# Production and Nutritional Evaluation of Extrusion-Cooked Full-Fat Soybean Flour[1]

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### Abstract

A processing method for preparing full-fat soybean flours for human consumption by a new extrusion-cooking method was developed. Biological evaluations were made of samples produced experimentally by this method to determine the best conditions for preparing a product of maximum nutritive value and stability. Twelve processed full-fat soybean flours, prepared under different conditions, were evaluated by means of chemical analyses, biological assays, available lysine content, organoleptic and bacteriological tests, and oxidative stability storage tests. Flour of high nutritive value and good stability can be prepared by preheating unextracted soybean flakes or grits to 200–212F, premixing and adding sparge steam at 212F to adjust moisture content to 18–21%, extruding for 1–1.5 min with final extrusion temp reaching 250–290F, cooling, drying and grinding. Clinical testing of the flour with infants up to 12 months of age has begun in two Far Eastern countries on a fairly extensive scale, and completed results should be available by late 1964.

### Introduction

The United Nations Children's Fund (UNICEF) has been improving local diets in the developing countries, especially of children and of pregnant and nursing mothers (7,10). Since milk is a logical food for this group, UNICEF has assisted in building and equipping over 200 milk-processing plants in the developing countries to provide safe milk or milk powder.

In many developing areas of the world, however, that are not suitable for dairying, supplementary proteins and fats are provided from other sources. UNICEF has assisted the Government of Chile in building a plant which is producing a stable deodorized 80% protein-fish flour. They have assisted the Government of India with two peanut flour processing plants, and more are planned.

Asians have traditionally used soybean foods, generally in a moist form. Some of these are: soy milk (a water extract of the ground whole bean); tofu (a precipitated curd similar to cottage cheese); and tempeh (a fermented product of the decorticated bean). Because of their relatively short shelf life they are usually made locally each day as a cottage or small village industry.

To provide a product of longer shelf life, which can be stored and transported more easily, UNICEF has assisted the Government of Indonesia with a plant to produce a spray-dried powder made from the water extract of soya and sesame. This powder blended with the necessary vitamins, minerals, carbohydrates and flavoring makes a highly acceptable infant food or beverage when reconstituted, but the cost of the rather elaborate processing and packaging required prevents its wide use by low-income groups. For this reason, UNICEF is interested in the development of a highly nutritious soybean-based stable product that can be economically processed and packaged. Since transport is difficult in most developing countries, the processing plant should be relatively small and self-contained for ease of construction and operation in bean-growing areas.

At present, plants producing full-fat soy flour are of large capacity and not suitable for use in developing areas. The complexity of their equipment prevents a scaling down for small-capacity plants. The need is, therefore, for an integrated plant in which the major portion of the processing can be done in one economical piece of equipment.

Cooked, unextracted soybeans have given beneficial results in poultry feeding tests (4,13). However, the use of full-fat soybeans in animals feeds depends upon certain economic factors (9). Experiments on several different ways of processing full-fat soybeans have been reported. The extrusion equipment described in this paper was used in 1961 to convert soybeans directly to full-fat meals for feed mixing. Swine feeding tests carried out on these meals at Purdue University were reported (5) to give comparable weight gains and feed conversion efficiencies of regular defatted soybean meal with added fat.

On the basis of the Purdue experiment, it was conceived that it might be possible to apply the cooker-extruder process to dehulled soybeans to produce an edible-grade full-fat soybean product which could be ground to a highly nutritious flour for human foods. Such a product would provide protein of high biological values as well as fat energy in the diets of many developing countries at low cost. Although the direct interests of each of the cooperating groups were somewhat different, all were basically interested in the cooker-extruder process as a new technique for processing soybeans.

A collaborative project was therefore sponsored by UNICEF, and undertaken by the No. Utiliz. Res. & Dev. Div., ARS, USDA, and the Wenger Mixer Manufacturing to develop and evaluate a simplified extrusion-cooking process for the production of full-fat soybean flour for edible uses.

Materials were produced from ton lots of soybeans under 12 different combinations of time, temp and moisture on industrial-size equipment. The test materials were then subjected to chemical, bacteriological, biological and clinical testing to determine the exact processing conditions needed to produce a full-fat soy flour of the highest quality for human consumption.

In developing a system for the cooking of whole soybeans, the objectives were a) to obtain a cooked, soy flour with a high biological value; b) to cook the beans in a manner suitable to inactivate the growth inhibitors in soybeans, without materially impairing the protein biological value or protein solubility of the product; c) to produce a bland and palatable

[1] Presented at the AOCS Meeting, Minneapolis, 1963.
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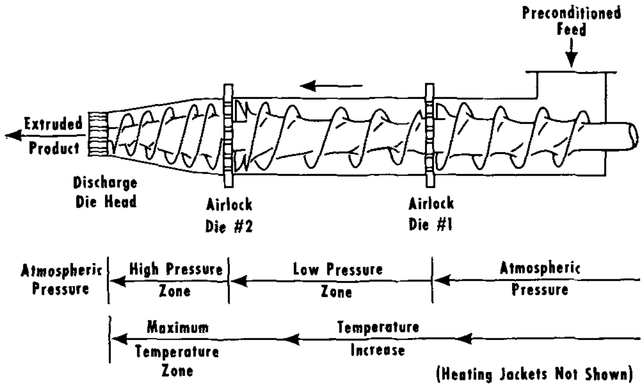


FIG. 1. Extruder screw standard configuration.

product which should be substantially free from the bitterness and beany taste indigenous to soybeans; d) to produce a product which should have adequate shelf life without refrigeration; e) to meet acceptable standards of sanitation, bacteriology and contamination; and f) to develop an economical process which can be carried out with a minimum of labor and equipment.

## Principle of the Extrusion Process

Oil cells of the seed are "ruptured" in the extrusion process due to the high levels of temp, pressure and moisture existing in the barrel of the extruder. The extrusion is performed in an extruder-screw configuration as shown in Figure 1. During passage through the various sections, the material is gradually subjected to increased pressure and temp. Pressure is increased by pitched screws separated by air-lock dies that create back pressure to prevent blowback through the feed inlet, which is at atmospheric pressure. Finally, the max pressure is created in the last tapered screw or cone-nose section; the amt of pressure can be varied by the thickness of the diehead as well as the number and the diameter of the holes in the die. Temp is partially controlled by steam jackets on the first two sections. Heat, of course, is also developed by the worm pressure on the solids during extrusion. Temp of the meal in the cone-nose section reaches values far above atmospheric boiling; however, boiling does not take place because the pressure is also above atmospheric. Thus, the extruder section is acting as a continuous pressure cooker. When the material extrudes through the final die or small apertures, the sudden, great reduction in pressure causes the material to expand, thus rupturing the cells. This transformation of the material has been responsible for the process being called the "extrusion or expansion process." A similar process is being used in making cereal-type breakfast foods, as well as pet foods.

