GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT INITIATION

Date: 1/25/72

Project Title: Cost Analysis of the Extraction of Protein from Peanut Meal and Presscake

Project No.: A-1395

Project Director: Mr. W. H. Burrows

Sponsor: Georgia Agricultural Commodity Commission for Peanuts

Effective: January 1, 1972 . . . Estimated to run until: December 31, 1972

Type Agreement: Memorandum of Agreement . . . Amount: $ 10,000

Reports: Progress Reports
Final Report

Contact Person: Mr. Ron C. Balkcom
Georgia Agricultural Commodity
Commission for Peanuts
P. O. Box 967
Tifton, Georgia 31794

Assigned to . . . Chemical Sciences & Materials . . . Division

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GEORGIA INSTITUTE OF TECHNOLOGY
Engineering Experiment Station

PROJECT TERMINATION

Date ~~April 26, 1973~~

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PROJECT NO: A-1395

PROJECT DIRECTOR: W. H. Burrows

SPONSOR: Georgia Agricultural Commodity Commission for Peanuts

TERMINATION EFFECTIVE: ~~December 31, 1972~~

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COST ANALYSIS OF THE EXTRACTION OF PROTEIN FROM PEANUT MEAL AND PRESSCAKE

Project Director

W. H. Burrows

Project A-1395
Progress Report
January 1, 1972-September 30, 1972

to

GEORGIA AGRICULTRUAL COMMODITY COMMISSION
FOR PEANUTS
Tifton, Georgia

October, 1972

TITLE

Cost Analysis of the Extraction of Protein from Peanut Meal and Presscake

OBJECTIVE

To determine, via pilot plant operation, the economics of the Georgia Tech Engineering Experiment Station process for protein, as applied to peanut meal and presscake.

BACKGROUND

The project initiated as of January 1, 1972, under the above title and with stated objective, was supported by the Georgia Agricultural Commodity Commission for Peanuts. Its purpose was to determine the feasibility of applying to peanut meal and presscake a process previously developed at the Engineering Experiment Station for extraction of protein and oil from seed. A previous project under station support had shown promising yields of aflatoxin-free protein isolate from restricted, as well as unrestricted, meal on a small (1/2 pound) laboratory scale. The present project increased the scale to 5 to 10 pounds of meal per batch in order to provide a basis for estimating process costs on an industrial scale, as well as to provide sufficient quantities of product for evaluation studies.

The process, as developed at the Engineering Experiment Station, consisted of the following steps:

(1) Size reduction by use of laboratory blender or mill

(2) Addition of sodium hydroxide solution to pH 10.5 to 11.0, stirring for 15-30 minutes to dissolve the protein. The weight ratio of solvent to meal is ca. 10:1.

(3) Centrifuging to remove insoluble residues

(4) Addition of hydrochloric acid or sulfur dioxide to pH 4.5 (the isoelectric point of the protein) to precipitate the protein from solution

(5) Filtering or centrifuging to separate the protein from the mother liquor

(6) Washing with water adjusted to pH 4.5

(7) Washing with acetone until water-free

(8) Washing with hexane until acetone-free

(9) Air drying

A flow diagram of this process is shown in Figure 1.

A cyclic process, involving counter-action of solids and solvents, had been devised and tested, with favorable results. In that process, the residue from (3) was extracted with fresh sodium hydroxide solution, which was then used to extract a second residue from (3) before being used for extraction of fresh meal. The effect of the repeated extraction was to provide a high overall meal-to-water ratio.

The high yields obtained in our process are attributed to the combined effects of the cyclic process and the comparatively high pH of extraction. The latter was found necessary in order to overcome the partial denaturation occuring during the oilmill operation.

EXPERIMENTAL PROCEDURES AND RESULTS

1. Equipment and Procedure, Original Process

Samples of both restricted and unrestricted meal, from both expeller and solvent mills, were provided by Goldkist Research Laboratory, Graceville, Florida and by the U.S.D.A. Peanut Quality Laboratory, Dawson, Georgia.

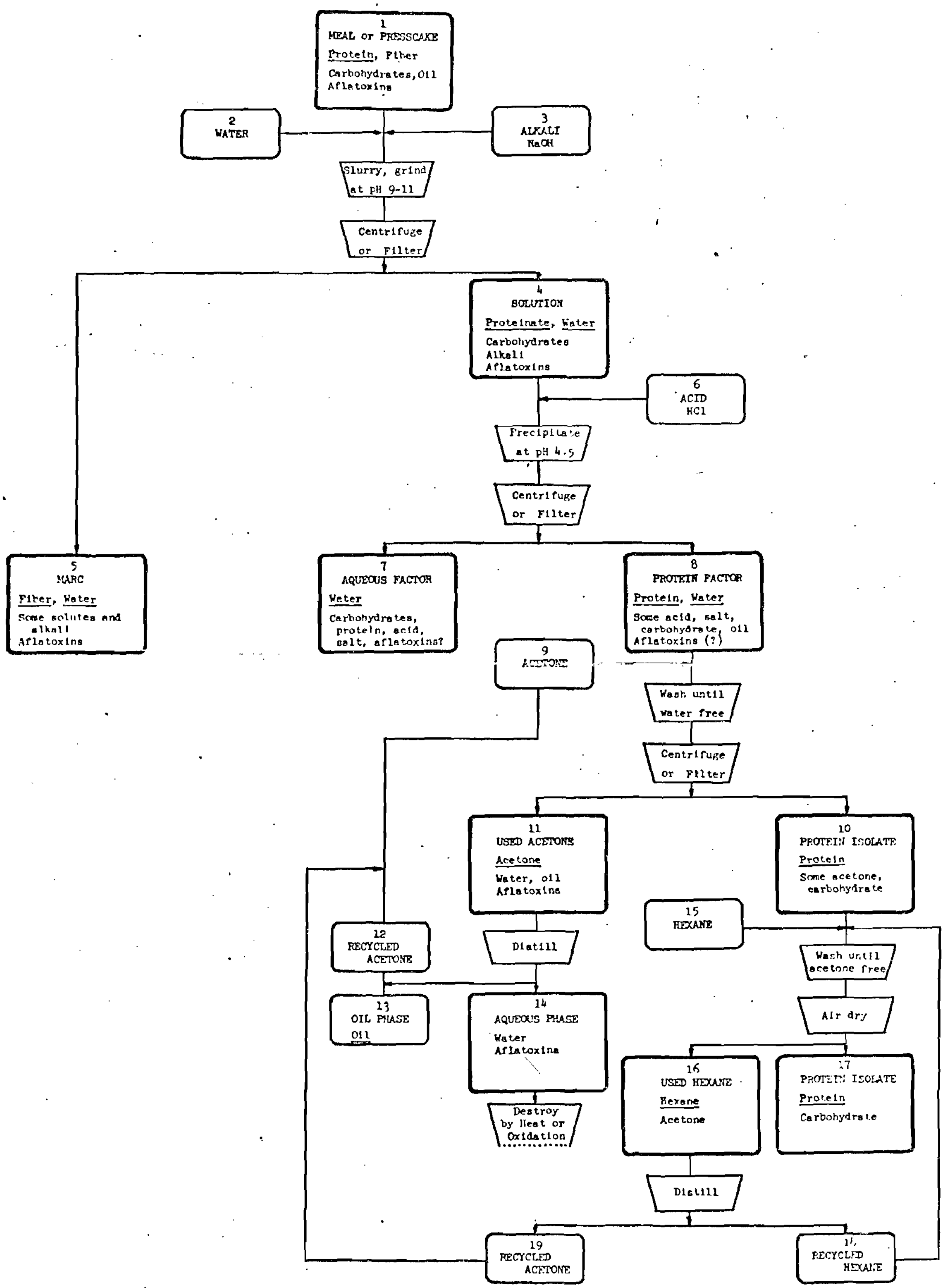


Figure 1. Flow Diagram of Original Process

Size reduction was accomplished by slurrying the meal in water and passing through the Morehouse Mill (Model 81402). Sodium hydroxide solution was added to the resulting suspension, and the mix was stirred for 15-30 minutes in a stainless steel processor. Insoluble residues were removed in a Fletcher Model 6863 centrifuge. Protein was precipitated from the centrifugate and separated from the liquor by either filtration or centrifugation. Initially, a Sparkler centrifuge, loaned by Dover Chemical Company, was used; however, this proved unsatisfactory for the purpose, and later work was done with a large Büchner funnel operated by reduced pressure. For some experiments, a cup type centrifuge or the Fletcher centrifuge was used, except for the acetone and hexane washes.

Acetone and hexane washes were conducted in preserving kettles, wherein the wet protein was dispersed in the solvent by stirring. The protein isolate was separated from solvent by vacuum filtration and air dried, or, if necessary, dried in a forced draft oven at 50°C.

Several batches of 10 pounds of meal were extracted; however, when the Sparkler filter proved inadequate for filtering the isolate, the batch size was reduced to 5 pounds. Records were kept on the source of meal, the quantities of all materials used, and the yields obtained. All variations in procedure were recorded, with results. It was found that a technician, working approximately 40% time, could make two extractions per week, including solvent wash and drying.

Yields of 70%, average, were obtained. The protein isolate was a fine, off-white powder, soluble in water at pH 7. When completely dried of its solvent wash, the isolate was odorless and tasteless; apparently, the hexane wash is sufficient to remove objectionable tastes sometimes left by acetone on protein isolates. Aflatoxin assays on original meals were 8 to 40 ppb total; on the isolate, 0. Amino acid profile is shown in Appendix I.

2. First Modification

A study was made of the aqueous effluent generated by the process. Table I shows the chemical oxygen demand (COD) and biological oxygen demand (BOD) of this effluent from runs dated as indicated. Also shown are the values of COD and BOD after periods of aeration. These data indicate that the effluent is extremely concentrated in comparison to domestic waste water, by 20 to 30 fold. Appendix II is a memorandum on the treatment needed for a 10,000 gallon daily discharge of this effluent. One is faced with the dilemma of locating the plant within the sewer service area of a city, where its discharge would be sufficiently diluted that no special treatment would be required at the disposal plant, or of providing a waste treatment facility of sufficient capacity at the plant site. Either course would be costly since the city would doubtless affix a charge based upon the COD, BOD and volume of the effluent.

