of high temperatures by the application of the Skipin process (3). In this process the kernel was ground dry, and the paste obtained was well mixed with 20% by weight of warm water at 60°C.(140°F.). The water displaced about 60% of the oil in the paste, and this oil was drained out. After decantation of the liberated oil the remaining paste was dispersed in seven parts of water, and the dispersion was processed as described earlier. By this modified process about 25% oil (on the weight of the paste) was obtained as free oil by the Skipin process, and another 15–20% was recovered from the cream-type emulsion.

TABLE II
Wet Grinding *vs.* Dry Grinding
Analysis of Starch Fiber Fraction from 2 kg. of Kernel

	Dry grinding	Wet grinding
	(g.)	(g.)
Total dry weight of solids	440	309
Fat	66	27
Protein	165	85
Carbohydrates (by difference)	209	197

In these laboratory trials it was found difficult to get reproducible results because a) the loss of oil in handling was a considerable proportion of the total oil content and b) the feeding rate to the centrifuge could not be accurately controlled. It was therefore decided to try out the process on bench pilot-plant scale where better control was possible. The preliminary experiments on the bench scale indicated that by proper adjustment of the cream screw or the ring dam of the separator centrifuge, the fat could be obtained directly in the free state, without the intermediate emulsion.

Bench Pilot-Plant Trials

The work reported below relates to 15 trials on batches of 100 lbs. (45.4 kg.) each. The main object of this work has been to get complete data on the yields of different products and to ascertain the reproducibility of the results. Further the experience gained in these bench-scale trials would be useful in anticipating difficulties in further developmental work.

Preparation of Raw Materials. In order to avoid the pigments from the cuticle of the kernel, which otherwise discolor the final protein, it was found desirable to use decuticled kernel as the starting material. This was done by giving a light roasting to the kernel at 70–80°C.(158–176°F.), and after cooling, the cuticle was easily removed by slight rubbing on a sieve. All these operations were done manually. Stones and other foreign matter were sorted out.

Grinding. The cleaned kernel containing 4% moisture was fed to a grinding mill at the rate of approximately 70 lbs./hr. The paste obtained was of the consistency of peanut butter and left the mill at approximately 60°C.(140°F.).

The mill used (No. 4 size Kek Mill) has two discs fitted with pins. The lower disc rotates at high speed, and the top disc is stationary. The material enters at the center and leaves as a paste at the periphery.

Skipin Process. Next 25 lbs. of the paste, obtained as above, were taken in the bowl of a planetary type mixer, (Consul model) fitted with a J-shaped mixing arm, and 4.4 lbs. of water at 60–65°C.(140–149°F.) containing 50 ml. of 50% sodium hydroxide solution were added gradually while the mixer was in operation at high speed. When the oil began to separate and the paste started forming lumps, the mixing was continued at low speed until the oil was clear. The water initially present in the oil was gradually absorbed by the paste to give a clear oil. The Skipin operation was completed in 10 min. The oil liberated at this stage, henceforth called Skipin oil, was decanted out, and the pasty residue was drained over a false bottom. Though practically all the oil was drained out in approximately 1–2 hrs., for convenience the oil was drained overnight. Four 25-lb. batches were put through the Skipin process every day.

Dispersion. The pasty residue from 25 lbs. of peanut was added gradually to 60 lbs. of water in the bowl of the planetary mixer (Consul model) fitted with a cage type of mixing attachment. Enough alkali (sodium hydroxide 40%) was added to bring the pH to about 10.0. When all the paste was added, another 60 lbs. of water were added to the dispersion. After transferring this dispersion to the feeding tank for the clarifying centrifuge, 60 lbs. of water were used to rinse out the bowl and the pump used for transferring. In all 180 lbs. of water were used for every 25 lbs. of paste.

Filtration. The dispersion obtained above was then passed through a 40-mesh sieve fitted on top of the tank feeding the clarifying centrifuge. The residue on the sieve was washed with rinse water from the mixer bowl. This residue, termed the sieve residue, consisted mostly of coarsely ground kernel.

Clarification. The filtered dispersion from above was fed to a solid bowl, horizontal basket centrifuge (Escher Wyss), fitted with a skimmer pipe and a scraper knife. The feed rate was controlled at 300–350 lbs./hr. by means of a flowrator. From previous experience it was known that the centrifuge bowl could hold the sediment from only 12–13 lbs. of peanut. After this quantity had been put through, the inside liquid was skimmed out and the sediment was scraped off. This sediment has been termed carbohydrate meal. Dispersion from 25 lbs. of peanut could be put through in about 45–50 min., including the time required for the two cleanings.

