Soybean Protein: Uses, Problems, and Potential

J.J. Rackis

(Editor's Note: The full text of the talk by J.J. Rackis to the Northeast Section Meeting on Dec. 8, 1976, is not available, but the following article is based on his talk. Necessary slides are included as is a list of references for further information.)

Soybeans are the world's major international protein source. As people in developing nations seek to increase the protein in their diet, and as the increased numbers of people in the world create a demand for more protein, the importance of soybeans as a protein source has been increasing.

While the meal portion of soybean production is used primarily for animal feed, small but increasing amounts of soybean protein are being converted to human food. An acre of land devoted to producing beef can yield 58 pounds of edible protein a year, 180 pounds of wheat protein, 323 pounds of corn protein, or 500 pounds of soybean protein.

With the soybean becoming increasingly important as a resource for food protein, the Northeast Section of the AOCS invited J.J. Rackis of the USDA's Northern Regional Research Center to speak at its December meeting on "Soybean Protein: Uses, Problems and Potential." Rackis, a veteran research worker on edible soy protein, was a speaker at the 1973 World Soy Protein Conference and recently has concentrated on flavor problems associated with soy protein for human consumption.

The status and potential of various protein resources and U.S. research and development capabilities that can best be applied to improving food production have been evaluated (1), Rackis said.

Copies of the executive summary of the NSF study can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC, Stock No. 038-000-00251-1. The cost is $1.75. In discussing world protein resources, Milner (2) has cited USDA projections that estimated demand for U.S. soybeans will increase by 73 percent by 1985, over 1970-72 production figures. Projected increased demand for other U.S. protein crops during that time span: peanuts, up 56 percent; chickens, up 39 percent; beef and veal, up 33 percent; and corn, up 30 percent. Thus the reliance on soybeans as a protein source will increase. Other figures also project that while the U.S. produced 42 million metric tons of soybeans in 1975, the figure will rise to 61 million metric tons by 1985, and 85 million metric tons by the year 2000. Exports totaled 13 million metric tons in 1975 and will climb to 26 million metric tons by 1985, and 40 million metric tons in 2000. Thus, while soybean production is doubling by the year 2000, exports will be tripling.

The dominance of soybeans hinges on continued research on bioagronomic constraints on soybean productivity and acceptance problems in food systems (1,3), Rackis said. Generally, edible defatted soy flour is the product with most poential. Anton (4) and Johnson (5) consider soy protein products to have a large potential (see Table I). While their figures differ slightly in emphasis on the type of soy protein, both anticipate edible soy protein usage will triple by 1980-85, if potentially restrictive problems are solved. Johnson's estimate of 200 million pounds consumption of soy milk-type products particularly is dependent on solving soy flavor problems, Rackis said.

Soybeans rank at the top of the list in total production compared to other oilseeds as food legumes (6). With approximate oil-protein ratios of 1:2, 2:1, and 1:5 for soybeans, other oilseeds, and food legumes, respectively (Table II), production of some of these protein resources could be affected by a projected fivefold increase in Malaysian palm oil by 1985 (7). An August 1976 U.S. International Trade Commission report estimated that Malaysian palm oil exports totaled 2,756 million pounds in 1975 and will increase to 6,779 by 1985. The Malaysians' share of total world palm oil exports will grow from 69 percent in 1976 to about 75 percent in 1985, according to the commission's report.

TABLE I

Estimated Production of Edible Soy Protein Products in 1974 and Future Projections in Millions of Pounds

Products	1974 I	1974 II	1980[a]	1985[b]
Soy flour and grits	300	900	600	2,000
Textured soy proteins	160	100	1,080	450
Soy protein concentrate	175	70	350	600
Soy protein isolate	75	60	400	450
Soy milk-type products	--	nil	--	200
Total	710	1,130	2,430	3,700

[a]Anton, J.J., Food Prod. Develop. 9:96 (October 1975).