TABLE I

WASTE WATER CHARACTERISTICS

Date	Raw		Treated		
	COD g/ℓ	BOD g/ℓ	Time of Aeration Days	COD g/ℓ	BOD g/ℓ
March 21	8.0	4.2	2	2.6	1.8
			3	0.33	0.25
March 28	5.5	3.3	2	2.9	--
			8(dispersion)	0.8	0.2
April 7	7.2	4.0	5		--
April 13	7.4	--	7	0.83	--

Examination of the effluent composition shows the cause of the high COD and BOD values to be due primarily to dissolved proteins, polypeptids and carbohydrates. The source of the problem is thus nutrient materials in a form too dilute to warrant recovery by ordinary means, but too concentrated for easy disposal. A second waste material of the process is the fibrous residue (marc) from the first centrifugation, which we considered drying, pulverizing and utilizing for fertilizer. This material also contains a portion of the soluble organic from the dissolution of the meal, and these solubles represent additional nutrient values.

Rather than waste the nutrient values of these two materials, while simultaneously creating disposal problems, we combined the two by reslurrying the marc in the aqueous effluent. The slurry was spray-dried, producing a light, fluffy material of deep beige color and pleasant fragrance. Judging from its nutrient content and the fact that it showed 0 to "trace" aflatoxin content, this material was considered to be an excellent candidate for animal feed. Figure 2 shows a flow diagram for the first modification of the Engineering Experiment Station protein process.

The addition of the marc, which has been separated at pH 11, to the aqueous phase, from which protein isolate has been precipitated at pH 4.5, produces a neutral, or nearly neutral mixture. Any slight variation from pH 7 can be titrated with sodium hydroxide or hydrochloric acid solution. The slurry entering the spray drier is, therefore, neutral and upon evaporation of water leaves a residue containing sodium chloride (common salt) as its principal electrolyte. This, again, is favorable for its use as an animal feed material.

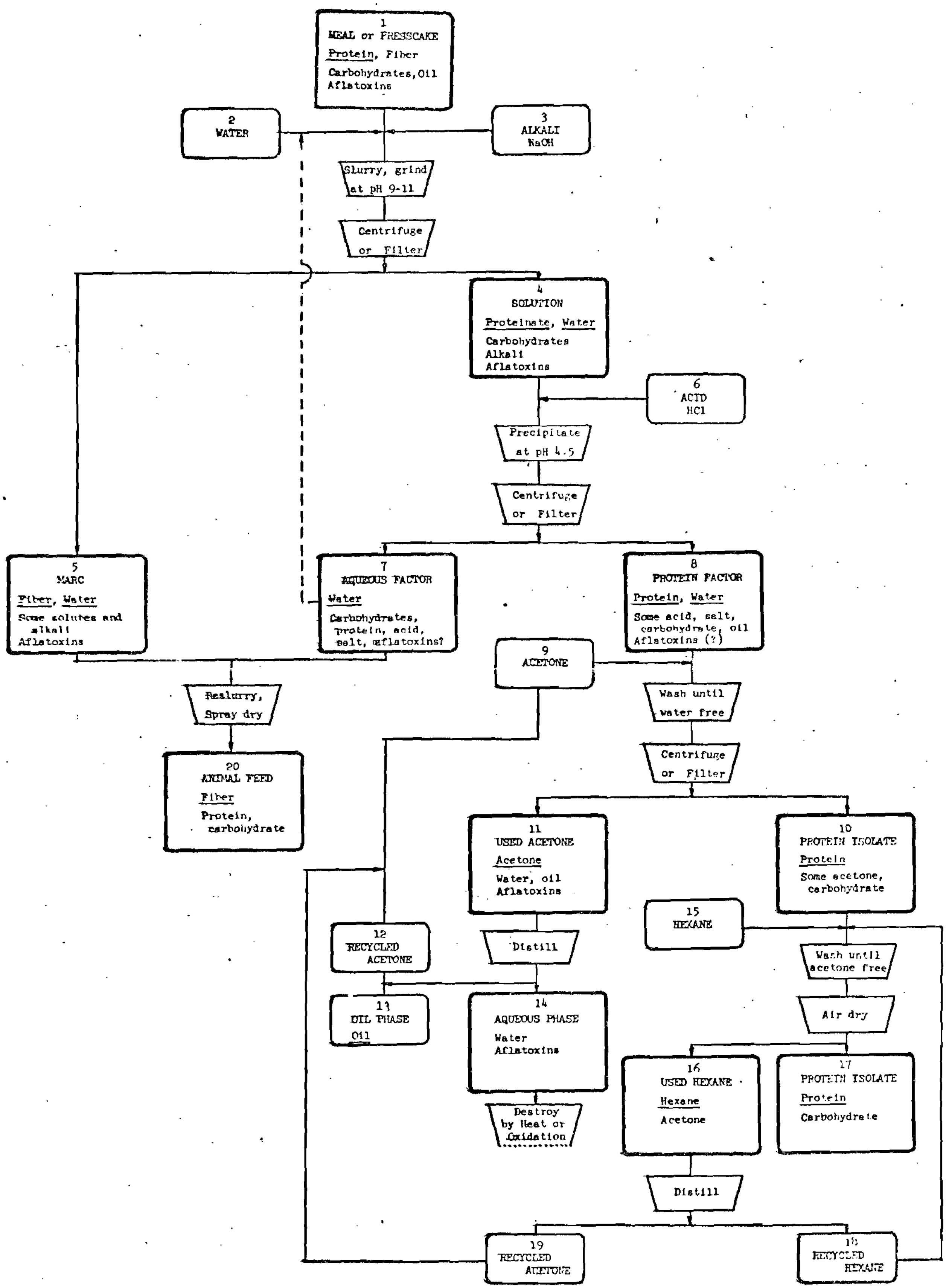


Figure 2. Flow Diagram of First Modification

3. Second Modification

The one drawback to the above modification lies in the fact that a relatively dilute slurry is formed by mixing the marc and the aqueous phase from a single extraction; consequently, the spray-drying operation involved the evaporation of considerable moisture to obtain a relatively small amount of solids. While there are means to offset the energy costs for this evaporation (e.g., utilization of waste heat from another industrial process, such as the peanut hull-charcoal process), it would be desirable to reduce the energy demand as much as possible through modification of the extraction procedure. Toward this end, we decided to recycle our process water, using it for three successive extractions, then reslurrying the fibrous residues from all three extractions in the one quantity of water. The resulting slurry was more concentrated, but still sufficiently fluid for effective spray drying.

At this point, we conducted a materials balance study to determine such factors as the composition of the slurry to be spray dried, the energy requirement of the spray-dry operation, the composition of the resulting animal feed material, and various other parameters of the three-cycle process. Results of this study are shown in Appendix III.

Of particular interest is the composition of the process water as it is recycled. Table II shows the composition of the aqueous factor at the point of recycling after cycles 1, 2 and 3. The protein, carbohydrate, water and oil are, by the third cycle, approaching constant levels, extrapolated to give the values shown in the final column. Salt continues to increase, due to the repeated additions of sodium hydroxide and hydrochloric acid. However, the total solute content is only slightly over 1% at that point, and, with salt being added at such a low level per cycle, the solute content would stay below any level requiring dumping for quite some time.

TABLE II

COMPOSITION OF AQUEOUS FACTOR IN FIRST THREE CYCLES

Component	Percentage Composition			
	First Cycle	Second Cycle	Third Cycle	Final Cycle
Protein	0.5974	0.7169	0.7354	0.740
Carbohydrate	0.1724	0.1975	0.2003	0.005
Oil	0.0653	0.0782	0.0802	0.806
Salt (sodium chloride)	0.0363	0.0756	0.1141	0.0363n*
Water	99.1286	98.9318	98.8700	**

*n = number of cycles

**water = 100% less sum of the above

On the strength of this development, we have made a second modification in the process. The process water is continually recycled, the protein isolate is precipitated as before, washed with acetone and hexane and air dried, and the marc instead of being reslurried and spray dried, is similarly dewatered with acetone, washed with hexane and dried. Thus, the more costly aspect of the first modification, spray drying, is eliminated; in its place is a larger use of acetone and hexane, requiring solvent recovery by distillation. Figure 3 shows the Engineering Experiment Station protein process in its second modification.

Two advantages accrue from this substitution. First, the quantity of water removed from the marc by acetone dewatering is considerably less than that which would have been evaporated in spray-drying the combined marc and aqueous factor, even from three cycles. Second, the heats of vaporization of acetone and hexane are considerably lower than that of water, requiring less heat energy for solvent recovery than for evaporation of water. At their boiling points, the heats of vaporization, in gram-calories per gram, are: acetone 124.5, hexanes 78.4 avg., and water 539.55.