Separation. A hollow bowl, high-speed centrifuge (Sharples Super Centrifuge), fitted with a separator ring dam, was used for the removal of fat from the clarified dispersion. As the clarified dispersion still had about 1% (v/v) sediment, it was necessary to use a separator with a high solids-holding capacity, hence a disc bowl centrifuge could not be used. In order to reduce the oil losses in handling it was desirable to keep the number of vessels used to the minimum. Therefore the clarified dispersion was directly pumped to the separator centrifuge. As the feeding rate for the latter was approximately 1,000 lbs./hr. as against approximately 300–350 lbs./hr. for the clarifying centrifuge, the feed to the separator was necessarily intermittent. At the end of the day's operations, when the separator was stopped, the liquid (free oil + emulsion) held in the bowl was drained out from the bottom and preserved in the cold storage. This was fed to the centrifuge the next day, after the water seal was formed but before the feed from the clarifying centrifuge was started.

Clear oil was obtained from the lighter liquid outlet, and the dispersion freed from most of the fat came out from the other outlet. This "skimmed milk" containing approximately 0.6% fat, the protein, and the water extractives was collected in the protein precipitation tanks.

When the centrifuge was stopped, the inside liquid drained out. The bowl was then opened, and the solid sediment was taken for drying. This sediment has been designated rotor bowl solids.

Protein Precipitation. The "skim milk," together with the rinse water from the equipment used earlier, weighed approximately 800 lbs. To this 1.0 N commercial HCl was gradually added until the pH was approximately 4.5 and a distinct precipitate was evident. This protein slurry was then transferred to the feeding tank of the clarifying centrifuge for sedimentation of the protein.

Protein Sedimentation. The horizontal basket centrifuge, used for clarifying the original dispersion, was again used for protein sedimentation. The feeding rate was 300–500 lbs./hr. The protein from 25 lbs. of peanut could be separated in one batch, and consequently the bowl had to be emptied only four times for each 100-lb. batch.

Drying. A cabinet tray drier holding 40 trays (32 × 16 in.) was used. It was set to work at 60°C. (140°F.). The wet carbohydrate meal from each cleaning of the centrifuge during the clarifying operation was spread on one tray in big lumps. This averaged to a tray-load of roughly 7.5 lbs./tray or approximately 2.1 lbs. of wet meal/sq. ft. of tray surface. Approximately 20–24 hours were required to dry this to 7–10% moisture content. The surface of the lumps was usually discolored during drying, but the inside remained white. Case-hardening was not a problem, and the material dried fairly well even when present as big lumps.

The wet protein was much more difficult to handle and dry. Though holding less water than the wet carbohydrate meal, it was more sticky. During the drying the outer surface dried quickly to a brown color, but the inside became darker in color. When dried completely (5% moisture level or less), it crumbled to a granular form. Because of the above characteristics it was necessary to spread the wet protein more finely than in the case of the wet carbohydrate meal.

The wet protein was spread approximately 2 lbs./tray, *i.e.*, approximately 0.6 lb. wet protein/sq. ft. of tray surface. Then 20–24 hrs. were required for proper drying at 60°C.(140°F.).

Results and Discussion

A flow sheet of the 100-lb. (45.4 kg.) batch is given in Figure 2. The yields of the various products obtained in the process are listed in Table III. The material balance for raw material, oil, and nitrogen

TABLE III

Yield of Various Products from Peanut on Moisture-Free Basis
Weight of Peanut Kernel per Batch of 100 lbs.
Weight on Moisture-Free Basis of 96.1 lbs.