[b]Johnson, D., "World Soybean Research," Edited by L.D. Hill, Interstate Printers and Publishers, Inc., Danville, IL, 1976.

TABLE II

Production and Protein Content of Oilseeds and Legumes[a]

Crop	Million metric tons	Protein content, %
Soybeans	46.52	40-43
Cottonseed	22.06	17-21
Peanuts	18.14	25-30
Sunflowerseed	9.65	20
Rapeseed	6.50	17-24
Linseed	4.14	24
Sesame seed	1.86	25
Food legumes	40.39	23-27

[a]FAO (1970) crop year 1970.

TABLE III

Heat-Labile Factors in Soybeans

Property	
Inhibit growth	Stimulate pancreatic enzyme secretion
Reduce protein digestibility	Stimulate gall bladder activity
Increase sulfur amino acid requirements	Reduce metabolizable energy
Enlarge pancreas	Inhibit proteolysis

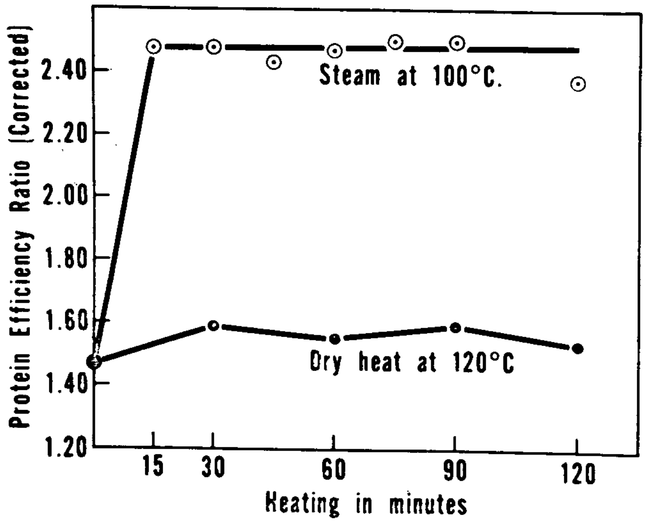

FIG. 1. Effect of type and extent of heating on nutritional value of soybean meal

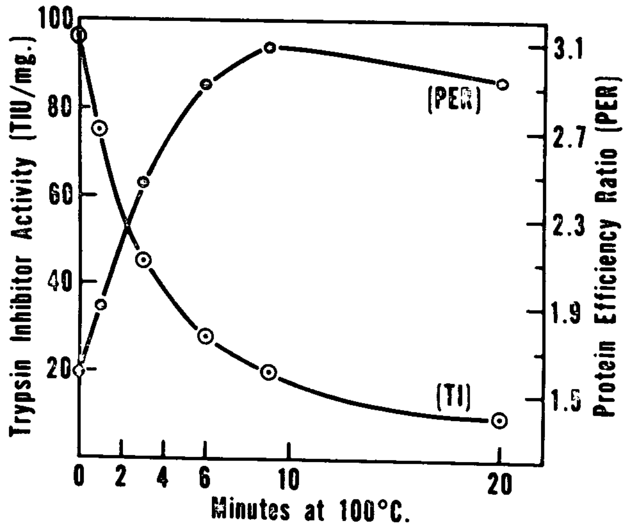

FIG. 2. Effect of steaming on trypsin inhibitor activity and protein efficiency ratio of soy meal

TABLE IV

Types of Soy Protein for Food
Approximate Prices and Production 1976

Protein form	Protein content percent	Price per lb. cents	Production estimate million lb.
Flour	50	9	625
Concentrates	70	30	80
Isolates	90	60	75

Among the problems that need research if the potential of soybeans is to be realized are production, detection methods for soy in foods, labeling requirements, antinutritional factors, functionality in foods, flavor, color, flatulence, and amino acid content, Rackis said.