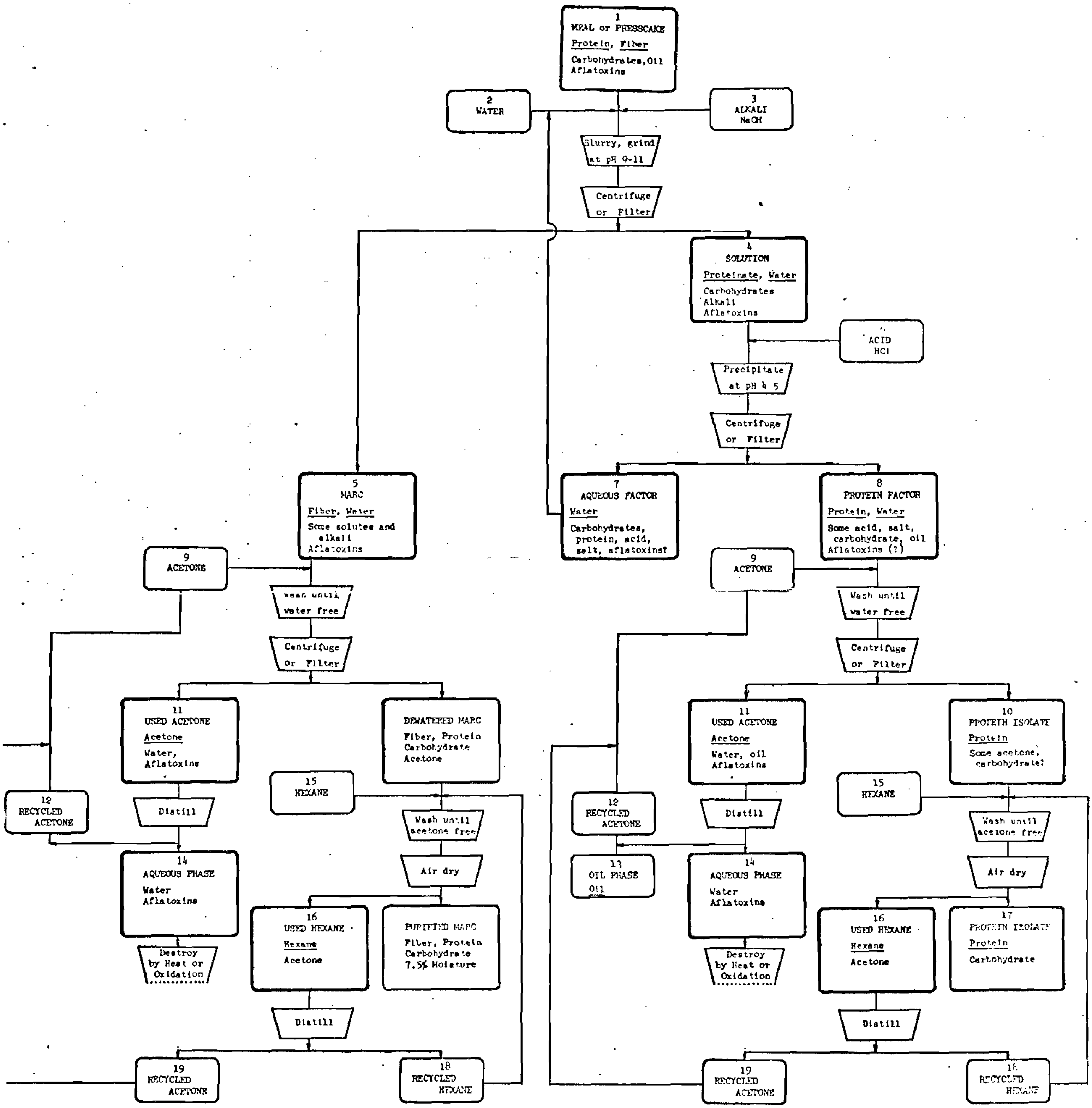


Figure 3. Flow Diagram of Second Modification

We have prepared samples of animal feed material by dewatering the marc separated from a single cycle, using the acetone and hexane washes. Appendix III shows the computed composition of this material in comparison with that obtained by spray drying the combined marc and aqueous factor from three cycles and with that obtained from the third cycle marc in continuous water reuse; in the first and last cases, acetone-hexane wash has eliminated the oil, which is present in the second because of the spray-drying operation.

ADVANTAGES OF THE MODIFIED ENGINEERING EXPERIMENT STATION PROCESS

1. Ecological Advantages

Developed during a period that gave little thought to the burden placed upon the air and water by waste products of its industries, the original Engineering Experiment Station protein process had the sole purpose of separating the protein and oil from seed; the process water, fibrous matter, etc., were considered to be of little or no value, and no plans were included for their recovery, reuse, or marketing. State water quality standards now preclude the discharge of effluent water with COD and BOD values such as those of our process water. Further, in September 1972 a Senate-House conference committee reported out a water pollution control bill tougher than that requested by the administration. This bill, if passed by both houses, will probably escape veto and will require all industries discharging wastes into the nation's waterways to use the "best practicable control technology" by July 1, 1977 and the "best available technology" by July 1, 1983.*

Both modifications of the original process, as described above, are directed toward elimination of aqueous discharge through utilization and/or recycling.

*Chemical Week, August 30, 1972, p.8; September 20, 1972, p. 23.

While these modifications have economic advantages, as pointed out below, in view of recent legislative action at both state and federal levels, it is our belief that these modifications represent more than a preferred alternative to the original process. They are necessary if the process is to be applied to peanut meal and presscake within the ecological restraints now being placed upon industry.

2. Economic Advantages

The modified Engineering Experiment Station protein process utilizes a raw material which is useful as an animal feed (if not restricted) or as fertilizer (if restricted). Its products are a purified peanut protein isolate, a purified peanut oil, and a fibrous residue containing residual nutrients, still suitable for use as an animal feed. The process water is recycled indefinitely, and the solvents are recovered for reuse by distillation. The raw material is substantially upgraded, and there are no waste products of volume sufficient to cause concern.

Whereas the first modification used spray drying as a technique for recovery of the nutrient values of the process water, the second modification provides a means for recovery of all nutrients in the products named above. The evaporation of large quantities of process water is eliminated; in its place is an increased amount of solvent use and solvent recovery, at much lower energy consumption. The importance of this from an energy consumption standpoint can hardly be overestimated. A recent article (Chemical Week, Sept. 27, 1972, p. 33) tells of efforts being made throughout the chemical industry to cut energy costs in the face of a nationwide energy crisis (see also Chemical Week, September 20, 1972, pp. 29-52). The modified Engineering Experiment

Station protein process is, therefore, at a stage of development which is in accord with both the economic and ecological restrictions currently being faced by the chemical process industries.

3. Patent Advantages

At the point of development of the first modification, a record of invention was filed with the Georgia Tech Research Institute, where it was turned over to patent attorneys for preliminary patent search. A similar procedure had been followed on the unmodified process, as applied to peanut meal and presscake, and at that time the attorney considered it unlikely that a patent might be obtained. It is now his opinion that the modification, offering a means of isolating additional nutrient materials from the marc and process water, afford a significant improvement over prior art and that an application for patent on the invention would be advisable. We have not as yet filed a record of invention on the second modification, but will proceed to do so. Having looked over the citations uncovered during these preliminary searches, it is our opinion that a good measure of patent protection can be obtained on the process as it now stands.

CONCLUSIONS AND RECOMMENDATIONS

It will be observed from the preceeding account that, while not all of the original objective has been realized, the process has been brought to a much more highly advanced state of development than was anticipated at the time our proposal was written and the contract signed. We have not completed the proposed cost analysis on the original process; however, to do so in the face of these developments would be to uselessly waste project funds. The original process would require the incurrence of heavy expenditures for installation and operation of waste treatment facilities, or equally expensive alternatives. These are unnecessary in the modified process, and it is this process with which we are concerned from the standpoint of cost analysis. To a degree, the same might be said for the first modification, since installation and operation of spray-dry equipment would represent costs well over those of the second modification process.

The following activities remain to be completed in order to establish the modified Engineering Experiment Station process as feasible from the standpoint of large laboratory-scale operation, ready for full-scale pilot plant operation:

1. A sufficient number of samples of protein isolate and fibrous animal feed material must be prepared to make a clear-cut case for this process as providing aflatoxin-free products. While some of these may be prepared from 1/2-pound batches of meal, the majority of extractions should be made with batches of at least 5 pounds. Samples must be prepared from (a) non-restricted expeller, (b) restricted expeller, (c) non-restricted solvent and (d) restricted solvent process meals. Aflatoxin assays must be run on the original meals as well as on the protein isolates and fibrous animal feed products.
2. Original materials and products must be analyzed as to protein content, and yields of each product must be obtained, together with other such data as are necessary to establish the materials balances.
3. A pilot plant, capable of handling larger quantities of meal (e.g., 1 to 10 tons per day) on a commercial production basis, must be designed from the standpoints of plant layout and equipment specifications. From the preceeding materials balances and related data, equipment sizes and

costs, operating costs, etc. must be estimated. These estimates should be sufficient to provide firm estimates of optimum pilot plant size, construction and operating costs of said optimum-size pilot plant, and an extrapolated estimate of costs for a full-scale commercial plant.

4. A patent application on the First Modification process must be prepared, in cooperation with a patent attorney. Selection of an attorney may be made by the Georgia Agricultural Commodity Commission for Peanuts; the Georgia Tech Research Institute will cooperate in the selection, if the Commission so desires.

5. A Record of Invention on the Second Modification process must be prepared and submitted for preliminary patent search. If the result of the search so indicates, a patent application must also be prepared for this process.

In view of the developments which have been made during the course of this study, and the additional activities that need to be conducted, we have requested that the Georgia Tech Research Institute apply to the Commission for a six-month extension in time on this project, and that funding for this extension be requested in the amount of $5,000. These funds would permit the needed activities to be pursued at the same rate of effort with which the initial work has been done. Allocation by categories would be in proportion to that of the initial grant; namely:

BUDGET ESTIMATE	Six Months
Direct Salaries and Wages	$2,870
Retirement: 7.75% of applicable D.S.& W.	120
Overhead, 57% of applicable D.S.& W.	1,635
Materials and Supplies	250
Travel	125
TOTAL ESTIMATED BUDGET, SIX MONTHS	$5,000

ADMINISTRATIVE PROCEDURES

The grant afforded by Georgia Agricultural Commodity Commission for Peanuts to the Engineering Experiment Station for this work was allocated on the basis of the following estimated needs:

Direct Salaries and Wages	$5;740
Retirement (7.65% of applicable direct salaries and wages)	240
Overhead (57% of applicable direct salaries and wages)	3,270
Materials and Supplies	500
Travel	250
Total Budget Estimate	$10,000

Montly expenditures under these categories have been as follows:

CATEGORY:	D.S.& W.	Ret.*	Overhead	M&S	Travel	Total
BUDGET:	$5,740.00	$240.00	$3,270.00	$500.00	$250.00	$10,000.00
January	475.80	- -	271.21	- -	- -	747.01
February	530.83	22.89	302.57	152.86	- -	1,009.15
March	515.32	20.35	293.73	56.12	- -	885.52
April	1,054.48	39.42	601.05	15.98	- -	1,710.93
May	1,098.24	79.75	626.00	115.41	- -	1,919.40
June	286.00	63.76	163.02	29.48	- -	542.26
July	781.01	21.88	445.18	18.62	- -	1,266.69
August	196.17	22.52	111.82	4.37	- -	334.88
September	267.92	- -	152.71	17.63	- -	438.26
Total Exp. to Date:	$5,205.77	$270.57	$2,967.29	$410.47	- -	$8,854.10
Anticipated Oct. Exp.	$366.67	$4.61	$209.67	- -	- -	$580.95
Anticipated Total Expended Through October 31, 1972						$9,435.05

*Retirement charges are posted each month on the basis of the preceeding month's direct salaries and wages.
In April the retirement rate was increased by the Board of Regents from 6.65% to 6.75%.