This process has an "oil expelling effect," which is advantageous for feeding. When the high-fat material reaches the high pressure zone, oil is expelled from the cell structure as "free" oil. However, as the oil and meal mixture passes through the die restriction and into the atmosphere the free oil is immediately reabsorbed in the hot meal. This effect of the oil in the free state has given higher digestibility to expanded corn and soybeans in feeding trials with dairy heifers, according to a report by University of Delaware researchers (3).

## Experimental

*Listing of Collaborators.* Complete facilities for the production of the test materials on industrial-size equipment were not available at any one location, and product testing required the cooperation of many types of laboratories. Twenty-four companies and institutions were used for the processing and testing. To double check results, most of the tests were performed in more than one laboratory.

A. The facilities of the following companies were used in the production of the test materials:
   1. Bean cleaning, drying, dehulling and flaking:
      Loma Linda Food Company, Mt. Vernon, Ohio
   2. Mixing, cooking, extruding and cooling:
      Wenger Mixer Manufacturing, Sabetha, Kan.
   3. Vacuum drying:
      Gunther Products, Inc.; Galesburg, Ill.
   4. Milling:
      Alpine American Corp., Saxonville, Mass.

B. Specific test milling techniques also were tried in the pilot-plant facilities of the following:
   Northern Regional Research Laboratory, Peoria, Ill.
   Raymond Div., Combustion Engineering, Inc., Chicago, Ill.
   B. F. Gump Co., Chicago, Ill.
   H. B. Taylor Co., Chicago, Ill.
   Allis-Chalmers, Milwaukee, Wis.

C. The 12 lots of test materials were analyzed by the following laboratories:
   1. Chemical analysis including amino acids:
      Northern Regional Research Laboratory, Peoria, Ill.
      Barrow-Agee Laboratories, Inc., Memphis, Tenn.
      Texas A & M University, College Station, Texas
      Merck Institute, Rahway, N. J.
   2. Bacteriology:
      Campbell Soup Co., Camden, N. J.
   3. Biological assay:
      a. Rat feeding:
         Columbia University, New York, N. Y.
         National Institute for Medical Research, London, England
         Department of National Health and Welfare, Food and Laboratories, Ottawa, Canada
         Central Institute for Nutrition and Food Research TNO, Utrecht, The Netherlands
         Philadelphia General Hospital, Philadelphia, Pa.
      b. Chick feeding:
         University of Maryland, College Park, Md.
   4. Clinical evaluation:
      State University of Iowa, Iowa City, Iowa
      National Taiwan University, Taipei, Taiwan
   5. Acceptability:
      P. N. Sarihusada, Jogjakarta, Indonesia
      National Taiwan University, Taipei, Taiwan
   6. Taste panel:
      Northern Regional Research Laboratory, Peoria, Ill.
   7. Accelerated storage:
      Northern Regional Research Laboratory, Peoria, Ill.
      Wisconsin Alumni Research Foundation, Madison, Wis.

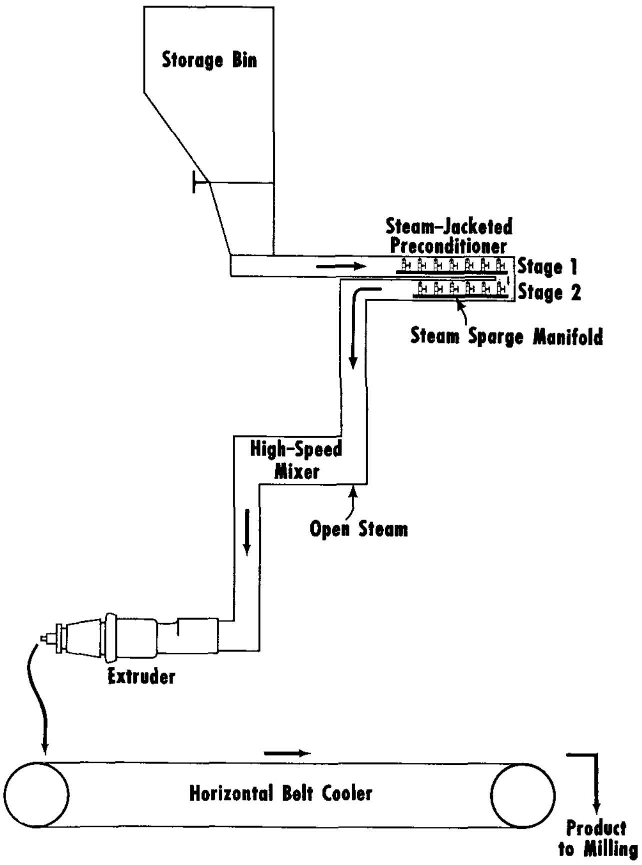


FIG. 2. Equipment layout for preconditioning, extrusion, cooling and drying steps.

*Materials.* Twelve tons of soybeans were dehulled and flaked for these tests. Approx 3 tons of this material, flaked to 0.004-in. thickness, were used in preliminary shakedown tests. The remaining soybeans were flaked to a thickness of 0.010 in. for 11 of the tests and 0.004-in. thickness for test J. The antioxidant (Tenox 7-Eastman) (6), which was blended with the flakes in test run P, consisted of a mixture of butylated hydroxyanisole, propyl gallate and of citric acid in a solvent combination of propylene glycol and glyceryl mono-oleate.

*Methods of Analysis.* Nitrogen solubility index (NSI) for the measurement of water-soluble protein was determined by a modified method of Smith and Circle (11); protein solubility in 0.02 *N* NaOH by the method of Lyman et al. (6); trypsin inhibitor by the method of Y. Wu and Scheraga (14). Urease activity was determined by a modified Caskey-Knapp procedure (2); available lysine by the adapted method of Baliga et al., based on the reaction with dinitrofluorobenzene (1). Peroxide values were determined by Soxhlet extraction of the full-fat flour with pentane-hexane and by recovery of the oil under vacuum using a rotary evaporator at 70C. The oil was then analyzed for peroxide value by the standard AOCS procedure (8). Other tests reported in this paper, unless otherwise designated, were also analyzed by standard AOCS procedures.