Careful processing control is required to improve nutritional quality, to ensure good flavor acceptability, and to maintain advantageous functional properties, he said. Research has brought soybean technology to a sophisticated level and can now be applied to solving problems with other protein resources (8). Rackis noted that in the raw form, soybeans contain many substances that cause differing biological and physiological responses in animals (Table III) but, when heat and other processing variables are properly controlled, nutritive value can be improved to

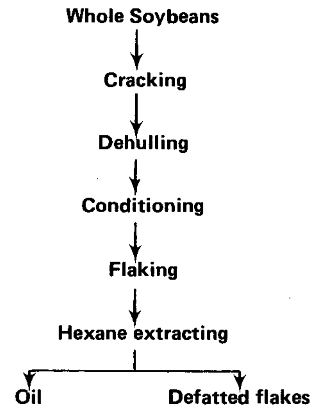

FIG. 3. Conversion of soybeans into oil and defatted flakes.

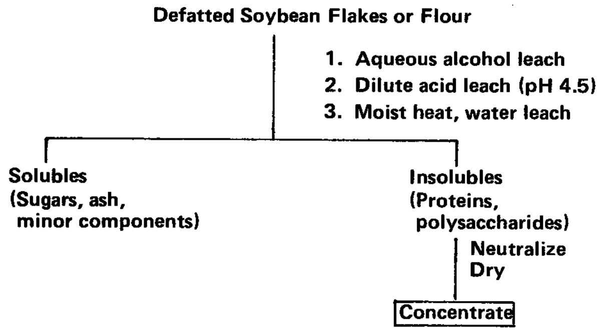

FIG. 4.

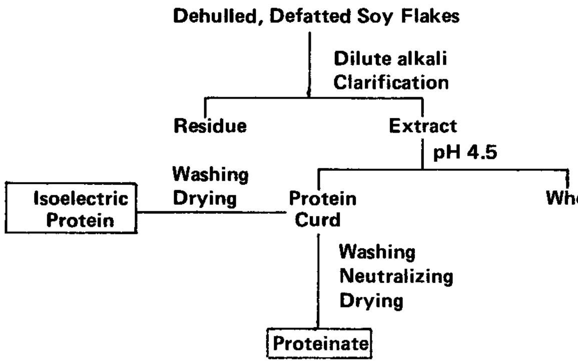

FIG. 5.

nearly that of meat and milk (9) (Figure 1). The USDA's Northern Regional Research Center and others have shown that residual trypsin inhibitor activity in toasted soy products has no nutritional significance (10). When trypsin inhibitor activity is 85 percent destroyed, soy flours have maximum nutritive value (Figure 2).

Soy flours, concentrates and isolates are the three basic forms of soy protein products (Table IV), which are further modified to create a large number of products used for specific nutritional purposes and specific functional purposes (as emulsifiers, water-binders, fat-binders, etc.). It is essential, Rackis said, that reports on soy protein describe the specific type of product and provide conditions of preparation, avoiding the generic term "soy protein" (Fig. 3-5). One magazine article on "soy protein" questioned the bioavailability of zinc and warned that supplemental zinc was necessary in "soy protein," Rackis said. Soy flour diets do not require supplemental zinc to support good growth of rats. Isolates manufactured for functional purposes require 15 to 100 parts per million of supplement zinc when fed as the sole source of protein (Table V). Isolates, manufactured specifically for soy-based infant formulas, do

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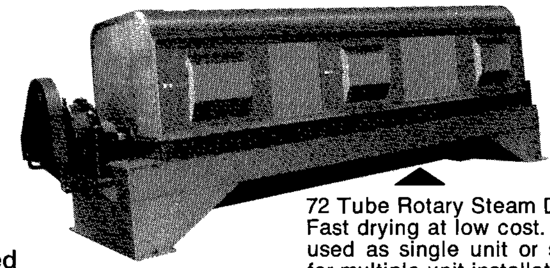

72 Tube Rotary Steam Dryers—Fast drying at low cost. Can be used as single unit or stacked for multiple unit installations.