Respectfully submitted,

[redacted]

W. H. Burrows
Project Director

APPENDIX I

AMINO ACID PROFILE

(Note: This information is in process of development by Dr. Clyde Young, Georgia Agricultural Experiment Station. It will be forwarded as soon as received.)

APPENDIX II

ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

May 3, 1972

MEMORANDUM

TO: W. Herbert Burrows

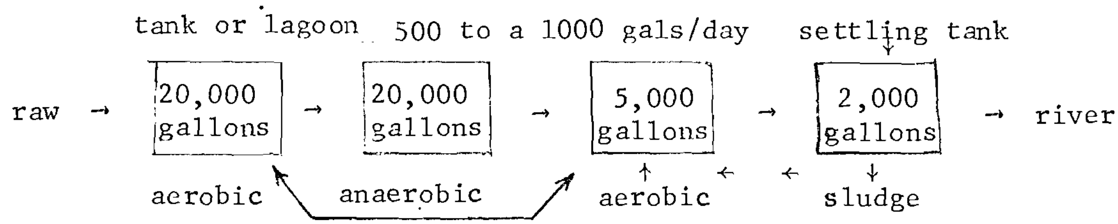
FROM: R. S. Ingols

SUBJECT: Waste Water from Peanut Processing -- Project A-1395

Enclosed is a table of data from the samples of waste process water from your laboratory after the production of protein from peanuts. The data for the analysis of the raw samples (as received by me) indicate that the waste water is extremely concentrated in comparison to domestic water (20 to 30 fold).

To add this waste to a sewer for treatment in a domestic waste water facility, the plant must have a capacity for the increment of volume of the process water and for the increase in BOD. Thus, if 10,000 gals per day of process water is anticipated, this volume is equivalent to an increase of 100 people, but there is also an increase in BOD of 2000 people. This is a common technique for expressing wastewater strength. I would strongly recommend the discharge of this waste water into a city sewer system where it is capable of accepting it, because dilution would be provided and no problems in treatment should be experienced.

Where an isolated production facility will be used, separate treatment of the wastewater will also be required. Separate treatment of the waste water will require an aeration basin of at least 5 days detention. On the basis of 10,000 gals per day raw wastewater, a 50,000 gallon aeration basin should be provided. For disposal into a very small stream or a large stream of very high quality requirements, it may be necessary to aerate for 2 days, allow anaerobic activity for two days, and then polish the second stage effluent with another aeration basin with a settling tank and return sludge.



The return from the third stage to the first would prevent a buildup of bacteria that had to be disposed of on land from the third stage, and provide for a continuous seed for the first stage.

RSI:lsg
Enclosure

APPENDIX III

MATERIALS BALANCE VALUES, 3-CYCLE PROCESS

The following values are computed from data accumulated on batches of five pounds of meal and represent the number of pounds of each component required or produced for a 3-cycle run utilizing a batch feed of one ton (2000 lbs) per cycle.

Numbers in parentheses refer to the numbers of items in Figures 1, 2 and 3.

1. Batch Feed: 2000 lb. per cycle

Component	Each Cycle	Total, 3 Cycles
Protein	1100 lb	3300 lb
Fiber	100 lb	300 lb
Other carbohydrates	560 lb	1680 lb
Oil	120 lb	360 lb
Moisture	120 lb	360 lb

2. Process Water

First cycle	40,000 lb)	
Second cycle	7,820 lb)--Total 56,959 lb	
Third cycle	9,138 lb)	

3. 10% Sodium Hydroxide Solution

Component	Each Cycle	Total, 3 Cycles
NaOH	48.5 lb	145.5 lb
Water	438 lb	1314 lb

4. Solution

Component	First Cycle	Second Cycle	Third Cycle
Protein	970 lb	1,118.6 lb	1,141.2 lb
Carbohydrate (est)	280 lb	308 lb	310.8 lb
Oil (emulsion)	106 lb	122.1 lb	124.5 lb
NaOH	40.2 lb	40.2 lb	40.2 lb
Water	35,767 lb	35,061 lb	34,965 lb

5. Marc (@ 10% solids)

Fiber	100 lb	100 lb	100 lb
Other carbohydrate	280 lb	308 lb	310.8 lb
Protein	130 lb	175.4 lb	182.4 lb
Oil	14 lb	19.14 lb	19.9 lb
NaOH	8.3 lb	8.3 lb	8.3 lb
Water	4,791 lb	5,497 lb	5,593.5 lb

6. Hydrochloric Acid (3.7% ~10% by volume or conc. HCl in water)

Component	Each Cycle	Total, 3 Cycles
HCl	36.7 lb	110.1 lb
Water	952 lb	2,856 lb

7. Aqueous Factor

Component	First Cycle	Second Cycle	Third Cycle
Protein	194 lb	223.7 lb	228.24 lb
Carbohydrate	56 lb	61.6 lb	62.16 lb
Oil	21.2 lb	24.4 lb	24.9 lb
Salt (NaCl)	11.8 lb	23.6 lb	35.4 lb
Water	32,192 lb	31,202 lb	30,685

8. Protein Factor (@ 20% solids)

Component	First Cycle	Second Cycle	Third Cycle
Protein	776 lb	894.9 lb	912.96 lb
Carbohydrate	224 lb	246.4 lb	248.64 lb
Oil	84.8 lb	97.7 lb	99.6 lb
Salt (NaCl)	47 lb	47 lb	47 lb
Water	4,527 lb	5,144 lb	5,232 lb

20. Animal Feed (3-Cycle Process)

Component	Marc (5) 3 cycles	Aq. Fact. 3rd Cycle	Slurry	Dried to 7.5% Mositure	
Protein	487.9 lb	228.2 lb	716.1 lb	716.1 lb	31.5%
Fiber	300 lb	-	300 lb	300 lb	13.2%
Carbohydrate	898.8 lb	62.2 lb	961 lb	961 lb	42.3%
Oil	53.0 lb	24.9 lb	77.9 lb	77.9 lb	3.4%
Salt	36.6 lb	11.8 lb	48.4 lb	48.4 lb	2.1%
Water	15,882	30,685 lb	46,567	170.5 lb	7.5%

20. Animal Feed (Continuous Recycle Process)

Component	Marc (per cycle)	Marc, Dried to 7.5% Moisture	
Protein	130 lb	130 lb	22.5%
Fiber	100 lb	100 lb	17.4%
Carbohydrate	280 lb	280 lb	48.4%
Oil	14 lb	14 lb	2.4%
Salt (by neutralization)	11 lb	11 lb	1.9%
Water	4,791 lb	43.4 lb	7.5%

COST ANALYSIS OF THE EXTRACTION OF PROTEIN FROM PEANUT MEAL AND PRESSCAKE

Project Director
W. H. Burrows

Project A-1395
Final Technical Report
January 1, 1972-December 31, 1972

to

GEORGIA AGRICULTURAL COMMODITY COMMISSION
FOR PEANUTS
Tifton, Georgia

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology

December, 1972

TITLE

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(3) Centrifuging to remove soluble residues

(4) Addition of hydrochloric acid or sulfur dioxide to pH 4.5 (the isoelectric point of the protein) to precipitate the protein from solution

(5) Filtering or centrifuging to separate the protein from the mother liquor

(6) Washing with water adjusted to pH 4.5

(7) Washing with acetone until water-free

(8) Washing with hexane until acetone-free

(9) Air drying

A flow diagram of this process is shown in Figure 1.

A cyclic process, involving counter-action of solids and solvents, had been devised and tested, with favorable results. In that process, the residue from (3) was extracted with fresh sodium hydroxide solution, with was then used to extract a second residue from (3) before being used for extraction of fresh meal. The effect of the repeated extraction was to provide a high overall meal-to-water ratio.

The high yields obtained in our process are attributed to the combined effects of the cyclic process and the comparatively high pH of extraction. The latter was found necessary in order to overcome the partial denaturation occurring during the oilmill operation.

PART I. EXPERIMENTAL PROCEDURES AND RESULTS

1. Equipment and Procedure, Original Process

Samples of both restricted and unrestricted meal, from both expeller and solvent mills, were provided by Goldkist Research Laboratory, Graceville, Florida and by the U.S.D.A. Peanut Quality Laboratory, Dawson, Georgia.

Size reduction was accomplished by slurrying the meal in water and passing through the Morehouse Mill (Model 81402). Sodium hydroxide solution was added to the resulting suspension, and the mix was stirred for 15-30 minutes in a stainless steel processor. Insoluble residues were removed in a Fletcher Model 6863 centrifuge. Protein was precipitated from the centrifugate and separated from the liquor by either filtration or centrifugation. Initially, a Sparkler centrifuge, loaned by Dover Chemical Company, was used; however, this proved unsatisfactory for the purpose, and later work was done with a large Büchner funnel operated by reduced pressure. For some experiments, a cup type centrifuge or the Fletcher centrifuge was used, except for the acetone and hexane washes.

Acetone and hexane washes were conducted in preserving kettles, wherein the wet protein was dispersed in the solvent by stirring. The protein isolate was separated from solvent by vacuum filtration and air dried, or, if necessary, dried in a forced draft oven at 50°C.

Several batches of 10 pounds of meal were extracted; however, when the Sparkler filter proved inadequate for filtering the isolate, the batch size was reduced to 5 pounds. Records were kept on the source of meal, the quantities of all materials used, and the yields obtained. All variations in procedure were recorded, with results. It was found that a technician, working approximately 40 percent, could make two extractions per week, including solvent wash and drying.

Yields of 70 percent, average, were obtained. The protein isolate was a fine, off-white powder, soluble in water at pH 7. When completely dried of its solvent wash, the isolate was odorless and tasteless; apparently, the hexane wash is sufficient to remove objectionable tastes sometimes left by acetone on protein isolates. Aflatoxin assays on original meals were 8 to 40 ppb total; on the isolate, 0. Amino acid profile is shown in Appendix I.

2. First Modification

A study was made of the aqueous effluent generated by the process. Table I shows the chemical oxygen demand (COD) and biological oxygen demand (BOD) of this effluent from runs dated as indicated. Also shown are the values of COD and BOD after periods of aeration. These data indicate that the effluent is extremely concentrated in comparison to domestic waste water, by 20 to 30 fold. Appendix II is a memorandum on the treatment needed for a 10,000 gallon daily discharge of this effluent. One is faced with the dilemma of locating the plant within the sewer service area of a city, where its discharge would be sufficiently diluted that no special treatment would be required at the disposal plant, or of providing a waste treatment facility of sufficient capacity at the plant site. Either course would be costly since the city would doubtless affix a charge based upon the COD, BOD and volume of the effluent.

