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D00473

Distr.
LIMITED

ID/WG.[illegible]
[illegible] January [illegible]

ORIGINAL: ENGLISH

United Nations Industrial Development Organization

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OILSEED PROTEIN FOR FOOD USES [1]

by

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[illegible] objective of [illegible] discussion will be to review the use of oilseeds as protein sources for foods, with main emphasis on soybeans. In particular the production of [illegible], the forms of soybean protein available, and the merits of their use in food will receive attention.

The edible oilseeds produced in greatest quantity are soybeans, cottonseed, peanuts [illegible], sunflower seed, sesame seed, [illegible]. The estimated [illegible] production is shown in Table 1. All except cottonseed [illegible] are used directly as

Table 1. [illegible] of Major Oilseeds [illegible] 1

	Production 19[illegible] [illegible]
Soybeans	[illegible]
Cottonseed	[illegible]
Peanuts	1[illegible]
[illegible]	[illegible]
Sunflower Seed 2	[illegible]
Sesame Seed 2	1,[illegible]
[illegible] 3	[illegible]

1 [illegible] Agricultural Statistics 19[illegible], U. S. Department of Agriculture

2 [illegible] of Food and [illegible]

3 [illegible]

Outside of the Orient soybeans did not become commercially important until about [illegible]. The increasing market for oil in Europe and the United States resulted in the development of a soybean crushing industry based at first on soybeans imported from the Orient. In general, the meal was used for animal feed although very limited amounts found outlets in food.

[illegible]. Experimental growing of soybeans was tried in many regions outside of the Oriental countries. However, no serious interest in production developed until about 1920 in the United States. Before that time some soybeans had been imported by both Europe and the United States for crushing to produce oil. Also soybean oil itself was imported, for example from Manchuria, to fill the increasing demand for food oils.

The remarkable history of the development of soybeans as a major crop in the United States has been reviewed by a number of writers. A very complete description up to about 1941 is to be found in a book by E. J. Dies (4).

Domestic soybeans were first crushed for oil commercially in 1915. However, oil production apparently was sporadic and largely experimental until about 1924. At that time, soybean production had reached about 1 million bushels per year.

The rapid rise after that in soybean production resulted from a favorable combination of circumstances. Soybeans proved useful to the farmer in crop rotation, first serving as a forage crop and to maintain soil productivity. The market for oil was increasing. The soybean processing industry took an aggressive position, assuring the farmers of a market for the soybeans produced. Finally, the value of the oilmeal meal as a feed protein supplement was demonstrated and well advertised. As part of some of the early oil production, the companies produced and sold mixed feeds incorporating the soybean meal, thereby encouraging the wider feed use of the meal.

Another factor in the early successes of soybeans in the United States was the availability initially of a number of varieties from the Orient that were adapted to a range of growing conditions. In general, these growing conditions were similar to those in the United States. Therefore, breeders and agronomists were able to select and develop varieties which would meet the needs of a wide area, even though any one variety had very limited adaptability in terms of such factors as response to day length.

The subject of some of the first successful varieties is covered, for example, in the book, "The Soybean", by C. V. Piper and W. J. Morse (5). This book is particularly interesting to read because it expresses optimism and enthusiasm over the soybean crop and its use when the development really was in its infancy. Some statements which probably at the time were considered overly optimistic, today seem extremely conservative and inadequate.

The rapid increase in soybean production is clearly demonstrated by a tabulation of annual harvest at 10-year intervals (Table 2). A

Table 2. Soybean Production in United States

Crop Year	Production Thousand Bu.	Yield per Acre Bu.
1919	2,500	14.1
1929	9,400	13.3
1939	90,000	20.9
1949	234,000	22.3
1959	533,000	23.5
1969[1/] (not available)	1,094,000	26.3

1/ Estimate, November 1969

major part of the production is in the Corn Belt, although the Southern and Southeastern States have been contributing an increasing proportion of the total.

The crushing of soybeans for oil in the United States amounted to about 580 million bushels in 1967-68. Food uses of the oil accounted for 4.9 billion pounds out of the total of 5.4 billion pounds of oil used in the United States (exclusive of export). These food uses were distributed approximately 25 percent for margarine, 35 percent for shortening, and 40 percent other uses, primarily as cooking and salad oil. Only about 500,000,000 pounds of soybean oil was used for non-food products such as paints, other drying oil products, and chemicals.

Production of soybean meal in 1967-68 was about 13,700,000 short tons in the United States. Of this, 10.7 million tons were used as feed and 3.0 million tons were exported. Only 30,000 tons went to non-food uses, about equally divided between food and industrial outlets.

Economics of soybean production. For a number of years the raising of soybeans and of corn in the United States have shown comparable profits. The lower yield of soybeans has been offset by higher price and by lower production cost. Less labor, machinery, and fertilizer are required for soybeans. Production of both soybeans and corn represents large-scale operations, with considerable attention to efficiency of production. In the Southern States soybeans often have been produced on acreage taken out of cotton production.