*Equipment and Instrumentation.* Preconditioning, extrusion, cooling and drying equipment used in the production of the test runs show in Figure 2. The continuous cooker was fed by a 2-stage preconditioner, steam jacketed, 12 ft long, equipped with 10-in. and 12-in. screws, respectively, driven by a variable speed motor, and equipped with steam manifolds and 6 steam injection points on both stages of the preconditioner. The high-speed mixer, which was an integral part of the continuous cooker, was 5 ft long, 16 in. in diam, and was equipped with a single steam manifold, steam control valve, and direct reading thermometer installed in the downspout to the extruder. The extruder was equipped with an initial steam-jacketed feeder section of screw, rifled sleeves, a steamlock die; a center airlock section (also steam-jacketed) equipped with a center airlock screw section and center steamlock die, a final cone-nose extruder section, special cone screw, and final extrusion die drilled with 25 untapered openings, each ¼ in. in diam. Three thicknesses of the final die were used in these runs (depending upon whether low, medium or high temp were desired). These thicknesses were 2.5 in., 2.75 in. and 3 in., respectively. The extruder was fitted just inboard of the final die, with a thermocouple, connected by a flexible cable to a direct reading pyrometer. Final processing temp inside the cone-nose section were reported on temp measured at this point. Slightly higher final temp inside the die can be anticipated, possibly as much as 10F higher than temp measured by the thermocouple. This standard configuration gave retention time in the entire 3-section extruder of approx 60 sec.

TABLE I

Preliminary Planning Sheet Designating Extruder Process Variables

| Retention time, min | Pretempering | Moisture level % | Temperature in cone-nose section |
|---|---|---|---|
| 1 | None | Medium (15.2) | Low<br>Medium<br>High |
| | Add 2.8% moisture | High (20.2) | Low<br>Medium<br>High |
| 1.5 | None | Medium (15.2) | Low<br>High<br>Low |
| | Add 2.8% moisture | High (20.2) | Medium<br>High |
| 1.5 [a] | Add 2.8% moisture | High (20.2) | Medium |

[a] Antioxidant Tenox 7 mixed in feed.

*Experimental Design, Measurements and Controls.* Design of the experiments was developed basically to study moisture, temp and retention time in the extruder. A preliminary design layout of the extruder process variables shows in Table I. Not all of these conditions, however, were achieved in the actual runs.

A. *Moisture Content of Product Entering System.* It was decided to provide two moisture levels for extrusion test runs:
   1. Medium moisture runs were made with dehulled flakes as received without any pre-application of moisture (other than moisture applied as steam in the preconditioning itself). Flakes were received with an average of 9.2% moisture content; medium moisture runs added approx 9% moisture as steam, bringing the product up to 18% estimated moisture content on extrusion, somewhat higher than that originally designed.
   2. High moisture runs were made with dehulled flakes as received, plus 2.8% moisture added as water in a pretempering step, plus the estimated 9% moisture added as steam in normal processing, bringing estimated moisture at time of extrusion to 21%.

B. *Preconditioning.* To minimize the number of

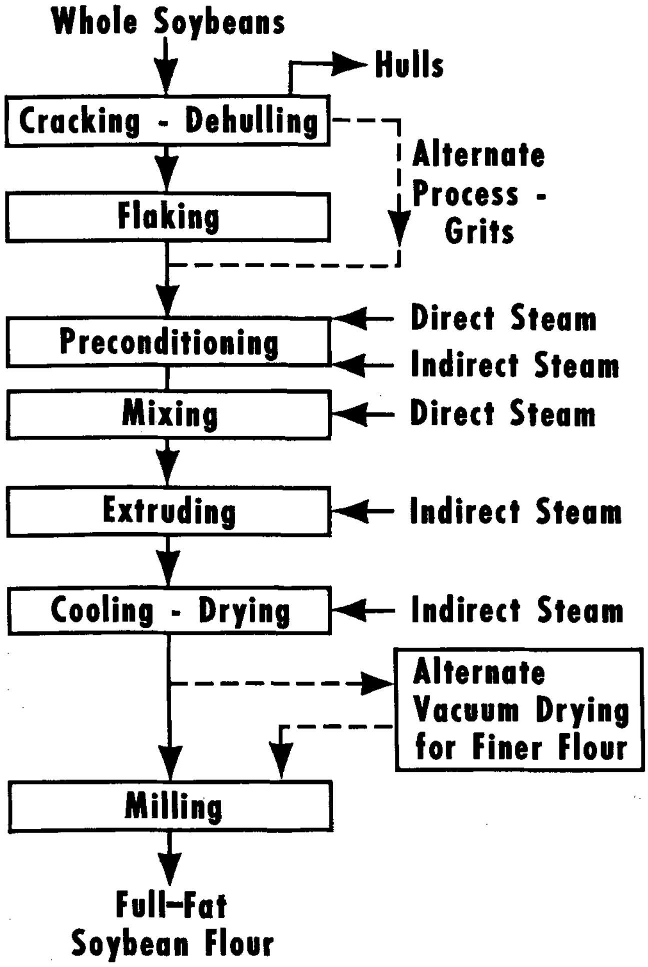


FIG. 3. Continuous extrusion process for the production of full-fat soybean flour.

variables in a run, the 2-stage preconditioner was adjusted for a throughput of 70 lb/min and left at the same feeder rpm for all runs. This rate provided a retention time in the preconditioner of approx 2.75 min. Preconditioning temp were controlled in all runs insofar as possible as follows:

1. For low-temp runs (GG and M) discharge temp from upper stage of preconditioner were 150F; from lower stage, 200F; and from high-speed mixer, 210F.
2. For medium-temp runs (A and P) discharge temp from upper stage preconditioner were 160F; from lower stage, 200F; and from high-speed mixer, 212–215F.
3. For high-temp runs (B, BB, H, K and O) discharge temp from upper stage preconditioner were approx 190F; from lower stage, approx 210F; and from high-speed mixer, 215–220F.

Some variation from predetermined conditions was necessary, however, to obtain desired final temp.

C. *Temperatures of Extrusion.* To attain desired temp, slight variations in die thicknesses from run to run were required. Steam jackets in feeder section and center airlock section(s) were fed with low pressure steam (40 psig).