Examination of the effluent composition shows the cause of the high COD and BOD values to be due primarily to dissolved proteins, polypeptids and carbohydrates. The source of the problem is thus nutrient materials in a form too dilute to warrant recovery by ordinary means, but too concentrated for easy

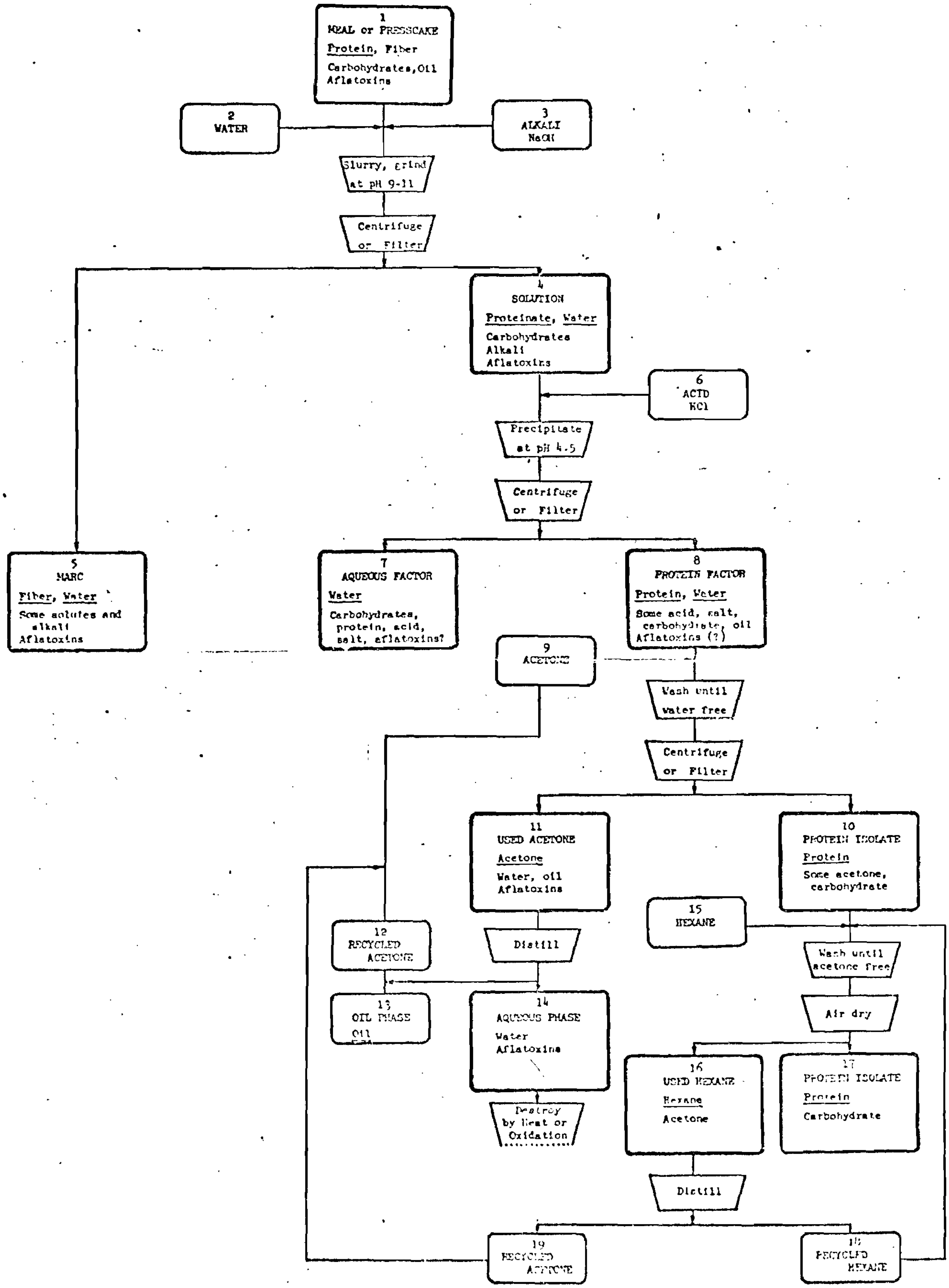

Figure 1. Flow Diagram of Original Process

TABLE I

WASTE WATER CHARACTERISTICS

Date	Raw		Treated		
	COD	BOD	Time of Aeration	COD	BOD
	g/ℓ	g/ℓ	Days	g/ℓ	g/ℓ
March 21	8.0	4.2	2	2.6	1.8
			3	0.33	0.25
March 28	5.5	3.3	2	2.9	--
			8(dispersion)	0.8	0.2
April 7	7.2	4.0	5		--
April 13	7.4	--	7	0.83	--

disposal. A second waste material of the process is the fibrous residue (marc) from the first centrifugation, which we considered drying, pulverizing and utilizing for fertilizer. This material also contains a portion of the soluble organic from the dissolution of the meal, and these solubles represent additional nutrient values.

Rather than waste the nutrient values of these two materials, while simultaneously creating disposal problems, we combined the two by reslurrying the marc in the aqueous effluent. The slurry was spray-dried, producing a light, fluffy material of deep beige color and pleasant fragrance. Judging from its nutrient content and the fact that it showed 0 to "trace" aflatoxin content, this material was considered to be an excellent candidate for animal feed. Figure 2 shows a flow diagram for the first modification of the Engineering Experiment Station protein process.

The addition of the marc, which has been separated at pH 11, to the aqueous phase, from which protein isolate has been precipitated at pH 4.5, produces a neutral, or nearly neutral mixture. Any slight variation from pH 7 can be

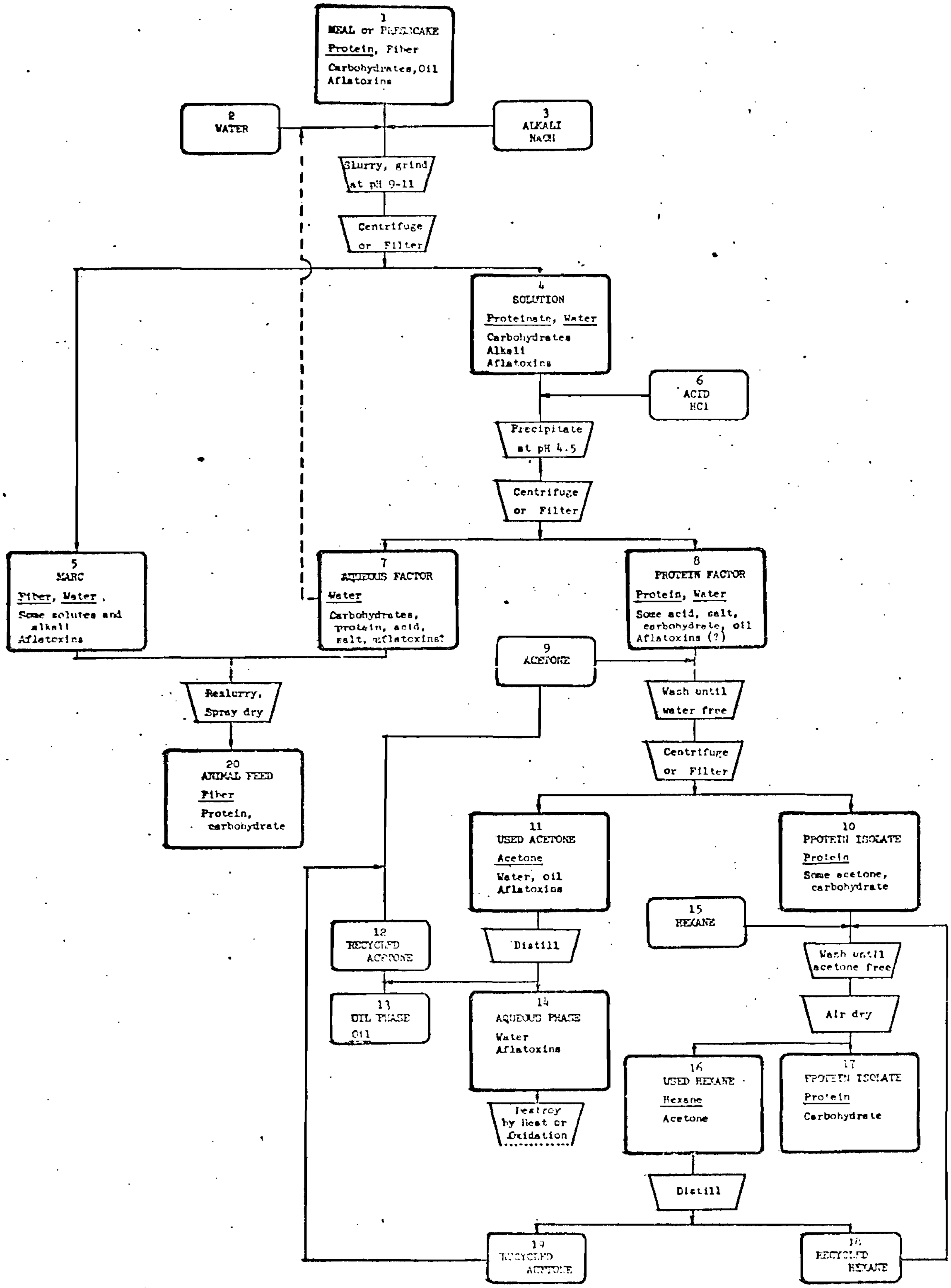

Figure 2. Flow Diagram of First Modification

titrated with sodium hydroxide or hydrochloric acid solution. The slurry entering the spray drier is, therefore, neutral and upon evaporation of water leaves a residue containing sodium chloride (common salt) as its principal electrolyte. This, again, is favorable for its use as an animal feed material.

3. Second Modification

The one drawback to the above modification lies in the fact that a relatively dilute slurry is formed by mixing the marc and the aqueous phase from a single extraction; consequently, the spray-drying operation involved the evaporation of considerable moisture to obtain a relatively small amount of solids. While there are means to offset the energy costs for this evaporation (e.g., utilization of waste heat from another industrial process, such as the peanut hull-charcoal process), it would be desirable to reduce the energy demand as much as possible through modification of the extraction procedure. Toward this end, we decided to recycle our process water, using it for three successive extractions, then reslurrying the fibrous residues from all three extractions in the one quantity of water. The resulting slurry was more concentrated, but still sufficiently fluid for the effective spray drying.