The economics of soybean production also depends, of course, on the marketing situation. Particularly important are the demand for oil and meal, the prices at which they can be sold, the efficiency of their production, and the export market for beans as well as oil and meal. In general, soybean marketing and processing are large-volume operations with a small unit profit margin.

Adaptability of Soybeans to Other Countries. World statistics on soybean production are given in Table 3. The countries listed, together

Table 3. Geographic Distribution of Soybean Production 1966 1/

Country	Production (thousand bushels)
United States	928,000
Mainland China	250,000
Brazil	22,000
USSR (Europe and Asia)	22,000
Indonesia	14,000
Canada	9,000
Japan	7,000
Korea (Republic of)	6,000
Mexico	4,000
Colombia	2,000

Other countries with production between 6,000 and 1,000,000 bushels include, in increasing order, Rhodesia, Italy, Other Europe (excluding USSR), Tanzania, Turkey (Europe and Asia), Cambodia, Romania, Yugoslavia, Paraguay, Nigeria, Argentina, Thailand.

1/ Agricultural Statistics, 1968 (U.S. Dept. Agr.).

with the different soybean-growing areas of the United States and Far East, represent a considerable range of climatic and growing conditions. This, alone, would suggest that soybeans could be grown even more widely than at present.

Limited space will be devoted here to a consideration of suitability of present and potential new varieties for growth in different parts of the world. I anticipate that this subject will be covered rather completely in the discussions the group will have at the University of Illinois. Some indication of the success in selecting U.S. varieties for production trials in India is given in a recent report from the University of Illinois (6).

The influence of day-length on flowering and seed production by the soybean plant is a controlling factor in the selection or development of varieties for specific locations. However, as indicated earlier, varieties covering a wide range of day-length responses now are available as a result of breeding and of selection from different locations in the Orient. However, one can not expect to make soybeans a profitable crop for all parts of the world. Other seed protein sources, obviously will have to be drawn upon to help round out the food needs.

Nutritive quality of Soybean protein. In animal feeds, soybean meal not only provides a high level of protein (40-50 percent) but also an amino acid composition which is advantageous relative to use as a supplement to feed grains. The protein of corn and sorghum, the main feed grains in the United States, is deficient in lysine and tryptophane, along with the sulfur amino acids (methionine and cysteine). The protein of soybeans, on the other hand, has considerably more than the required proportion of lysine. For several other amino acids, also, the composition of soybean protein is complementary to that of corn and sorghum protein. However, the sulfur amino acid content is equally low in all, so that supplementation with methionine is required to give optimum feed value for some animal feeding.

For the human diet, soybean protein similarly offers the possibility of improving the balance of essential amino acids, particularly where the cereal grains constitute a major source of dietary protein. Dependence on cereal grains, of course, has been noted to be characteristic of many areas where malnutrition and undernourishment exist. In such cases, also, total protein intake may be low. The high concentration of protein in soybean products therefore is advantageous for raising the protein level as well as improving the protein quality of the diet.

The complementary relation of essential amino acid composition from the viewpoint of human needs is apparent from the data in Figures 1 and 2. The amino acid composition of the protein in the mixture is expressed as percent of the amount present in whole egg protein taken as the "ideal" protein. The mixture is more nearly ideal (100 percent) than either corn protein or soybean protein alone. Further details of amino acid composition are given in Table 4.

Table 4. Essential Amino Acid Pattern[1/]

Essential Amino Acid	Whole Egg Protein[2/]	Soy Flour	Whole Corn Meal	75/25 Corn-Soy[3/]
Aromatic AA	195	200	217	206
Isoleucine	129	125	94	113
Leucine	172	188	328	237
Lysine	125	154	66	122
Sulfur AA	107	75	75	75
Threonine	99	100	85	96
Tryptophan	31	33	17	27
Valine	141	127	118	124

1/ Each essential amino acid (EAA) is expressed as milligrams per gram of total EAA in the protein.

2/ 1965 FAO provisional pattern based on whole egg protein.

3/ 75 Percent whole corn meal (10 percent protein) plus 25 percent defatted soy flour (52 percent protein) = 20.5 percent protein (dry basis).

in which the amounts of each amino acid are expressed as milligrams per gram of total essential amino acids in the protein.

The nutritional effectiveness of soybean protein as a protein supplement has been demonstrated in human feeding trials. For example, full-fat soybean protein prepared by extrusion-cooking gave good results in the feeding of infants in Taiwan (7). Both soybean and cottonseed protein are used in supplementary food products with good results. Probably most information on feeding is available on Incaparina while data on CSM is also accumulating.