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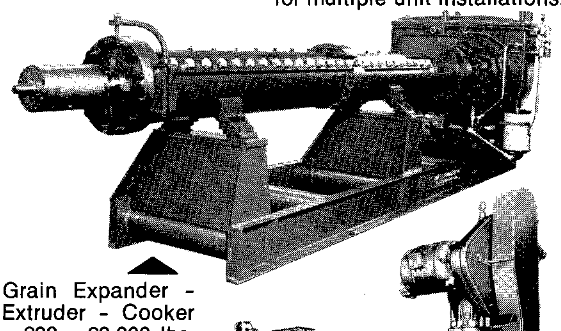
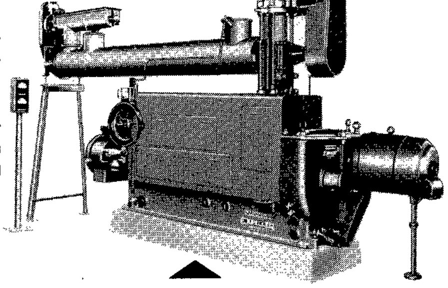
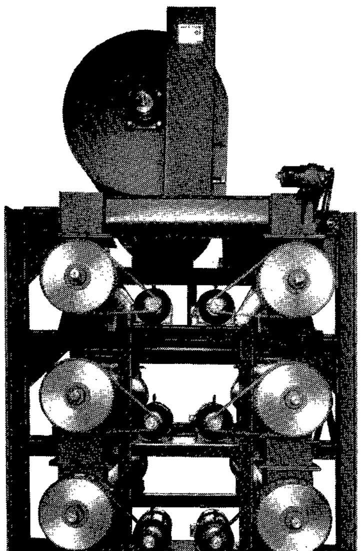


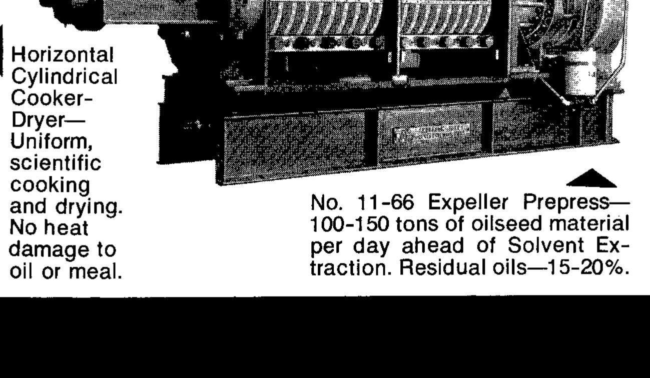
Grain Expander - Extruder - Cooker —200 - 20,000 lbs. per hour depending on material being processed. Produces human snacks, meat extenders, textured vegetable protein and pet foods.



Expeller Press — Capacity ranges from 3-40 tons of oilseed material per day, full press. Residual oils—3-12%.



Horizontal Cylindrical Cooker-Dryer—Uniform, scientific cooking and drying. No heat damage to oil or meal.



No. 11-66 Expeller Prepress—100-150 tons of oilseed material per day ahead of Solvent Extraction. Residual oils—15-20%.

TABLE V

Zinc Requirement and Carrier Capacity of Soy Protein Products as Sole Source of Protein in Diet

Product	Supplementation, Zinc, ppm	Solubility of ^{65}Zn, %
Soybean meal	none	28
Soy protein isolate-A	15	7
Soy protein isolate-B	30	2

Solubilization of ^{65}Zn from an insoluble ^{65}Zn-labeled phytate complex at intestinal pH of 6.8. Lease J. Nutr. 93:523 (1967).

more valuable the oil is, the less expensive the other products need to be to make the crop a profitable one for growers, and vice versa.