At this point, we conducted a materials balance study to determine such factors as the composition of the slurry to be spray dried, the energy requirement of the spray-dry operation, the composition of the resulting animal feed material, and various other parameters of the three-cycle process. Results of this study are shown in Appendix III.

Of particular interest is the composition of the process water as it is recycled. Table II shows the composition of the aqueous factor at the point of recycling after cycles 1, 2 and 3. The protein, carbohydrate, water and oil are, by the third cycle, approaching constant levels, extrapolated to give the

TABLE II

COMPOSITION OF AQUEOUS FACTOR IN FIRST THREE CYCLES

Component	Percentage Composition			
	First Cycle	Second Cycle	Third Cycle	Final Cycle
Protein	0.5974	0.7169	0.7354	0.740
Carbohydrate	0.1724	0.1975	0.2003	0.005
Oil	0.0653	0.0782	0.0802	0.806
Salt (sodium chloride)	0.0363	0.0756	0.1141	0.0363n*
Water	99.1286	98.9318	98.8700	**

*n = number of cycles

**water = 100% less sum of the above

values shown in the final column. Salt continues to increase, due to the repeated additions of sodium hydroxide and hydrochloric acid. However, the total solute content is only slightly over 1% at that point, and, with salt being added at such a low level per cycle, the solute content would stay below any level requiring dumping for quite some time.

On the strength of this development, we have made a second modification in the process. The process water is continually recycled, the protein isolate is precipitated as before, washed with acetone and hexane and air dried, and the marc instead of being reslurried and spray dried, is similarly dewatered with acetone, washed with hexane and dried. Thus, the more costly aspect of the first modification, spray drying, is eliminated; in its place is a larger use of acetone and hexane, requiring solvent recovery by distillation. Figure 3 shows the Engineering Experiment Station protein process in its second modification.

Two advantages accrue from this substitution. First, the quantity of water removed from the marc by acetone dewatering is considerably less than that which

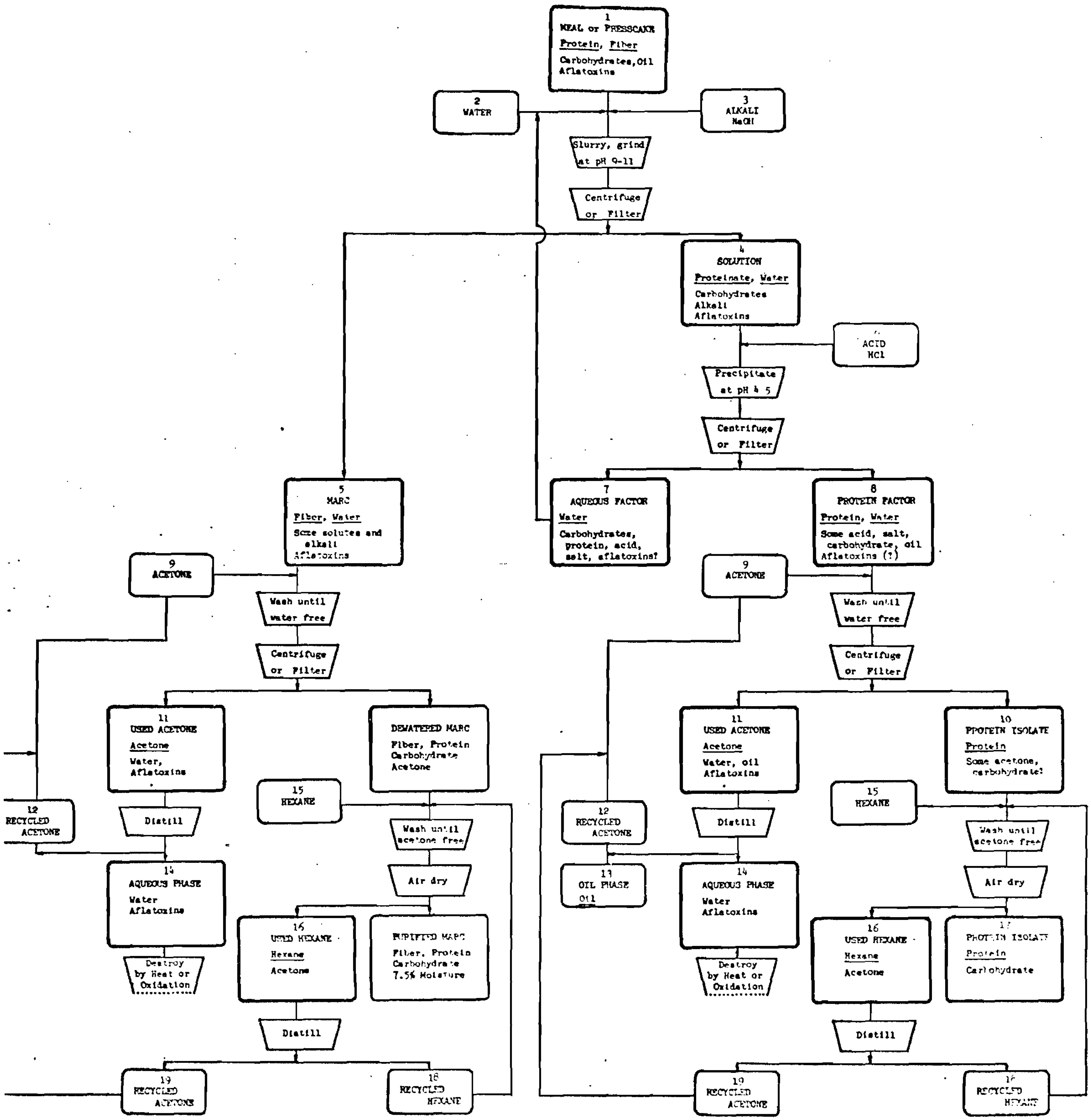

Figure 3. Flow Diagram of Second Modification

would have been evaporated in spray-drying the combined marc and aqueous factor, even from three cycles. Second, the heats of vaporization of acetone and hexane are considerably lower than that of water, requiring less heat energy for solvent recovery than for evaporation of water. At their boiling points, the heats of vaporization, in gram-calories per gram, are: acetone 124.5, hexanes 78.4 avg., and water 539.55.

We have prepared samples of animal feed material by dewatering the marc separated from a single cycle, using the acetone and hexane washes. Appendix III shows the computed composition of this material in comparison with that obtained by spray drying the combined marc and aqueous factor from three cycles and with that obtained from the third cycle marc in continuous water reuse; in the first and last cases, acetone-hexane wash has eliminated the oil, which is present in the second because of the spray-drying operation.

ADVANTAGES OF THE MODIFIED ENGINEERING EXPERIMENT STATION PROCESS

1. Ecological Advantages

Developed during a period that gave little thought to the burden placed upon the air and water by waste products of its industries, the original Engineering Experiment Station protein process had the sole purpose of separating the protein and oil from seed; the process water, fibrous matter, etc., were considered to be of little or no value, and no plans were included for their recovery, reuse, or marketing. State water quality standards now preclude the discharge of effluent water with COD and BOD values such as those of our process water. Further, in September 1972 a Senate-House conference committee reported out a water pollution control bill tougher than that requested by the administration. This bill, if passed by both houses, will probably escape veto and will require all industries discharging wastes into the nation's waterways to use the "best practicable control technology" by July 1, 1977 and the "best available technology" by July 1, 1983.*

Both modifications of the original process, as described above, are directed toward elimination of aqueous discharge through utilization and/or recycling. While these modifications have economic advantages, as pointed out below, in view of of recent legislative action at both state and federal levels, it is our belief that these modifications represent more than a preferred alternative to the original process. They are necessary if the process is to be applied to peanut meal and presscake within the ecological restraints now being placed upon industry.

2. Economic Advantages

The modified Engineering Experiment Station protein process utilizes a raw material which is useful as an animal feed (if not restricted) or as fertilizer (if restricted). Its products are a purified peanut protein isolate, a purified peanut oil, and a fibrous residue containing residual nutrients, still suitable for use as an animal feed. The process water is recycled indefinitely, and the solvents are recovered for reuse by distillation. The raw material is substantially upgraded, and there are no waste products of volume sufficient to cause concern.

Whereas the first modification used spray drying as a technique for recovery of the nutrient values of the process water, the second modification provides a means for recovery of all nutrients in the products named above. The evaporation of large quantities of process water is eliminated; in its place is an increased amount of solvent use and solvent recovery, at much lower energy consumption. The importance of this from an energy consumption standpoint can

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*Chemical Week, August 30, 1972, p. 8; September 20, 1972, p. 23.

hardly be overestimated. A recent article (Chemical Week, Sept. 27, 1972, p. 33) tells of efforts being made throughout the chemical industry to cut energy costs in the face of a nationwide energy crisis (see also Chemical Week, September 20, 1972, pp. 29-52). The modified Engineering Experiment Station protein process is, therefore, at a stage of development which is in accord with both the economic and ecological restrictions currently being faced by the chemical process industries.

PATENT ADVANTAGES

At the point of development of the first modification, a record of invention was filed with the Georgia Tech Research Institute, where it was turned over to patent attorneys for preliminary patent search. A similar procedure had been followed on the unmodified process, as applied to peanut meal and presscake, and at that time the attorney considered it unlikely that a patent might be obtained. It is now the attorney's opinion that the modification, offering a means of isolating additional nutrient materials from the marc and process water, afford a significant improvement over prior art and that an application for patent on the invention would be advisable. We have not as yet filed a record of invention on the second modification, but will proceed to do so. Having looked over the citations uncovered during these preliminary searches, it is our opinion that a good measure of patent protection can be obtained on the process as it now stands.