D. *Retention Time in Extruder.* The product was tested at two retention periods in the extruder when system was operated at 70 lb/min—1 min (standard) and approx 1.5 min (augmented):

1. For standard retention time, one center airlock section provided a retention time of 60 sec.
2. For augmented retention time, two center airlock sections were needed to give a retention time of approx 90 sec.

*Operation.* Figure 3 is a flowsheet of the continuous extrusion process. Material was fed to the preconditioner from an overhead bin, and control of feed rate was obtained by adjustment of a variable speed drive motor on the preconditioner. When the desired throughput was obtained, the preconditioner rpm was maintained constant for all runs (except run BB, in which the preconditioner was increased in speed to reach the desired high temp). Product throughput for each run was measured by checkweighing throughput for a 1-min period. As the cooked product was expelled from the extruder it was conveyed by an inclined belt conveyor to a 14-ft single-stage horizontal cooler, in which the agglomerates were cooled and dried by ambient air pulled up through the moving wire-mesh belt which conveys the product through this cooler.

For the preparation of the 25-lb samples used for chemical, organoleptic, biological and storage testing, the cooled product was vacuum dried to approx 3.5% moisture and passed through smooth rolls to obtain a 95–98% through 100-mesh flour.

All biological test samples consisted of these sample flours, with the following exception: Since larger quantities were required in poultry feeding studies, whole soybeans were processed in a separate run under identical conditions as those used in test N and fed as grits for both battery and floor pen feeding.

When large samples were prepared for the clinical testing programs, lots were combined to give adequate quantities for the tests. Nearly 1,000 lb material made up from test lots H, K and M were shipped to Indonesia. Approx 800 lb material made up from lots N, O and P were sent to Taiwan. Before shipping, these lots were dried to approx 3.5% moisture in a commercial vacuum rotary drier, cooled, and then milled through a rotary Contraplex pin mill to a granulation of approx 98% through 100-mesh.

*Stability Tests.* A food-grade antioxidant (Tenox 7) was blended with the feed flakes of test P (level = 0.02% oil basis) and compared with test N as a control to evaluate the effect of an antioxidant on the oxidative stability of the flour products.

Shelf-storage tests for products H, N and P were carried out by placing the samples in screwcap glass bottles and storing at room temp in either a well-lighted area or in a dark closet.

Accelerated oxidation tests were conducted on products N and P at elevated temp of 100 F and 113F. Samples at 100F were stored with air at 45% relative humidity and those at 113F with air at 25% relative humidity. Free fatty acid and peroxide values were then measured periodically at 3-week intervals for a total of 26 weeks' storage.

## Results and Discussion

*Chemical Composition.* Test data for preconditioning, extrusion and cooler-dryer operations show in Table II. Analyses of the full-fat flour products obtained in each test are presented in Table III.

Analytical data in Table III for moisture, protein, crude fat, ash, crude fiber, as well as granulation, are within the ranges specified for general purpose full-

TABLE II

Test Data for Preconditiong, Extrusion, and Cooling-Drying Operations

| Test run and sample designation | Moistures, % | | | | | | Temperatures, F | | | | | Retention times min | | Steam flow lb/min | | Horse-power to ex-truder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pretem-pering (original moisture = 9.2%) | Leaving mixer[a] | | Leav-ing ex-truder | Leav-ing cooler | After vac-uum drying | Preconditioner Upper stage | Preconditioner Lower stage | Leav-ing mixer | In extruder cone-nose section[a] | | Precon-ditioner | Ex-truder | Precon-ditioner | Mixer | |
| A | None | 15.2 | 18.0 | 16.0 | 11.4 | 3.6 | 160 | 200 | 212 | 250 | 258 | 2¾ | 1 | 3.0 | 1.5 | 60 |
| B | None | 15.2 | 19.7 | 16.8 | 12.4 | 4.3 | 180 | 200 | 220 | 275 | 279 | 2¾ | 1 | 3.5 | 2.5 | 63 |
| BB | None | 15.2 | 17.6 | 15.4 | 10.4 | 4.0 | 200 | 210 | 220 | 300 | 285 | 2½ | ¾ | 4.0 | 2.5 | 78 |
| G | 9.2 → 12 | 20.2 | ...... | ...... | ...... | 3.2 | ...... | ...... | ...... | 250 | 269 | ...... | ...... | ...... | .... | .... |
| GG | 9.2 → 12 | 20.2 | 20.5 | 18.2 | 12.6 | 3.1 | 150 | 200 | 210 | 230 | 242 | 2¾ | 1 | 2.5 | 2.5 | 53 |
| H | 9.2 → 12 | 20.2 | 21.5 | 18.2 | 12.0 | 3.7 | 180 | 205 | 215 | 275 | 279 | 2¾ | 1 | 3.5 | 3.0 | 63 |
| J | None | 15.2 | 16.6 | 15.2 | 11.0 | 3.2 | 130 | 138 | 135 | 250 | 242 | 2¾ | 1½ | 2.0 | 1.0 | 78 |
| K | None | 15.2 | 21.1 | 15.8 | 11.6 | 2.8 | 180 | 210 | 215 | 275 | 279 | 2¾ | 1½ | 3.5 | 3.0 | 75 |
| M | 9.2 → 12 | 20.2 | 15.6 | 14.8 | 10.4 | 3.1 | 150 | 200 | 210 | 230 | 242 | 2¾ | 1½ | 2.0 | 2.0 | 56 |
| N | 9.2 → 12 | 20.2 | 21.1 | 17.5 | 12.6 | 3.5 | 180 | 210 | 215 | 250 | 253 | 2¾ | 1½ | 3.5 | 3.0 | 56 |
| O | 9.2 → 12 | 20.2 | 21.6 | 16.9 | 11.4 | 3.4 | 200 | 210 | 218 | 275 | 290 | 2¾ | 1½ | 4.0 | 2.5 | 83 |
| P[b] | 9.2 → 12 | 20.2 | 19.8 | 17.2 | 12.4 | 3.8 | 160 | 200 | 215 | 250 | 255 | 2¾ | 1½ | 3.0 | 2.0 | 60 |

[a] Percentages in first column represent estimates before run; in second column, actual measurements before run.
[b] Test incorporated, Tenox 7 antioxidant; test N used as control with no antioxidant.

fat flour, as outlined by the Soybean Council of America (12).