<u>Forms of Soy Protein for Food Use</u>. Several types or forms of soybean protein, differing in protein content and properties, are available commercially in the United States. The main ones are listed in Table 5, together with the

Table 5. Costs and Production Estimates of Soybean Proteins

Protein Form	Protein Content	Cost Per Pound	Estimated Production[1/]
	Percent	Cents	Million pounds
Flours and grits	40-50	6-1/2-7	105-110[2/]
Concentrates	70	18-25	17-30
Isolates	90-95	35-39	22-35

1/ Estimates for 1967.

2/ An additional 100 million pounds were used in corn-soy-milk product (CSM).

Source: C.P. Eley, Marketing and Transportation Situation, August 1968.

approximate selling price and estimated production in 1967. The lower end of the range of protein contents shown for flour and grits would apply to full-fat flour. Whole soybeans, as the raw material, cost about 4 cents per pound.

Other papers undoubtedly will give details for production of different soybean proteins. For convenience, however, I will give simplified flow diagrams for defatted soy flour, soy protein concentrate, and isolated soy protein, together with a few comments about them.

The production of defatted soy flour, outlined in Figure 3, is essentially the same as for soybean meal used for animal feed. The main differences are in selection of highest quality beans, completeness of dehulling, and the use of facilities meeting the requirements for food processing.

The toasting step, which is a moist heat treatment, is optional depending on the use to be made of the soy flour. Any request for delivery of soy flour should specify the degree of toasting since this treatment has a considerable influence on properties and, therefore, use. For example, untoasted flour is required when bleaching action is desired in breadmaking. On the other hand, maximum nutritional value and mildest flavor can be obtained only by toasting. Excessive heat treatment generally is to be avoided because of decrease in nutritional quality and destruction of functional properties.

Soy protein concentrate, containing about 70 percent protein, can be made by at least three processes, all of which involve removal of sugars and other low molecular weight soluble constituents from defatted soybean flakes by extraction. The process and alternative extraction ("desugaring") conditions are outlined in Figure 4. The products differ in such properties as solubility, primarily because of differences in extent of denaturation of the protein. Therefore, they would not be completely interchangeable in those uses for which degree of denaturation would be influential. Differences in extent of flavor removal also may be observed.

The least denaturation occurs in the process based on extraction at pH about 4.5, which is the isoelectric point or pH of minimum solubility for most of the protein in the soybean. Extraction with aqueous alcohol, in the second process, causes considerable protein denaturation but apparently is rather effective in removing flavor constituents. In the third process the protein solubility first is reduced by heat denaturation so that the soybean flakes can be extracted with water at neutrality.

Production of isolated soy protein, containing over 90 percent protein, is outlined in Figure 9. The starting material, defatted flakes or meal, must have had minimum heat treatment since the retention of protein solubility is essential. The isolation procedure depends on solubility of most of the protein at pH 7 to 9 and precipitation from solution at the isoelectric point, about pH 4.5. The neutralized product, soy proteinate, displays functional properties including solubility while the isoelectric protein is relatively inert.

The difference in prices of the various forms of soy protein reflect costs inherent in the processes, as well as other factors including scale of operation. The form of protein used in foods depends on the functional properties required, the extent to which nonprotein constituents are acceptable, and the effect of price on the market for the final product.

Importance of Functional Properties. Some of the functional properties of soy protein products are listed in Table 6. Food uses associated with

Table 6. Functional Properties of Soybean Proteins in Food Systems

Functional Property	Food System
Emulsification	Ground meats Whipped toppings Baked goods
Fat control (retention and blocking)	Ground meats Doughnuts Pancakes
Water control (absorption and retention)	Macaroni Bread Cakes Confections
Texture	Soup mixes Gravies Ground meats Simulated meats
Aeration	Whipped toppings Confections Chiffon mixes
Color control (bleaching and browning)	Bread Breading mixes

the functional properties also are indicated, although the listing does not represent all uses. In the United States these functional properties are the reason behind many uses of soy proteins. Nutritional quality in such cases is a secondary but important benefit. In general, a given soy protein product does not have all of the functional properties listed so the processing and handling of the protein must be controlled in each case to retain or develop the properties specifically required to whatever extent is possible.

Importance of [illegible] Treatment. For most food uses, moist heat treatment of [illegible] is desirable. [illegible] as a bleaching agent ([illegible]) where protein [illegible] is required, as in the production of isolated protein.

Moist heat destroys antinutritional factors such as trypsin inhibitor. The effect of heat on nutritional quality is shown by the results of rat-feeding experiments shown in Figure 6. The protein efficiency (weight gain per unit weight of protein consumed) was nearly doubled when the soy meal was steamed at the higher initial moisture content (19 percent). The final protein efficiency was nearly as high as that of the reference protein, casein. The increase in protein efficiency coincides with the decrease in trypsin inhibitor activity, although other constituents with similar sensitivity to moist heat may also be involved in the improvement of nutritive value of the soybean meal.