PART II

COSTS OF CONSTRUCTION AND OPERATION OF ONE TON PER HOUR PLANT

Plant Design

A tentative plant design has been prepared, consisting of the following units:

1. Weighing hopper, with loader, to weigh out 500-pound quantities of raw material on a 15-minute cycle and discharge them into a mixer-mill.
2. Mixer-mill, composed of a continuous-stream mixer and micropulverizer, to mix and grind the meal with the necessary quantity of water and discharge it into one of two mixing tanks, with the necessary quantity of sodium hydroxide.
3. Mixing tanks, two, each 1500 gallons, with agitators. One will mix while the other is emptying, then refilling. They will alternate on 15-minute cycles.
4. Continuous centrifuge-dewaterer, which will be fed alternately by the two mixing tanks, separating the marc from the protein solution. This item will operate without interruption.
5. Centrifugal pump to forward solution to precipitation tanks.
6. Precipitation tanks, two, each 1500 gallons, with agitators. Hydrochloric acid is added, under pH control, during this mixing to precipitate the protein. These are filled, operated, and emptied alternately, as in step 3.
7. Continuous centrifuge, clarifier, which will be fed alternately by the two precipitation tanks, separating the protein from the mother liquor. This

item will operate without interruption.

8. Centrifugal pump to forward mother liquor to surge tank.

9. Centrifugal pump to return mother liquor to mixer-mill.

10. Centrifugal filters, two, to remove water from protein, followed by acetone washes (5) and hexane washes (5).

11. Drier, slow draft, warm air, with fume scrubber and air return (closed cycle) to remove traces of hexane from the product protein.

12. Drier, forced draft, to dry fibrous residue (animal feed material), with grinder.

13. Solvent recovery units for acetone and hexane.

14. Product handling and packaging equipment.

All operations are integrated and controlled by a master time sequence control unit, together with such additional controls (pH, temperature, etc.) as are needed for individual processes. Integration of processes is complete; equipment idle time is reduced to a minimum.

This equipment will start a 500-pound batch of meal through each 15 minutes. Each batch will require approximately 90 minutes for completion. On this basis, the cost analysis has assumed the processing of seven tons of meal per day, (151.7 tons per average month) allowing needed time for start-up and close-down of each operation. Utilities are calculated on the basis of a full eight-hour day.

Plant Costs

A summary of plant operating costs, on a monthly basis, is shown in Table I, Appendix IV. The raw material used for this summary is solvent process meal, unrestricted, at the current price of $135 per ton. Substitution of restricted for unrestricted meal would reduce the raw materials cost from $20,480 to $16,687 per month.

Costs of utilities are based upon single-plant use. Integration of this plant with an oil plant would enable the enterprise to realize economies in utility costs, especially in greater use of steam for heat, in solvent recovery costs, labor administrative costs, and building and depreciation expenses.

Estimates of labor and supervision include 0.2 EFT (equivalent full time) for manager and 0.5 EFT for machine and control supervisor. A plant this size would not require a full-time person at either position; hence, these fractional values permit projection to a larger plant or integration of this operation with that of a related plant, such as an oil mill.

In anticipation of such integration, cost estimates have not been included for such items as certification and quality control testing; undoubtedly, some overall plant costs would be prorated to these items. There may also be some allocation of additional general and administrative costs (corporate, purchasing, liability insurance, general maintenance and janitorial, security, etc.), dependent upon parent operation.

Building and Equipment Costs

Table II, Appendix IV, shows an estimate of building and equipment costs, together with pertinent data for the summary statement.

The building size (10,600 square feet) would be adequate for the location of the above described machinery, with related piping, services, etc., access areas, storage areas, etc. A one-acre plot of ground would provide access to transportation, and limited parking for employees.

No estimate has been included for architectural and engineering services for building design and equipment layout.

Sales and Profits

Anticipated sales and profits for an operation based upon the rate of seven tons of raw material per hour (solvent process, unrestricted) is shown in Table III, Appendix IV.

Were the plant to operate on restricted, rather than unrestricted meal, the raw materials costs would be reduced, reflecting a variable cost of $294,000, as against $340,000 shown in the table. Resulting net income would be $156,000, representing 30 percent return on fixed investment, or 25 percent return on total capital investment.

PART III. CONCLUSIONS AND RECOMMENDATIONS

It will be observed from the preceding account that all of the original objective has been realized and that, in addition, the process has been brought to a much more highly advanced state of development than was anticipated at the time our proposal was written and the contract signed. The cost analysis shows a very favorable return on investment, reflecting a payout period of 4 to 5 years. By contrast, the original process would have required the incurrence of heavy expenditures for installation and operation of waste treatment facilities, or equally expensive alternatives. These are unnecessary in the modified process, and it is this process with which we are concerned from the standpoint of cost analysis. To a degree, the same might be said for the first modification, since installation and operation of spray-dry equipment would represent costs well over those of the second modification process.

The following activities remain to be completed in order to establish the modified Engineering Experiment Station process as feasible from the standpoint of large laboratory-scale operation, ready for full-scale pilot plant operation:

1. A sufficient number of samples of protein isolate and fibrous animal feed material must be prepared to make a clear-cut case for this process as providing aflatoxin-free products. While some of these may be prepared from 1/2-pound batches of meal, the majority of extractions should be made with batches of at least 5 pounds. Samples must be prepared from (a) non-restricted expeller, (b) restricted expeller, (c) non-restricted solvent and (d) restricted solvent process meals. Aflatoxin assays must be run on the original meals as well as on the protein isolates and fibrous animal feed products.
2. Original materials and products must be analyzed as to protein content, and

yields of each product must be obtained, together with other such data as are necessary to establish the materials balances.

3. A pilot plant, capable of handling larger quantities of meal (e.g., 1 to 10 tons per day) on a commercial production basis, must be designed from the standpoints of plant layout and equipment specifications. From the preceding materials balances and related data, equipment sizes and costs, operating costs, etc. must be estimated. These estimates should be sufficient to provide firm estimates of optimum pilot plant size, construction and operating costs of said optimum-size pilot plant, and an extrapolated estimate of costs for a full-scale commercial plant.
4. A patent application on the First Modification process must be prepared, in cooperation with a patent attorney.
5. A Record of Invention on the Second Modification process must be prepared and submitted for preliminary patent search. If the result of the search so indicates, a patent application must also be prepared for this process.

In view of the developments which have been made during the course of this study, and the additional activities that need to be conducted, we have requested that the Georgia Tech Research Institute apply to the Commission for a six-month extension in time on this project, and that funding for this extension be requested in the amount of $5,000. These funds would permit the needed activities to be pursued at the same rate of effort with which the initial work has been done. Allocation by categories would be in proportion to that of the initial grant, except that the current overhead rate is 65%, and the retirement deposit 7.75%, of applicable personal services, as opposed to the 57% and 7.65% which were in effect when the first grant was made. These allocations would be:

BUDGET ESTIMATE	Six Months
Direct Salaries and Wages	$2,737
Retirement: 7.75% of applicable D.S.& W.	109
Overhead, 65% of applicable D.S. & W.	1,779
Materials and Supplies	250
Travel	125
TOTAL ESTIMATED BUDGET, SIX MONTHS	$5,000

ADMINISTRATIVE PROCEDURES

The grant afforded by Georgia Agricultural Commodity Commission for Peanuts to the Engineering Experiment Station for this work was allocated on the basis of the following estimated needs:

Direct Salaries and Wages	$5,740
Retirement (7.65% of applicable direct salaries and wages)	240
Overhead (57% of applicable direct salaries and wages)	3,270
Materials and Supplies	500
Travel	250
Total Budget Estimate	$10,000

Monthly expenditures under these categories have been as follows:

CATEGORY:	D.S.& W.	Ret.*	Overhead	M&S	Travel	Total
BUDGET:	$5,740.00	$240.00	$3,270.00	$500.00	$250.00	$10,000.00
January	475.80	--	271.21	--	--	747.01
February	530.83	22.89	302.57	152.86	--	1,009.15
March	515.32	20.35	293.73	56.12	--	885.52
April	1,054.48	39.42	601.05	15.98	--	1,710.93
May	1,098.24	79.75	626.00	115.41	--	1,919.40
June	286.00	63.76	163.02	29.48	--	542.26
July	781.01	21.88	445.18	18.62	--	1,266.69
August	196.17	22.52	111.82	4.37	--	334.88
September	267.92	--	152.71	17.63	--	438.26

(cont'd)

CATEGORY:	D.S.& W.	Ret.*	Overhead	M&S	Travel	Total
October	421.86	5.56	240.46	15.84	16.30	700.02
November	278.76	2.29	158.89	5.94	--	445.88
Total Expended to date	$5,906.39	$278.42	$3,366.64	$432.25	$16.30	$10,000.00

*Retirement charges are posted each month on the basis of the preceding month's direct salaries and wages.
In April the retirement rate was increased by the Board of Regents from 6.65% to 6.75%.

ACKNOWLEDGEMENTS

The Engineering Experiment Station wishes to express its appreciation to the following for their support of and participation in this project:

The Georgia Commodity Commission for Peanuts, which supplied a grant in the amount of $10,000 to support this work.

Mr. Ronnie Balkcom, Food Technologist and Agronomist with the Peanut Commission for his invaluable advice and cooperation in many aspects of the research.

Dr. Charles Holaday and the U.S.D.A. Peanut Quality Laboratory, Dawson, Georgia, for cooperation in supplying samples of raw materials, conducting aflatoxin assays on raw materials and products and providing background information on peanut quality and analytical procedures.

Dr. Lewis Branscomb and the Goldkist Laboratories, Graceville, Florida, for providing samples of raw materials and helpful advice.

Dr. Clyde Young and the Georgia Experiment Station, Griffin, Georgia, for conducting protein quality analyses and amino acid profiles.

Respectfully submitted,

[redacted]

W. H. Burrows
Project Director

APPENDIX I[1]

AMINO ACID PROFILE
Sample #115

Amino Acid		Presscake	Protein	Ratio	AA Change in Isolate
1.	Aspartic Acid	8.67	9.46	2.11	Increase
2.	Threonine*	2.09	1.49	1.38	Decrease
3.	Serine	3.33	3.36	1.95	
4.	Glutamic Acid	17.18	19.02	2.14	Increase
5.	Proline	1.62	1.46	1.75	
6.	Glycine	4.37	5.39	2.38	Increase
7.	Alanine	2.50	2.89	2.23	Increase
8.	Valine*	3.24	3.73	2.23	Increase
9.	1/2 Cystine*	1.19	0.76	1.23 }	Decrease
10.	Methionine*	0.47	0.60	2.48 }	
**11.	Isoleucine*	10.55?	9.20?	1.68	
12.	Leucine*	2.76	1.90	1.33	Decrease
13.	Norleucine	--	--		
14.	Tyrosine*	2.35	3.30	2.71	Increase
15.	Phenylalanine*	4.42	4.89	2.14	Increase
17.	Lysine*	3.12	2.26	1.40	Decrease
18.	Histidine	1.75	1.98	2.18	Increase
19.	Arginine	12.78	12.32	1.86	
	Ammonia	3.07	2.83	1.78	
	Total Protein (factor 5.48)	42.8%	82.7%	1.94 av.	
	Total Protein (factor 6.25)	48.8%	94.3%		

*Essential amino acids (tryptophane not determined)

**Too high and highly variable

(1)Data supplied by Dr. Clyde Young, Georgia Experiment Station.