The available lysine content, expressed as percentage of protein, ranging from 4.73–5.93, averaging 5.34%, compares favorably with commercial full-fat soy flours, one of which when tested contained 4.61%.

*Removal of Growth Inhibitors.* Adequate removal of growth inhibtors was reflected by assays for trypsin inhibitor and urease activity, except in test J. All other runs analyzed 95% or higher of trypsin inhibitor destroyed and had very low to zero urease activity. By contrast, test J retained a trypsin inhibitor activity that was nearly as high as raw soybean meal. These results indicate that run J had insufficient heat treatment, probably attributable to the low temp attained in the preconditioner and the extrusion step, as well as to the many adjustments required during processing.

Test J was also a very poor run from the standpoint of reaching equilibrium conditions and achieving a reliable temp reading in the extruder. The measured values are, at best, only estimates since considerable moisture and temp fluctuations occurred in the preconditioner, mixer and extruder during the test. However, the results of test J were included to show some effects of the lower temp parameter, particularly in preconditioning.

Since the trypsin inhibitor assays for the runs other than J were 95% or higher, it appears that even min temp in the range of 240-250F were sufficiently high to remove the inhibitor present. The corresponding biological data for these runs also support the conclusion that run J was not sufficiently heat-treated.

*Protein Solubility.* In most cooking processes, either the percentage of soluble protein or NSI generally reflects the degree of heat treatment received by the product. Figure 4 shows a plot of NSI vs. temp reached in the extruder cone-nose section.

The values ranging from 12.9–20.8 correlate inversely with temp, lower protein solubility being associated with higher temp. Since the urease enzyme and the trypsin inhibitors were quite completely deactivated, possibly NSI values could be significantly increased without reducing biological values.

*Vitamin Content.* The effect of heat treatment in commercial processing of soybeans generally reduces such vitamins as thiamine and niacin to low levels. Comparison of these values before and after extruder-cooking shows in Table IV, which gives residual contents of vitamin $B_1$, $B_2$ and niacin for the raw untreated flakes and for two experimental flours, A and H. These values indicate that the heat treatment in the extruder process results in little destruction of the original vitamin content.

*Bacteriological Status.* The overall bacteriological status of all the products (Table V) was excellent with the exception of G. This sample was probably contaminated due to environmental conditions in the plant, rather than to processing factors. The low total count of most samples, as shown in Table V, indicates that the process lends itself well to the production of a sanitary product.

*Nutritional Evaluation of Products.*

A. *Rat Feeding.* The results of both the protein efficiency ratio (PER) and the net protein utilization (NPU) tests obtained in rat feeding indicate the experimental extruded prod-

TABLE III

Full-Fat Soy Flour Analyses
("As-is" basis unless otherwise noted)

| Sample lot designation | Moisture % | Protein (N x 6.25) % | Crude fat % | Ash % | Acid insoluble ash % | Crude fiber % | Nitrogen solubility index (water) % | Nitrogen solubility[a] (% solubility) in 0.02 N NaOH % | Trypsin inhibitor destroyed % | Urease activity pH change | Available lysine[a] % of protein | Peroxide value meq/1,000 g extracted oil | Free fatty acid[b] (in extracted oil) % | Granulation (% through 100 mesh) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | 3.6 | 44.44 | 19.89 | 4.81 | 0.02 | 3.5 | 17.2 | 89.5 | 99.1 | 0.05 | 5.93 | 0.19 | 0.50 | 95.3 |
| B | 4.3 | 42.97 | 19.90 | 4.84 | 0.04 | 3.2 | 12.9 | 85.6 | 95.5 | 0.03 | 5.10 | 0.27 | 0.55 | 96.2 |
| BB | 4.0 | 45.22 | 19.64 | 4.82 | 0.02 | 2.8 | 14.8 | 89.5 | 95.5 | 0.03 | 5.74 | 1.84 | 0.55 | 94.3 |
| G | 3.2 | 44.53 | 18.95 | 4.96 | 0.01 | 3.0 | 17.2 | ...... | 95.1 | 0.02 | 5.17 | 0.21 | 0.53 | 96.8 |
| GG | 3.1 | 44.09 | 20.45 | 5.01 | 0.08 | 2.9 | 16.6 | 86.5 | 95.5 | 0.03 | 5.36 | 0.42 | 0.52 | 98.0 |
| H | 3.7 | 44.78 | 20.10 | 4.85 | 0.02 | 2.9 | 15.0 | 81.9 | 95.5 | 0 | 4.73 | 0.12[c] | 0.55 | 94.1 |
| J | 3.2 | 41.62 | 21.20 | 5.20 | 0.03 | 2.8 | 64.4 | 93.7 | 0 | 1.98 | 5.18 | 0.62 | 0.46 | 97.8 |
| K | 2.8 | 45.98 | 20.41 | 5.02 | 0.03 | 3.2 | 13.0 | 91.3 | 95.5 | 0 | 5.12 | 0.38 | 0.58 | 95.7 |
| M | 3.1 | 44.48 | 20.17 | 5.00 | 0.02 | 3.0 | 15.7 | 90.5 | 95.5 | 0 | 5.05 | 0.76 | 0.52 | 95.7 |
| N | 3.5 | 44.10 | 20.28 | 4.95 | 0.01 | 3.0 | 18.2 | 88.1 | 95.5 | 0.05 | 5.49 | 0.22[d] | 0.49 | 95.7 |
| O | 5.4 | 43.11 | 19.31 | 4.90 | 0.02 | 3.1 | 12.3 | 81.7 | 95.5 | 0.04 | 5.62 | 0.28 | 0.55 | 95.0 |
| P | 3.8 | 44.16 | 19.90 | 4.89 | 0.02 | 3.4 | 20.8 | 88.5 | 97.6 | 0.06 | 5.53 | 0.16[e, f] | 0.55 | 96.2 |

[a] Dr. C. Lyman, Texas A & M College, College Station, Texas (6).
[b] Barrow-Agee Laboratories, Memphis, Tenn.
[c] At 42 days storage: stored in dark = 0.199, stored in light = 0.173.
[d] At 42 days storage: stored in dark = 0.130, stored in light = 0.143.
[e] At 42 days storage: stored in dark = 0.160, stored in light = 0.314.
[f] Run P incorporated Tenox 7 antioxidant.