Flavor is another property that is improved by moist heat treatment. The increase in flavor score (indicating a blander product) and change in the type of flavor on steaming of soy flour is shown in Table 7. While

Table 7. Flavor of Soy Flour: Effect of Steaming

Steaming (minutes)	Flavor Score 1/	Main Flavor Type 2/
0	1.5	Bitter, green
3	4.5	Bitter
10	6.0	Nutty
40	6.1	Nutty

1/ 1 = Strong; 10 = Bland

2/ All characterized as beany

the so-called beany flavor persisted throughout, the mild nutty flavor that was developed is considered distinct improvement. The flavor is mild enough to be either not objectionable or easily masked by other flavors in many food formulations. The complete removal of flavors from soy protein products for the most exacting uses still is a subject of research. On the other hand, the flavor of toasted soybean flour often is acceptable to people who traditionally have used soybean foods.

In conclusion, I trust that these comments on soybeans will provide a suitable background for the more detailed discussions to be presented.

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FIGURE

Essential Amino Acid Patterns of Corn and Soy

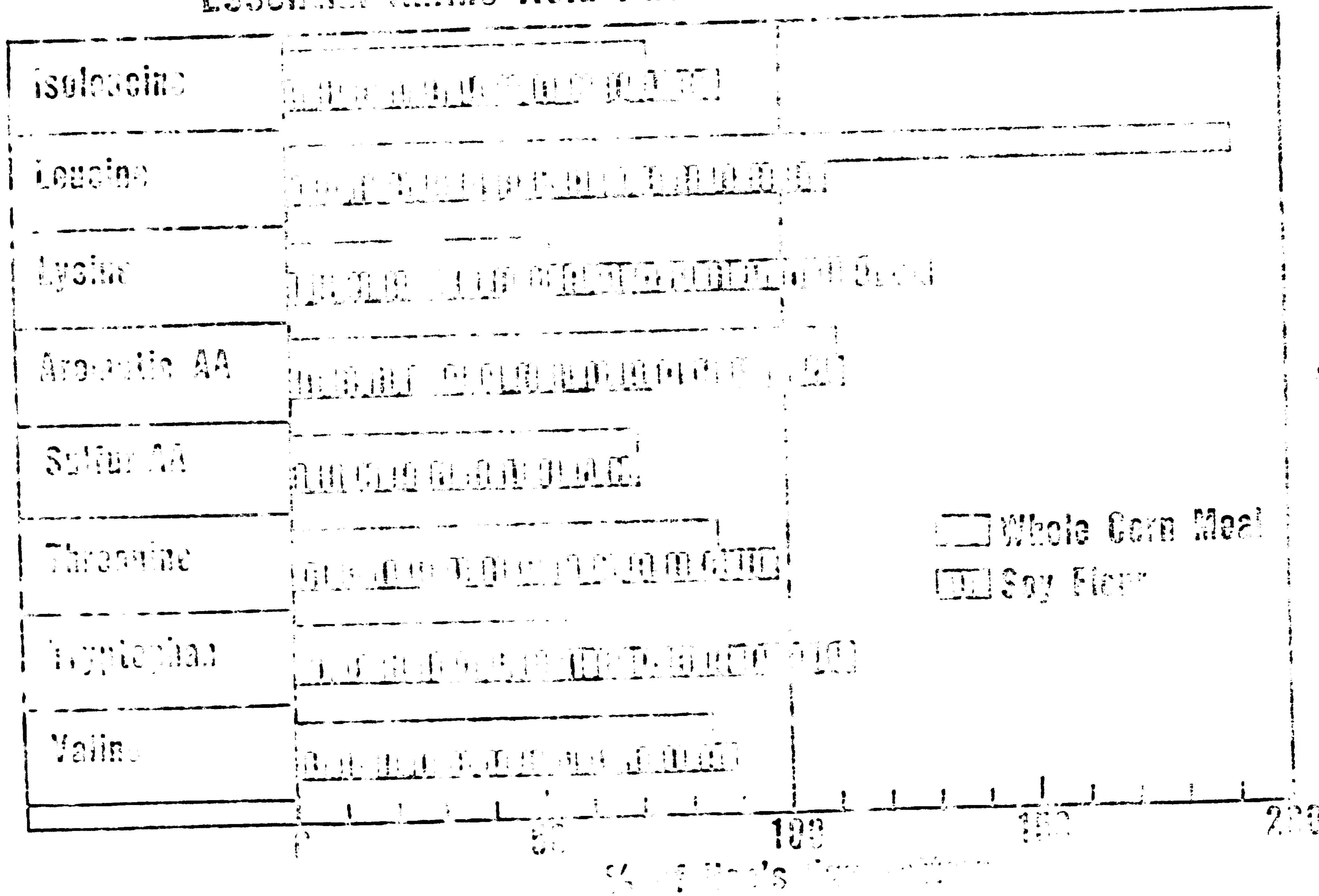


FIGURE 2

Essential Amino Acids of 75/25 Whole Corn Meal-Defatted Soy Flour Compared with Ideal Protein