APPENDIX II

EXPERIMENT STATION 225 North Avenue, Northwest · Atlanta, Georgia 30332

May 3, 1972

MEMORANDUM

TO: W. Herbert Burrows

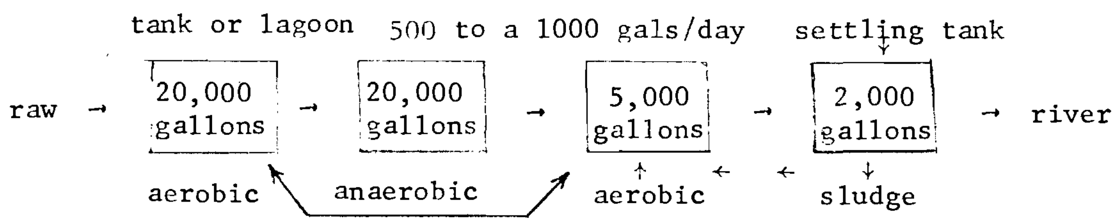
FROM: R. S. Ingols

SUBJECT: Waste Water from Peanut Processing -- Project A-1395

Enclosed is a table of data from the samples of waste process water from your laboratory after the production of protein from peanuts. The data for the analysis of the raw samples (as received by me) indicate that the waste water is extremely concentrated in comparison to domestic water (20 to 30 fold).

To add this waste to a sewer for treatment in a domestic waste water facility, the plant must have a capacity for the increment of volume of the process water and for the increase in BOD. Thus, if 10,000 gals per day of process water is anticipated, this volume is equivalent to an increase of 100 people, but there is also an increase in BOD of 2000 people. This is a common technique for expressing wastewater strength. I would strongly recommend the discharge of this waste water into a city sewer system where it is capable of accepting it, because dilution would be provided and no problems in treatment should be experienced.

Where an isolated production facility will be used, separate treatment of the wastewater will also be required. Separate treatment of the waste water will require an aeration basin of at least 5 days detention. On the basis of 10,000 gals per day raw wastewater, a 50,000 gallon aeration basin should be provided. For disposal into a very small stream or a large stream of very high quality requirements, it may be necessary to aerate for 2 days, allow anaerobic activity for two days, and then polish the second stage effluent with another aeration basin with a settling tank and return sludge.



The return from the third stage to the first would prevent a buildup of bacteria that had to be disposed of on land from the third stage, and provide for a continuous seed for the first stage.

RSI:lsg
Enclosure

APPENDIX III

MATERIALS BALANCE VALUES, 3-CYCLE PROCESS

The following values are computed from data accumulated on batches of five pounds of meal and represent the number of pounds of each component required or produced for a 3-cycle run utilizing a batch feed of one ton (2000 lbs) per cycle.

Numbers in parentheses refer to the numbers of items in Figures 1, 2 and 3.

1. Batch Feed: 2000 lb. per cycle

Component	Each Cycle	Total, 3 Cycles
Protein	1100 lb	3300 lb
Fiber	100 lb	300 lb
Other carbohydrates	560 lb	1680 lb
Oil	120 lb	360 lb
Moisture	120 lb	360 lb

2. Process Water

First cycle	40,000 lb)	
Second cycle	7,820 lb)	--Total 56,959 lb
Third cycle	9,138 lb)	

3. 10% Sodium Hydroxide Solution

Component	Each Cycle	Total, 3 Cycles
NaOH	48.5 lb	145.5 lb
Water	438 lb	1314 lb

4. Solution

Component	First Cycle	Second Cycle	Third Cycle
Protein	970 lb	1,118.6 lb	1,141.2 lb
Carbohydrate (est)	280 lb	308 lb	310.8 lb
Oil (emulsion)	106 lb	122.1 lb	124.5 lb
NaOH	40.2 lb	40.2 lb	40.2 lb
Water	35,767 lb	35,061 lb	34,965 lb

5. Marc (@ 10% solids)

Fiber	100 lb	100 lb	100 lb
Other carbohydrate	280 lb	308 lb	310.8 lb
Protein	130 lb	175.4 lb	182.4 lb
Oil	14 lb	19.14 lb	19.9 lb
NaOH	8.3 lb	8.3 lb	8.3 lb
Water	4,791 lb	5,497 lb	5,593.5 lb

6. Hydrochloric Acid (3.7% ~10% by volume or conc. HCl in water)

Component	Each Cycle	Total, 3 Cycles
HCl	36.7 lb	110.1 lb
Water	952 lb	2,856 lb

7. Aqueous Factor

Component	First Cycle	Second Cycle	Third Cycle
Protein	194 lb	223.7 lb	228.24 lb
Carbohydrate	56 lb	61.6 lb	62.16 lb
Oil	21.2 lb	24.4 lb	24.9 lb
Salt (NaCl)	11.8 lb	23.6 lb	35.4 lb
Water	32,192 lb	31,202 lb	30,685

8. Protein Factor (@ 20% solids)

Component	First Cycle	Second Cycle	Third Cycle
Protein	776 lb	894.9 lb	912.96 lb
Carbohydrate	224 lb	246.4 lb	248.64 lb
Oil	84.8 lb	97.7 lb	99.6 lb
Salt (NaCl)	47 lb	47 lb	47 lb
Water	4,527 lb	5,144 lb	5,232 lb

20. Animal Feed (3-Cycle Process)

Component	Marc (5) 3 cycles	Aq. Fact. 3rd Cycle	Slurry	Dried to 7.5% Mositure	
Protein	487.9 lb	228.2 lb	716.1 lb	716.1 lb	31.5%
Fiber	300 lb	-	300 lb	300 lb	13.2%
Carbohydrate	898.8 lb	62.2 lb	961 lb	961 lb	42.3%
Oil	53.0 lb	24.9 lb	77.9 lb	77.9 lb	3.4%
Salt	36.6 lb	11.8 lb	48.4 lb	48.4 lb	2.1%
Water	15,882	30,685 lb	46,567	170.5 lb	7.5%

20. Animal Feed (Continuous Recycle Process)

Component	Marc (per cycle)	Marc, Dried to 7.5% Moisture	
Protein	130 lb	130 lb	22.5%
Fiber	100 lb	100 lb	17.4%
Carbohydrate	280 lb	280 lb	48.4%
Oil	14 lb	14 lb	2.4%
Salt (by neutralization)	11 lb	11 lb	1.9%
Water	4,791 lb	43.4 lb	7.5%

TABLE I

MONTHLY MANUFACTURING COSTS
Solvent Process Meal, Unrestricted

Plant Costs (round dollar estimate)				$28,328
Materials and Energy			$26,366	
Raw Material, 151.7 tons @$135		$20,480		
Processing chemicals, 151.7 x $25.57		3,879		
Acetone make-up, 38.5 gal	$14.52			
Hexane make-up, 38.5 gal	8.66			
Hydrochloric acid, 36.7 lb	0.55			
Sodium hydroxide, 48.5 lb	1.84			
Utilities (subject to plant location)		1,907		
Electricity, 32,388 kwh/187 kw	$730			
Gas, 13,800 therms	977			
Water and sewer, 180,00 gal	200			
Maintenance materials and operating supplies		100		
Labor and Supervision			1,960	
Manager, 0.2 EFT @$1500		$300		
Machine & control supervisor, 0.5 EFT @$1250		625		
Laborers, 2 EFT @$390		780		
Payroll burden (benefits, etc.), 15%		255		
Sales Expenses				10,411
Cash discount, 2% on 50% of sales			$ 732	
Containers, (2% of sales)			1,464	
Brokerage fees, 5% of sales			3,761	
Advertising & promotion, 5% of sales			3,761	
Freight out			663	
General Expenses				10,754
Administrative costs			$2,400	
Accountant		750		
Stenographer		625		
Clerk		625		
Payroll burden (benefits, etc.), 20%		400		
Depreciation			3,072	
Building @ 30 year rate		4,200/an		
Machinery, @ 12 year rate		29,167/an		
Auxiliary equipment @ 10 year rate		3,500/an		
Interest			3,496	
7.25%/an on fixed capital		3,194		
6% for 6 month on working capital		302		
Advalorem Taxes			804	
Actual value of plant, $511,000				
Assessed value	204,400			
Insurance			232	
Building & machinery, $2,245/an				
Raw materials & finished goods, $538/an				
Miscellaneous			750	

TABLE II

BUILDING AND EQUIPMENT COSTS

		Life (yrs)	Annual Depreciation
Building Costs			
Building, 10,600 sq. ft. @ $11.54/sq. ft.	$122,000		
Land, 1 acre @ $4,000	4,000		
Total	$126,000	30	$4,200
Machinery Cost	$350,000	12	$29,167
Auxilliary Equipment Cost	$35,000	10	$3,500
Depreciation Rate			
Annual			$36,867
Monthly			$3,072
Capital Investment (round thousands)			
Fixed capital			$511,000
Working capital			121,000
one month finished goods $72,215			
two months raw materials 48,718			
Total Capital Investment			$632,000

TABLE III

SUMMARY STATEMENT
Annual, in Round Thousands

Annual Income		
Gross sales		$867,000
Protein isolate (94% protein)		
2,382,000 lb. @ $.35/lb	$834,000	
Animal feed material (23% protein)		
528 tons @ $44/ton	23,000	
Oil, 58,800 lb @ $0.17	10,000	
Variable (plant) costs, @ $28,328/month		340,000
Variable profit		$527,000
Sales expenses, @ $10,411/month		125,000
Out-of-pocket fixed costs, @ $7,681/month		92,000
(General expenses, except depreciation)		
Cash Income		$310,000
Depreciation		37,000
Net Income Before Taxes		$273,000
Federal taxes, @ 45%		123,000
State taxes		16,000
Net Income		$134,000
Investment		**Annual Return**
Fixed Investment	$511,000	26%
Working Capital	121,000	
Total Capital Investment:	$632,000	21%