Batch No.	Oil	Protein	Carbohydrate	Sieve residue [b]	Rotor solids [b]	Whey solids [a, b]	Total [b]
	(lbs.)	*(lbs.)*	*(lbs.)*	*(lbs.)*	*(lbs.)*	*(lbs.)*	
1	42.3	22.6	13.0	2.2	....	....	....
2	42.0	24.4	16.0	2.0	1.3	12.0	97.7
3	42.4	23.1	16.3	....	....	11.2	....
4	42.4	22.7	16.9	2.6	0.9	....	....
5	41.7	22.8	11.0	2.8	1.6	....	....
6	42.3	23.5	15.2	....	1.1	10.5	....
7	41.4	21.7	15.1	4.8	1.2	11.2	95.4
8	41.4	21.9	16.3	2.7	1.1	12.7	96.1
9	43.3	21.7	16.7	2.1	1.1	13.5	98.4
10	41.8	21.6	16.0	2.3	1.3	12.7	95.7
11	41.4	17.1	15.2	2.7	1.4	12.0	89.8
12	42.7	21.5	17.2	2.4	1.1	12.0	96.9
13	42.4	21.8	17.8	2.3	1.2	11.2	96.7
14	42.1	21.5	17.0	2.1	1.3	13.5	97.5
15	41.4	20.8	15.7	2.8	2.0	12.0	94.7
Total	631.0	328.7	235.4	39.0	19.2	180.6	1438.5

[a] Whey solids not recovered; calculated from per cent solids in whey.
[b] Missing values taken as the average of others for calculating the total.

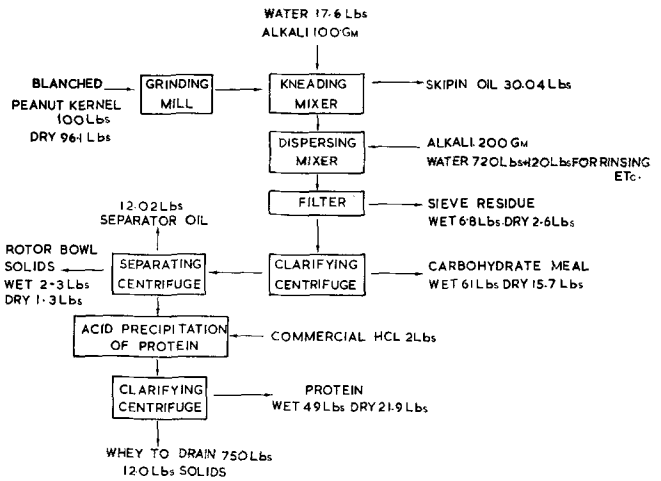

FIG. 2. Modified flow sheet of the bench-scale process.

TABLE IV

Material Balance Sheet for Raw Material, Oil, and Nitrogen

General	
Oil	42.1
Protein	21.9
Carbohydrate meal	15.7
Whey solids	12.0
Sieve residue	2.6
Rotor bowl solids	1.3
	95.6
Unaccounted	0.5
Weight of raw material on moisture-free basis	96.1
Oil	
Oil recovered	42.1
Protein + whey (skimmed milk)	4.8
Carbohydrate meal	1.2
Sieve residue	1.0
Rotor bowl solids	0.3
	49.4
Error	0.6
Oil in the raw material	48.8
Nitrogen	
Protein	3.05
Carbohydrate meal	0.46
Whey solids	0.41
Sieve residue + rotor bowl solids	0.16
	4.08
Unaccounted	0.23
Nitrogen in the raw material	4.31

are given in Table IV. The grand total represents the over-all yield from 1,500 lbs. (681 kg.) of peanut. The oil, protein, and the carbohydrate meal represent the three major products of the process. The whey solids also form a considerable proportion of the raw material, but because they are present in low concentration (less than 1.5% in the whey), it was not considered worthwhile to recover them for the present. The sieve residue, which forms 2.0–3.0% of the peanut paste, is rich in fat (35%) hence is responsible for an appreciable percentage of the oil loss. It was observed that it consisted mostly of improperly ground kernel and some coarse fiber. The type of grinding, the effect of the moisture content of the kernel and the effect of recycling this residue through the grinder need further investigations.

The rotor bowl solids, though rich in fat (25%), putrify so fast that it may not be desirable to mix them with any other fraction. They would constitute a necessary waste.

Oil. The oil is one of the major products of the process. The data on the quantity and quality of the oil obtained by the Skipin process and from the separating centrifuge are given in Table V. It is to be noted that two grades of oil are obtained. Skipin oil forms roughly 70% of the total oil recovered. Though it is not significantly different in color from the separator oil, it has a distinctly higher free-fatty-acid content. The moisture content (0.04%) was just enough to give a slight turbidity to the oil. On the other hand, the separator oil, forming less than 30% of the oil yield, was a completely refined oil with a free fatty acid content of 0.04% and a moisture con-