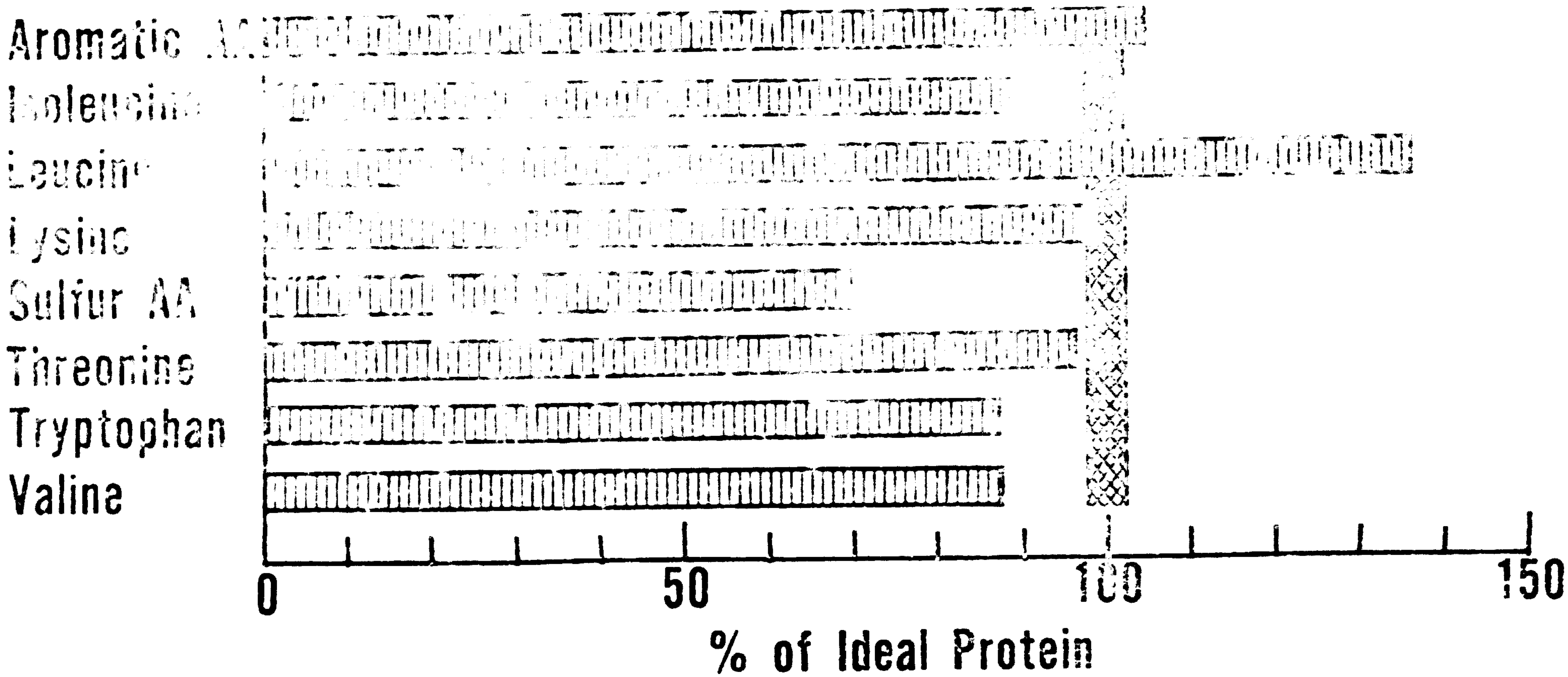


FIGURE 3

Preparation of Defatted Soybean Flour or Grits