TABLE VI

Flavor Scores and Enzyme Activity of Processed Soy Flakes

Processing conditions	Flavor scores*	Lipoxygenase μmoles O_2/min/g	Peroxidase, absorbance units
Hexane-defatted, raw	4.0	248	1584
Hexane-defatted, toasted	6.6	0.4	225
3 hr, azeotrope-extd	7.5	1.8	1840
3 hr, azeotrope-extd (toasted)	7.9	0.5	71

*15-member taste panel, scores based on 1 for strong; 10 for bland.

not require supplemental zinc (11). Rackis also points out that "alpha protein" used in some lab diets as a sole source of protein is not intended as a foodstuff at all, but is used as a paper coating and sizing agent.

While the causes for problems such as flatulence and antinutritional factors associated with use of soy protein in food have been virtually solved, the question of flavor has remained the last major roadblock. Commercial flours, concentrates, and isolates produced odor scores of 5.8 to 7.5 and flavor scores of 4.2 to 6.6 (a score of 10 would be perfectly bland) in one test of 18 samples. New solutions appear near. Hexane-ethanol azeotrope extraction can be used to produce soy flour and concentrates with flavor scores approaching the blandness of wheat flour (13). Toasting after azeotropic extraction has raised flavor scores of soy flours and concentrates to 7.9, a value that compares favorably with 8.1 for wheat flour. Odor also was judged the same as that of wheat flour by an experienced taste test panel (Table VI).

The use of soybean lipoxygenase in breadmaking and application of enzymes to modify functional properties have been reviewed in other literature (14).

While there are many potential sources of protein for the human diet, in the foreseeable future, soybeans appear to be the most likely source. The use of soybean oil is important to the potential use of soybean protein in that the more valuable the oil is, the less expensive the other products need to be to make the crop a profitable one for growers, and vice versa.

BIBLIOGRAPHY

1. National Science Foundation. Protein Resources and Technology. Status and Research Needs (Research Recommendations and Survey, Vol. 1, Washington, DC, 1976).
2. Milner, M., "How Can Science Expand World Protein Resources," Soya Protein Conference and Exhibition, London, American Soybean Association, Hudson, Iowa, 1975.
3. "World Soybean Research Proceedings of the World Soybean Research Conference," Edited by L.D. Hill, Interstate Printers and Publishers, Inc., Danville, IL, 1976.
4. Anton, J.J., "Good Market Climate Nurtures Soy Industry Growth," Food Product Development, 9(8):96.
5. Johnson, D.W., "World Soybean Research Proceeding of the World Soybean Research Conference," Edited by L.D. Hill, Interstate Printers and Publishers, Inc., Danville, IL, 1976, pp. 1014-17.
6. Food and Agriculture Organization of the United Nations 1970. Production Yearbook, Vol. 24, FAO, Rome.
7. Yong, M.L., and A.M. Gavin, "Palm Oil Expansion to Continue," JAOCS 53:660A (1976).
8. "Soybeans: Chemistry and Technology," Vol. 1, Edited by A.K. Smith and S.J. Circle, AVI Publishing Co., Westport, CT, 1972.
9. Rackis, J.J., "Biological and Physiological Factors in Soybeans," JAOCS 51:161A (1974).
10. Rackis, J.J., J.E. McGhee, and A.N. Booth, "Biological Threshold Levels of Soybean Trypsin Inhibitor by Rat Bioassay," Cereal Chemistry 52:25 (1975).
11. Churella, H.R., and V. Vivian, "The Effect of Phytic Acid in Soy Infant Formulas on the Availability of Minerals for the Rat," Federation Proceedings 35(3): Abstract No. 2972 (1976).
12. Rackis, J.J., "Processing Soybeans Into Foods: Selected Aspects of Nutrition and Flavor," JAOCS 52:249A (1975).
13. Honig, D.H., K. Warner, and J.J. Rackis, "Toasting and Hexane: Ethanol Extraction of Defatted Flakes: Flavor or Fours, Concentrates, and Isolates," J. Food Science 41:642 (1976).
14. Rackis, J.J., "Enzymes in the Beverage and Food Industry," American Chemical Society Symposium Series, in press.

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