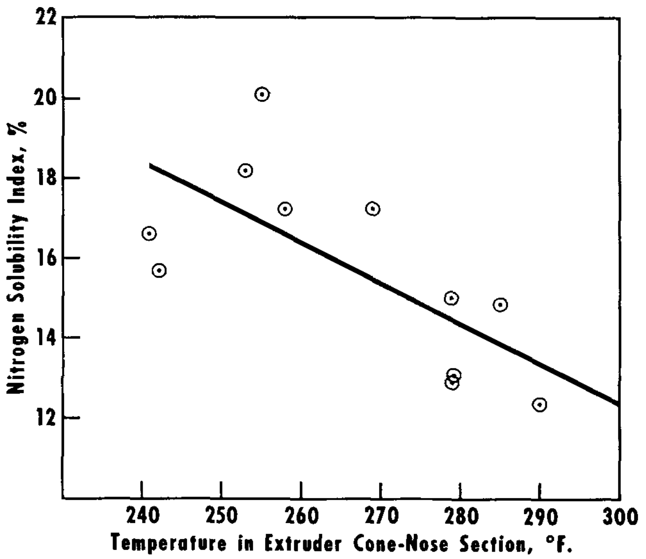


FIG. 4. Effect of extruder temp on nitrogen solubility index.

ucts are of the same general value as commercially prepared full-fat soy flours and defatted soy flours. The PER values of extruded flours show in Table VI, and ranged from 2.28–2.53 and from 1.90–2.36 by two different investigators. These may be compared with 2.09–2.46 for 10 commercial products. The NPU values for different lots of extruded product ranged between 55 and 64, as compared with a NPU of 64 on a single commercial product.

B. *Poultry Feeding.* Data on controlled feeding tests with broiler chicks showed the extruded product to be superior to a good quality, commercial, full-fat soy flour both in promoting growth and in efficiency of feed conversion. Supplementation studies suggest that the methionine and cystine in the extruded product are probably more available which could account for the higher biological values obtained for chick feeding. Results were similar, however, when methionine was added to the diet. Table VII shows wt gains and feed conversion of 240 chicks fed to 4 weeks in a completed battery trial; one group was fed a dehulled soybean meal plus soybean oil (control), another a commercial full-fat soy flour, and a third extruded soybean meal. Table VIII shows results of 1,400 broiler chicks maintained in floor pens and fed rations containing identical levels of protein and fat from the same three products.

TABLE IV

Vitamin Content of Extruded Soy Flours Compared to Untreated Soybean Flakes[a]

| Sample | Vitamin $B_1$ | Vitamin $B_2$ | Niacin |
|---|---|---|---|
| | | μg/g | |
| Original flakes | 9.0 | 2.9 | 50 |
| Test A | 9.9 | 3.1 | 63 |
| Test H | 9.5 | 2.9 | 47 |
| Commercial soy flour | 5.3 | 3.5 | 19 |

[a] Central Institute for Nutrition and Food Research, Utrecht, The Netherlands.

*Product Milling.* Full-fat soya meals normally processed in other than the extrusion process are milled to flours of 100–300 mesh, as desired, in conventional hammer mills with air classifiers.

The relatively free oil in the meal from the extrusion process caused both the industrial-size hammer mill and the hammer mill air-separator combination to plug immediately, and it was not possible to mill the product with this type of equipment. Additional pilot-plant milling tests were unsatisfactory when using various hammer mills with screens and mechanical air separators, a pin mill and a micropulverizer. All the mills plugged and the rolls became caked. Laboratory-size roller milling at the Northern Laboratory successfully ground the extruder product to a flour of 95% through 100 mesh. However when roller mill testing was conducted on large quantities in commercial-size rolls, laboratory conditions were not duplicated and satisfactory comminution was not obtained.

The Alpine industrial-size number 250 CWS Contraplex pin mill, which has a large capacity airswept chamber with bag collectors, proved satisfactory for milling the meal to a flour with 98% passing a 100-mesh sieve. The 2% remaining on the 100-mesh sieve appeared to be fiber only.

The starting material contained 4% moisture and the milled material slightly less, due to air drying. Since the product was not dusty, no part passed to the bag collectors, and the collectors served as air exits only. There was a slight product buildup (¼ in. to ⅜ in. thick) on the inside surface of the mill chamber, which was easily removed by light brushing. No cakes, lumps or free oil were formed in the mill and all the milled product appeared uniform.

During milling, ambient temperatures ranged from 15–20C and the temp of the product increased by approx 16C. The mill required 13 hp when operating at a capacity of 425 lb of product/ hr, with the pin rotors operating at 5,600 and 11,000 rpm and with 400 cfm of air passing through the mill.

A test run was made on the same product in which the starting material was tempered to 10% moisture instead of 4%. All other conditions remained the same. Moisture in the finished product was reduced to 8.5% from air drying in the mill. The milled prod-

TABLE V

Bacteriological Status[a]
(Number of Organisms per Gram of Sample)

| Sample lot designation | Total plate count | Coliforms | Staphylococci | Yeasts and molds | Enterococci | *Salmonella shigellae* | Aerobia spores | Anaerobic spores |
|---|---|---|---|---|---|---|---|---|
| A | 13,000 | 240 | <10 | 15 | 24 | <0.18 | 1,100 | 460 |
| B | 17,000 | 110 | <10 | <10 | 110 | <0.18 | 1,100 | 1,100 |
| BB | 14,000 | 240 | 10 | 10 | 24 | <0.18 | 460 | >1,100 |
| GG | 2,200 | 460 | <10 | 20 | 46 | <0.18 | 240 | 460 |
| G | 100,000 | 1,100 | 10 | <10 | >1,100 | <0.18 | 1,100 | >1,100 |
| H | 2,500 | 240 | <10 | <10 | 24 | <0.18 | 240 | 1,100 |
| J | 4,600 | 46 | 10 | 10 | 24 | <0.18 | >1,100 | >1,100 |
| K | 700 | 240 | <10 | 10 | 24 | <0.18 | 240 | 460 |
| M | 1,800 | 240 | <10 | 35 | 46 | <0.18 | 240 | 460 |
| N | 1,300 | 460 | <10 | <10 | 75 | <0.18 | 460 | 240 |
| O | 800 | 240 | <10 | 20 | 110 | <0.18 | 240 | 460 |
| P | 1,600 | 46 | <10 | <10 | 75 | <0.18 | 460 | 460 |

[a] F. Gunderson, Director, Bacteriological Research, Campbell Soup Co., Camden, N. J.