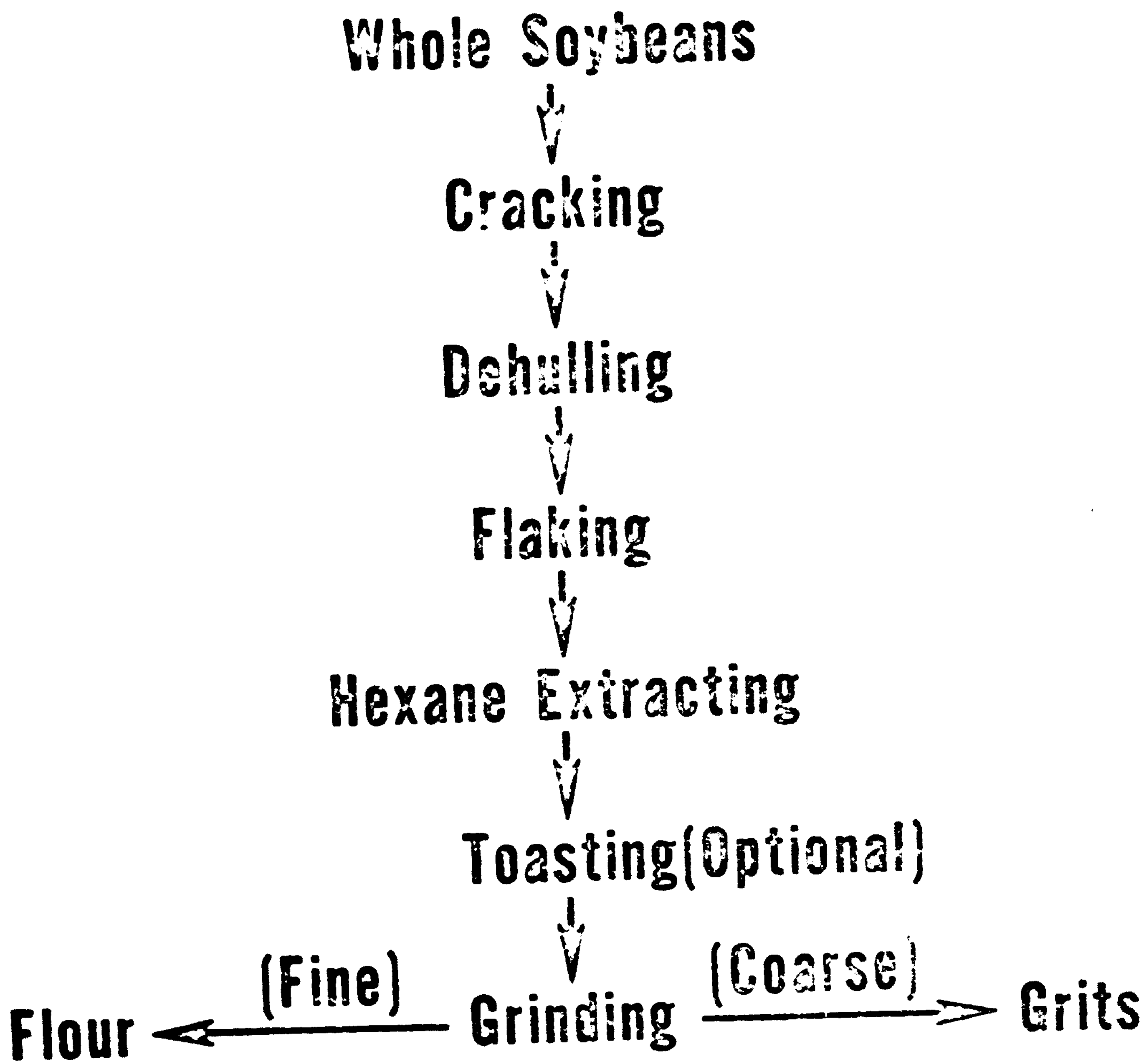
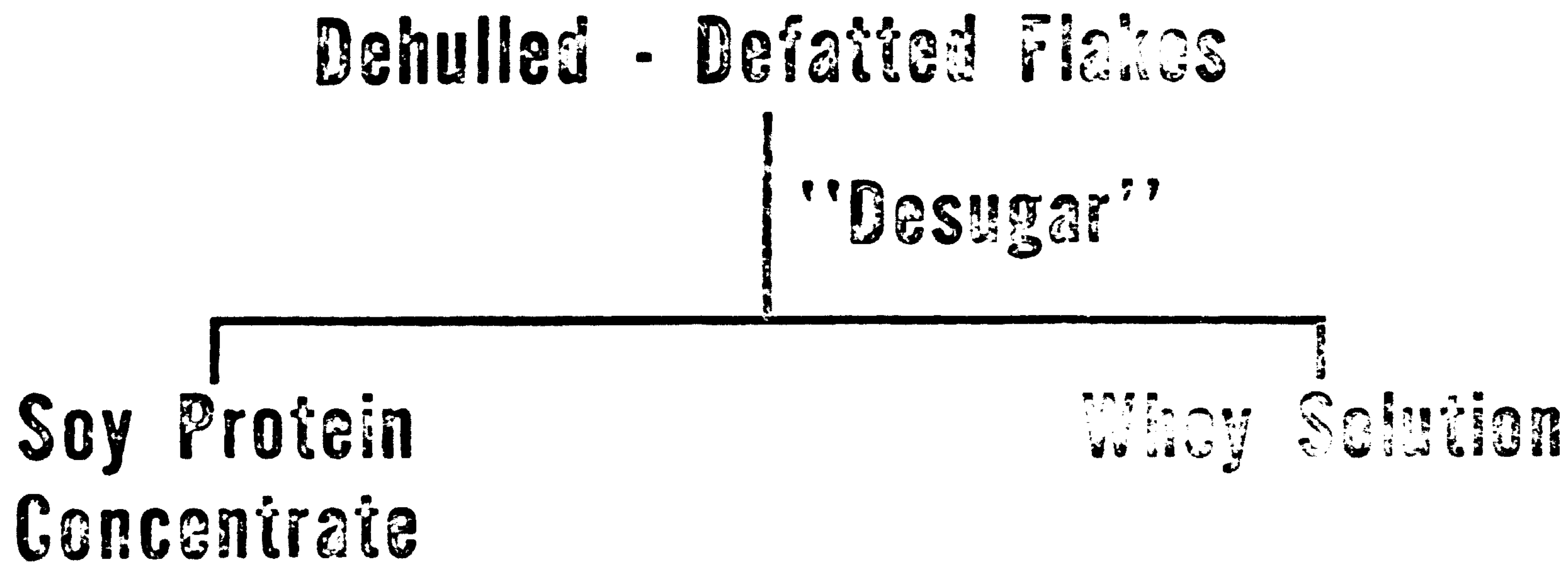