TABLE V

Yield and Quality of Oil

	Yield	F.F.A.	Color [a]	
			Red	Yellow
Skipin oil	*(lbs.)*	*(%)*		
Range	28.3—31.5	0.10—0.38	0.4—1.2	4.4—10.0
Mean ± S.D. [b]	30.0± 1.1	0.17±0.08	0.7±0.2	8.9± 1.6
Separator oil				
Range	10.0—14.1	0.03—0.06	0.6—1.2	7.0—10.0
Mean ± S.D. [b]	12.0± 1.1	0.04±0.01	0.7±0.2	8.7± 1.2
Total oil				
Range	41.4—43.3	0.10—0.30	0.4—0.8	7.5—10.0
Mean ± S.D. [b]	42.1± 0.6	0.16±0.06	0.6±0.1	8.7± 1.1

[a] Lovibond units, measured in 40-mm. cell.
[b] Mean of 15 values; standard deviation obtained by the formula

$$\sqrt{\frac{\Sigma (x-\bar{x})^2}{(n-1)}}$$

TABLE VI

Yield, Moisture, and Fat Content of Carbohydrate Meal and Protein

	Wet product		Dried product		
	Weight	Moisture	Weight	Moisture	Fat
Carbohydrate meal	(lbs.)	(%)	(lbs.)	(%)	(%)
Range	53.9—84.4	69.0—79.0	12.2—19.0	4.8—12.4	5.5—10.0
Mean ± S.D.	60.9± 7.2	72.1± 3.2	17.0± 1.8	7.4± 2.2	7.1± 1.3
Protein					
Range	37.0—52.7	47.0—59.0	17.5—25.3	1.7— 7.5	4.3—18.1
Mean ± S.D.	49.2± 4.1	53.9±3.2	22.7± 1.8	3.5± 1.6	9.9± 2.9

tent of 0.01%. The over-all recovery of 631 lbs. of oil from 1,500 lbs. of peanut containing 48.8% oil is equivalent to 85% recovery. The main reason for this low recovery is the low efficiency of the separation process. The "skim milk" contained an average of 0.6% fat, equivalent to a loss of 4.8% oil on the weight of the peanut processed. The separator efficiency should therefore be considered for further investigation.

Samples of oil stored in air-tight, 4-oz. tin cans at room temperature (75–90°F.) over a period of 12 months were organoleptically evaluated and found to be acceptable. The peroxide value of the total oil (Skipin oil + Separator oil) increased from an initial value of 2.1 to 6.3 (millimoles of peroxide per kg. of fat) and the F.F.A. from 0.16 to 0.23% during the period of storage.

Protein. Protein is the other important product of the process. The quality of the protein had to be sacrificed in these trials to arrange a suitable working schedule. For example, the Skipin process, making use of alkaline water, was carried out the previous afternoon; the paste was drained over-night and dispersed next morning. It is not known how much this long contact with alkali affects the quality of the protein. Again the wet protein was dried at 60°C. (140°F.) in order to increase the drying rate. The extent to which the different operations of the process affect the protein also needs study. In the present series of experiments nearly 70% of the original nitrogen in the peanut was recovered as protein. The protein obtained was of greyish yellow color and had a high fat content; a specimen of the mixed lot of protein on analysis gave moisture 6.2%, fat 9.0%, protein 85.0%, and ash 0.4%. As pointed out earlier, a more efficient separator not only will considerably increase the oil yield but also at the same time reduce very much the fat content of the protein and improve the keeping quality.

Carbohydrate Meal. This fraction was obtained as small lumps which had a grey-brown color on the surface. When quickly dried, the product was practically odorless and bland. The drying process offered no difficulties. The ground meal had a slight dull color and was analyzed as follows: moisture 12.0%, protein 16.2%, fat 6.1%, starch 41.6%, crude fiber 10.3%, ash 6.0%, unaccounted portion 7.8%.

Table VI gives the yield and moisture and fat content of the carbohydrate meal and protein.

Summary

Bench-scale experiments were carried out on the processing of peanut by a new method. The decuticled kernels were pasted, and the paste was subjected to the Skipin process to recover approximately 30% oil; the residual paste was made into a dispersion at 10.0 pH and clarified to get a carbohydrate meal (15.7% moisture-free); the clarified dispersion was centrifuged to obtain another 12% fat and the remaining dispersion was acidified to get the protein (21.9% moisture-free).

Fifteen batches of 100-lb. (45.4 kg.) each have been processed, and the reproducibility of the yields has been ascertained. The scope for increasing the oil yield and for improving protein quality is discussed.

Acknowledgment

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