TABLE VI

Biological Values by Rat Bioassay

| Sample lot designation | Protein efficiency ratio (PER) 4 weeks, 10% protein level | | Net protein utilization (NPU)[c] | | |
|---|---|---|---|---|---|
| | | | Maintenance level | 10% Protein level | |
| | Gyorgy[a] | Morrison[b] | Platt[d] | TNO[e] | Platt |
| A | 2.36 | 2.39 | 62 | 60 | 57 |
| B | 2.26 | 2.28 | 62 | 60 | 57 |
| BB | 2.22 | 2.46 | 62 | 57 | 57 |
| G | 1.90[f] | 2.46 | 63 | 63 | 58 |
| GG | 2.24 | 2.51 | 62 | 62 | 57 |
| H | 2.29 | 2.44 | 62 | 61 | 57 |
| J | 1.31 | ...... | 46 | 26 | 45 |
| K | 2.04 | 2.52 | 64 | 59 | 59 |
| M | 2.33 | 2.53 | 63 | 58 | 58 |
| N | 2.25 | 2.39 | 61 | 59 | 56 |
| O | 2.15 | 2.41 | 61 | 56 | 56 |
| P | 2.06 | 2.42 | 57 | 55 | 53 |
| Casein control | ...... | 3.09 | .... | 74 | .... |
| Dry skim-milk control | 3.00 | ...... | .... | .... | .... |

[a] P. Gyorgy, Philadelphia General Hospital, Philadelphia, Pa.
[b] A. B. Morrison, Vitamins and Nutrition Section, National Health and Welfare, Food and Drug Laboratories, Ottawa, Canada.
[c] Net protein utilization (NPU) by carcass analysis at the protein level required for both maintenance and at protein level in the diet fed (namely 10 g protein/100 g diet).
[d] B. Platt, National Institute for Medical Research, London, England.
[e] Central Institute for Nutrition and Food Research, Utrecht, The Netherlands.
[f] Apparent low value probably due to laboratory procedure rather than to poor sample.

uct appeared the same as that obtained in the production run; however, the sieving test gave only 92% through a 100-mesh sieve as compared to 98% for the low-moisture material. The material remaining on the sieve appeared to be mostly fiber, the same as in the previous run. Successful milling of a 10%-moisture product suggests that vacuum drying after cooling is probably not necessary if the resulting fineness is acceptable for the flour.

*Flavor Evaluation of Product.* From the standpoint of consumer acceptance of soybean products, the prevention of off-flavors and odors which result from fat deterioration is of major importance. Because soy flours may be stored for 1–2 years at room temp or even higher temp, poor stability of the flour for these periods could be a serious deterrent to their successful marketing or disposition.

Good stability of extruded soy flour seems indicated. Peroxide values were measured on three lots (H, N and P) after 42 days in storage either kept in darkness or exposed to light (Table III). It should be noted that only lot P was stabilized with an antioxidant.

The relative stabilities of test flours N and P, as determined in accelerated tests conducted at 100F and 113F, show in Table IX. Both products had good stability at the end of 9 months when stored at 100F. At the higher temp of 113F, test N began to show evidence of rancidity by its elevated peroxide value of 6.4 at the end of 15 weeks. Rancidity of this sample was pronounced at the end of 26 weeks when the peroxide value reached 54. Test P, the sample with added antioxidant, retained a peroxide value of 3.3 at the end of the 9-month period. An estimate submitted by the organization conducting these tests suggests that 3–4 months at 100F and 1–2 months at 113F might be equivalent to 1 year's storage at 70F. On this basis, these flours appear to have adequate storage stability.

Organoleptic testing of the 12 experimental soy flours showed that 11 of the products scored relatively good with regard to flavor (Table X). Removal of the strong bitter-beany flavor and development of the desired nutty flavor was indicated. Statistical analysis of the mean flavor scores in Table X indicates that sample J gave a significantly lower score than the remaining 11 experimental soy flours. This low flavor score correlates with the other poor data obtained for J, caused by insufficient heat treatment. Samples A, BB and K gave significantly higher scores than the commercial soy flour tested. All adequately heated experimental flours scored higher than the commerical sample with which they were compared.

*Proposed Clinical Testing.* A 1,000-lb lot of the milled soy flour product has been forwarded to the P. N. Sarihusada Co., Jogjakarta, Indonesia, where it will be formulated and packaged for acceptability testing in the areas now supplied by the plant with the dried water-extracted soya milk formulation.

TABLE VII

Weight Gains and Feed Conversions of Chicks Fed Diluted Diets Containing Soybean Proteins Processed Differently[a]

| Soybean source | Av. 2-week gain, g (2–4 weeks) | | Feed/gain (2–4 weeks) | |
|---|---|---|---|---|
| | Control | +Methionine | Control | +Methionine |
| Control dehulled soybean oil meal +soybean oil | 262 | 312 | 2.48 | 2.15 |
| Commercial full-fat soy flour | 244 | 306 | 2.60 | 2.22 |
| Extruded full-fat soy product | 278[b] | 315 | 2.45 | 2.19 |

[a] Diluted diet calculated to contain 12.7% protein, 0.19% methionine, 0.195% cystine, 0.7% lysine and 1601 kilocalories of metabolizable energy/lb. All diets were obtained by diluting 44.2, 42.1 or 45 parts of the complete unsupplemented control soybean meal, commercial meal, or the extruded product, respectively, with 30 parts of a protein-free diet so as to obtain 12.7% protein.
[b] Better than value obtained with commercial full-fat flour but not better than control meal at a 95% level of significance.

TABLE VIII

Weight Gains and Feed Conversions of Broiler Chicks Maintained in Floor Pens and Fed Rations Containing Identical Levels of Protein and Fat from Soybeans

| Added methionine %[a] | % Meth. + cystine ÷ M cal. of M.E./lb | Control soybean oil meal + soy oil | Commercial full-fat soy flour | Extruded full-fat soy product |
|---|---|---|---|---|
| Av. 4.5-week body wt, g | | | | |
| ........ | 0.416 | 606 | 589 | 613 |
| 0.073 | 0.463 | 650 | 627 | 625 |
| 0.145 | 0.509 | 678 | 646 | 653 |
| 0.218 | 0.555 | 691 | ...... | ...... |
| Feed consumed/unit wt (0–4.5 week) | | | | |
| ........ | 0.416 | 1.57 | 1.65 | 1.58 |
| 0.073 | 0.463 | 1.54 | 1.62 | 1.52 |
| 0.145 | 0.509 | 1.50 | 1.53 | 1.50 |
| 0.218 | 0.555 | 1.45 | ...... | ...... |

[a] Basal ration contained 34.35% dehulled soybean meal (48.43% protein), 1.47% fat and 52.92% corn as only protein sources. Rations calculated to contain 21.4% protein.