FIGURE 4

Preparation of Soy Protein Concentrates



Procedures

a. Extraction at pH 4.5

b. Aqueous alcohol extraction

c. Water extraction of toasted flakes

FIGURE 5. PREPARATION OF ISOLATED SOYBEAN PROTEIN.

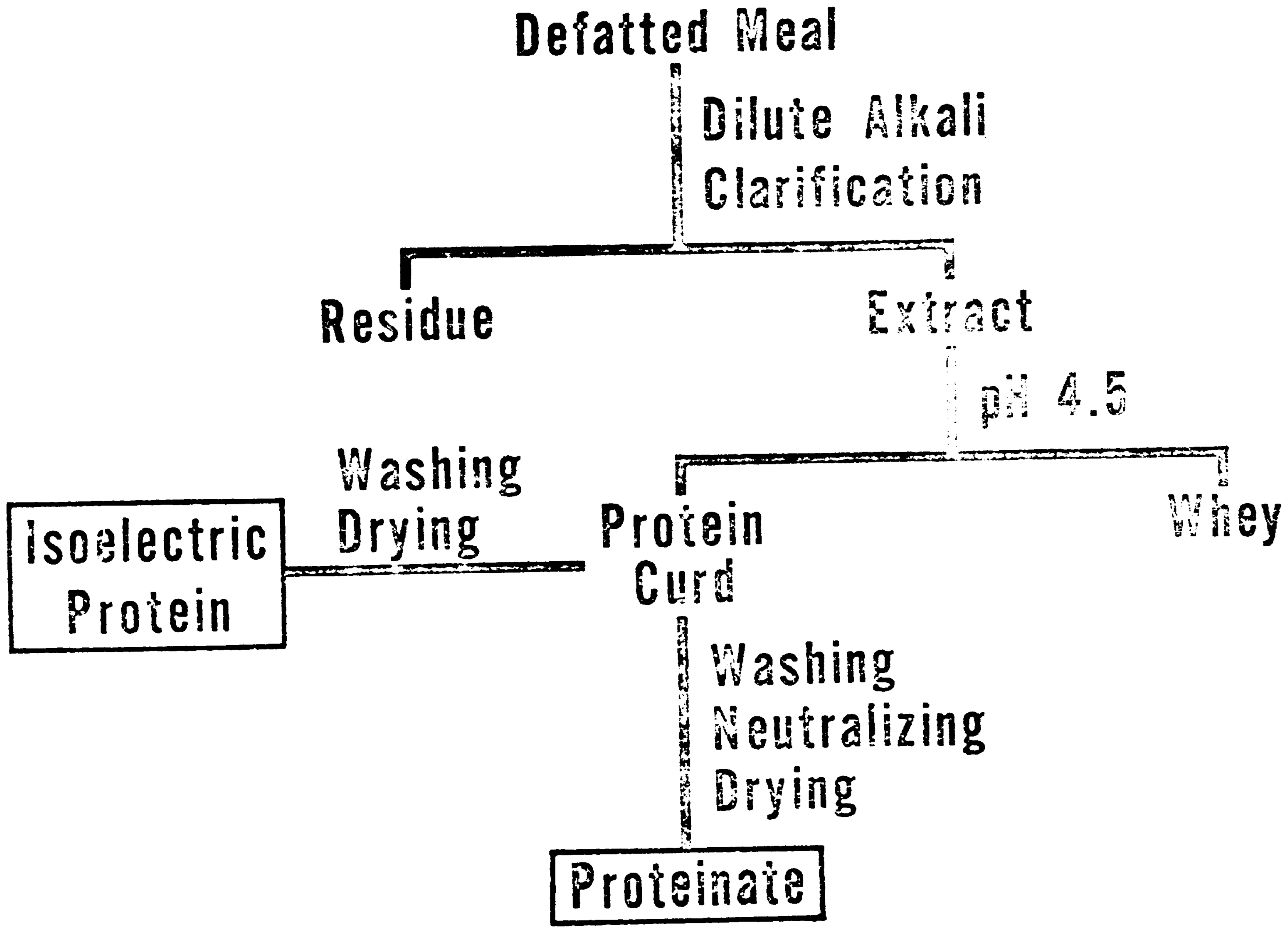
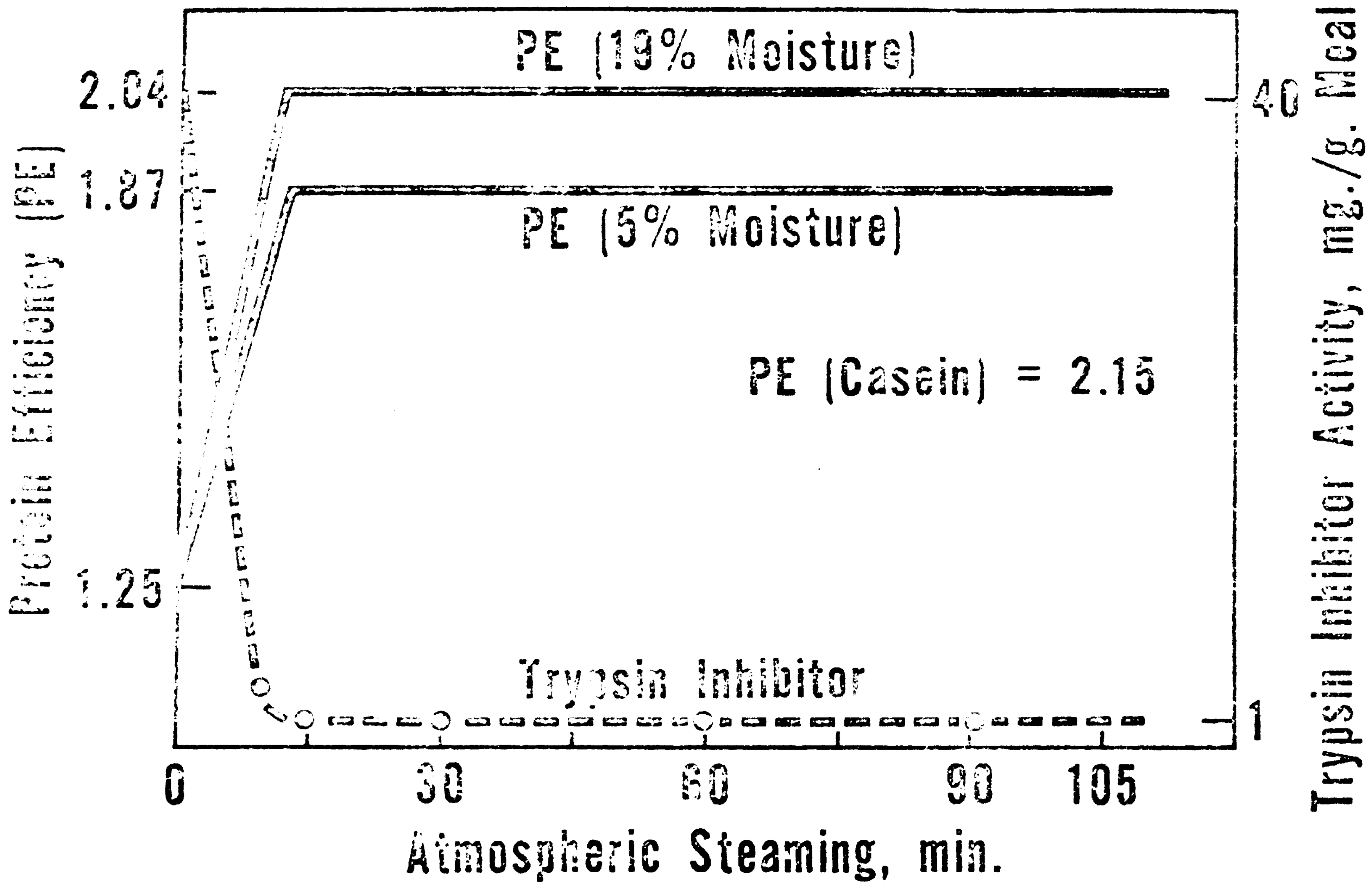


FIGURE 6. EFFECT OF STEAMING OF SOYBEAN MEAL ON PROTEIN EFFICIENCY FOR RATS AND ON TRYPSIN INHIBITOR ACTIVITY.



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