TABLE IX

Relative Stabilities of Extrusion-Cooked Full-Fat Flours at 100F and 113F up to 9 Months Storage

| Storage temp and humidity | Time, weeks | Free fatty acids calculated as oleic | | Peroxide value-meq/1,000 g oil in sample | |
|---|---|---|---|---|---|
| | | Test N % | Test P % | Test N % | Test P % |
| 100F Relative humidity, 45% | 0 | 0.42 | 0.39 | 1.0 | 1.2 |
| | 3 | 0.54 | 0.49 | 2.2 | 2.4 |
| | 6 | 0.55 | 0.55 | 2.2 | 2.2 |
| | 9 | 0.56 | 0.56 | 2.2 | 2.2 |
| | 15 | 0.80 | 0.75 | 2.5 | 2.2 |
| | 26 | 0.86 | 0.92 | 2.8 | 2.4 |
| | 39 | 0.99 | 0.99 | 3.0 | 2.5 |
| 113F Relative humidity, 25% | 0 | 0.42 | 0.39 | 1.0 | 1.2 |
| | 3 | 0.55 | 0.50 | 2.2 | 2.5 |
| | 6 | 0.56 | 0.56 | 2.2 | 2.3 |
| | 9 | 0.66 | 0.66 | 2.8 | 2.6 |
| | 15 | 0.87 | 0.72 | 6.4 | 3.0 |
| | 26 | 0.88 | 0.85 | 54.0 | 3.1 |
| | 39 | 4.84 | 0.99 | 65.8 | 3.3 |

[a] Wisconsin Alumni Research Foundation, Madison, Wis.

TABLE X

Mean Organoleptic Scores of Experimental Full-Fat Flours (12 Evaluations by Taste Panel)

| Sample lot designation | Mean score[a] | Samples associated with the same letter do not differ significantly at the 95% level | | |
|---|---|---|---|---|
| J[b] | 3.73 | x | | |
| Commercial soy flour[c] | 4.93 | x | y | |
| P | 5.63 | | y | z |
| GG | 5.92 | | y | z |
| O | 6.14 | | y | z |
| N | 6.14 | | y | z |
| M | 6.41 | | y | z |
| H | 6.44 | | y | z |
| B | 6.51 | | y | z |
| G | 6.58 | | y | z |
| BB | 6.72 | | | z |
| A | 6.80 | | | z |
| K | 6.87 | | | z |

[a] Scoring—strong flavor (O) → bland (10).
[b] Significantly lower than samples K,A,BB,G,B,H,M,N,O,GG and P.
[c] Significantly lower than samples A,K and BB.

Clinical and acceptability testing is also being done by the College of Medicine of the National Taiwan University, Taipei, Taiwan. It is part of a large-scale clinical test with infants up to 12 months of age to compare the extruded soy flour formulated as a milk, with various other soybean products.

## Conclusions

The studies described indicate that a full-fat soybean flour of good flavor, high-nutritive value, low-bacteria count and good oxidative stability can be produced by the new extruder-cooking process. The high-nutritive value of the soy flour is attributed to the relatively high temp-short retention time process. Growth inhibitors are effectively destroyed, whereas the heat-labile amino acids, vitamins and other nutrients are preserved. The process largely removes the objectionable bitter-beany taste in soybeans as shown by acceptance scores obtained in taste-panel tests.

The studies were carried out in commercial-scale equipment, which is highly compact for its capacity due to the very short retention periods. The design of this equipment and the extruder-cooking process, therefore, should meet the requirements of UNICEF in providing compact, high-efficiency processing units for installation in newly developing countries.

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# Report AOCS Industrial Oils and Derivatives Committee, 1964

The Industrial Oils and Derivatives Committee and four of its Subcommittees met during the AOCS meetings in New Orleans April 20 and 21, 1964. The following summary of these meetings is published to keep the members of the Society informed regarding the activities of this committee, K. E. Holt, Chairman.

## Consolidation of Methods

Following the 1963 fall meeting of the Society it was reported that tentative approval had been given to the consolidation of the methods coming under the jurisdiction of the Industrial Oils and Derivatives Committee. Along with this consolidation a "Recommended Practices for Testing" Method would be written for each group or type of product that falls into the category of industrial oils or derivatives of these oils. These methods have now been completed and approved by the Industrial Oils and Derivatives Committee and are ready for submission to the Uniform Methods Committee. If they meet the approval of this Committee, they will be published in the next revision of the AOCS Official Methods Book.

**Fatty Nitrogen Products Subcommittee,** G. G. Wilson, Chairman

Three Task Groups of the Fatty Nitrogen Products Subcommittee reported on the progress of their work. Task Group 1 on Fatty Amido Amines reported that no progress has been made on the development of methods for primary amine value, hydroxyl value and non-amine and imidazoline value. They will continue to work on these methods. Task Group 3 on Fatty Diamines and Task Group 4 on Fatty Amines are working to develop a procedure to adapt the gas chromatograph for the separation and analysis of these products. Each of the Task Groups will prepare a standard sample by use of pure diamines in the case of Task Group 3 and pure amines in the case of Task Group 4. The Task Group members will use the official AOCS Gas Chromatograph Method or any other Gas Chromatograph Method that will give adequate separation of the standard sample components. They will report peak areas, response factors and percent of components.

**Epoxidized Oils Subcommittee,** Dave Barlow, Chairman

Results of scouting tests on hydroxyl procedure for epoxidized oils were presented at the Subcommittee meeting. These tests were carried out in the laboratories of Union Carbide, Swift and Archer Daniels Midland and the procedures scouted were 1) a phenyl isocyanate method, 2) an infrared spectral method, 3) the AOCS method using acetic anhydride and 4) a modified acetylation procedure. Only the last method, a room temperature acetylation, appears amenable to further study. It was decided that a full Subcommittee collaborative study should be made on the modified acetylation procedure at room temperature.

The application of an idione value method and