Cottonseed Protein Food Products

C.M. CATER,[1] **K.F. MATTIL, W.W. MEINKE, M.V. TARANTO,** and **J.T. LAWHON,**
Food Protein Research and Development Center, Texas A&M University, College Station, Texas 77843, and **B.B. ALFORD,** Texas Woman's University, Denton, Texas 76204

ABSTRACT AND SUMMARY

Upward trending world population and increasing costs for traditional food proteins provide many incentives for utilization of oilseed proteins directly in human diets. Cotton, as one of the world's major oilseed crops, represents a potential source of food protein. Acceptability of oilseed protein products in terms of functional properties in food systems and nutritional value will largely determine the extent of their utilization by the food industry. Liquid cyclone process cottonseed flour, defatted glandless cottonseed flour, storage protein isolates, and cottonseed whey proteins have been evaluated by various functionality tests and in a number of food systems. The cottonseed flours have been subjected to processing by extrusion texturization. Human feeding studies have also been conducted. Results indicate a good potential for use of cottonseed protein products in a variety of food systems.

It is generally accpeted today that, in order to adequately feed the world's rapidly expanding population in the future, plant proteins must be used directly in the human diet in increasing amounts. The most readily available new sources of food proteins in large quantities are the oilseeds. Secretary of Agriculture Earl L. Butz, in his address to the World Soy Protein Conference in Munich, 1973 (1), referred to the current use of textured soy protein in the U.S. school lunch program and said, "At present, these textured vegetable proteins are derived entirely from soybeans, but it is possible that cottonseed, peanuts, safflower seed, sunflower seed, and grains will be used increasingly as well. In USDA programs, plant proteins are blended with other foods, and the combination results in foods with a better balanced amino acid pattern than if these foods were used alone." Textured soy proteins are but one of a spectrum of new protein foods being developed by food scientists to meet nutritional needs and consumer demands around the world.

Cottonseed, sunflower seed, peanuts, coconuts, sesame, rapeseed, and others hold a similar potential. These crops have been traditionally produced and processed as a source of edible oil and the defatted protein residue has been used as a source of animal feed. It is the conversion of these defatted protein residues into food ingredients which offers the greatest immediate opportunity for increasing the supply of food-grade protein for human consumption.

As we look to the future, we must consider many factors in determining the allocation of available land and energy resources necessary to produce crops which will yield the maximum amount of products for man's use. From this standpoint, cotton should rank well up in the priorities for crop production in the future since it is the only crop which, from the same plant, provides not only a renewable resource of fiber for man's clothing and industrial use, but edible oil and protein for his food and feed for his animals. The food use of cottonseed protein is not nearly so new an idea as many people might think. Cottonseed protein has been processed and marketed in this country as a food additive since the 1930s. Small quantities, usually less than 5%, of this cooked defatted cottonseed flour product were added to improve dough machinability and control cookie spread, to reduce fat absorption during frying of doughnuts, to improve browning of bakery products, to combat "oiling off" or loss of oil from the coating on chocolate candies, and many other uses. However, this use was primarily for the functional properties of cottonseed protein rather than for its nutritional qualities.

Cottonseed protein became quite widely known as a potential source of nutrients for humans during the late 1950s and the 1960s as a result of the development by Scrimshaw et al. (2) at the Institute of Nutrition of Central America and Panama of the low-cost food product called INCAP vegetable mixture 9 or "Incaparina."

Although the production of Incaparina utilized two million pounds of cottonseed in Colombia and Guatemala in 1964 (3) and is still being manufactured today, the need for low-cost protein foods with good consumer acceptance still exists in these countries and round the world. Although cottonseed protein has demonstrated, in Incaparina, that it is an acceptable source of food protein, one of the principal deterrents to wider acceptance and use has been the presence of the pigment gossypol.

Research during the past 50 years has developed a number of products from cottonseed which have potential for food use. These include defatted flours produced by pre-press solvent extraction from glanded cottonseed or direct solvent extraction from glandless cottonseed, which have a protein content of 55 to 60%. A relative newcomer is liquid cyclone process (LCP) cottonseed flour which contains 65% or more protein. The LCP flour was developed at the Southern Regional Research Center in New Orleans (4) and involves the centrifugal separation of intact pigment glands from the cottonseed protein in a hexane slurry. Cottonseed protein concentrates may be also produced by air-classification of defatted flours (5) or by water extraction (6,7). The essential amino acid content of some of thesyproducts is shown in Table I. Air-classification of defatted glandless cottonseed flour increased the protein content from 63.3% initially to 68.3% on a moisture-free basis (mfb) in the high protein fraction. This increase resulted primarily from the removal of fiber rather than from any significant fractionation of the protein as can be seen in the minimal differences in essential amino acid content. The wet process concentrates shown in Table I contained 74.3% and 73.5% protein (mfb) respectively in the products dried at pH 4.5 and 6.8. The extraction to produce these materials was conducted at pH 4.0, the point of minimum solubility of the low-molecular weight nonstorage protein. This accounts for the small changes seen in essential amino acid content between the starting defatted glandless cottonseed flour and the concentrates. The slight increase in valine, methionine, isoleucine, leucine, and phenylalanine seen in the concentrate dried at pH 4.5, probably results from a partial extraction of storage protein which is soluble in the acid pH range. Note, in particular, the content of available lysine in these products. Lysine is considered by some researchers to be the "first-limiting" amino acid in cottonseed and, consequently, the amount present in "available" form (i.e., having a free epsilon-amino group) is of considerable nutritional significance.

More highly purified products in the form of cottonseed protein isolates may be prepared by classical isolation or by the selective precipitation (Process B) (8) or two-step extraction (Process C) (9) procedures developed by Berardi et al. Each of the latter two procedures produce two protein isolates from cottonseed. The major fraction is a high molecular weight material which is designated "storage

[1] Deceased

TABLE I

Essential Amino Acid Content of Cottonseed Flours and Protein Concentrates

Amino acids	LCP[a] flour	Glandless cottonseed flour for wet proc.	Wet process protein conc. dried at pH 4.5	Wet process protein conc. dried at pH 6.8	Air classif. protein conc.	Glandless cottonseed flour for air classif.
			(g/16gN)			
Lysine	4.2	4.0	3.6	4.0	4.0	4.2
Trypotphan	1.4	1.5	1.4	1.5	1.5	1.5
Threonine	3.1	3.2	3.2	3.1	3.1	3.2
Valine	4.4	4.5	4.9	4.9	4.4	4.4
Methionine	1.5	1.4	1.8	1.5	1.6	1.6
Isoleucine	3.0	3.1	3.4	3.2	3.0	3.1
Leucine	5.7	6.0	6.4	6.2	5.7	5.7
Phenylalanine	5.7	6.0	6.3	6.2	5.3	5.3
Available lysine	3.6	3.8	3.1	3.1	3.6	3.5

[a]LCP = liquid cyclone process.

TABLE II

Essential Amino Acid Content of Products from Pilot Plant Protein Isolation Using Glandless Cottonseed Flour

Amino acids	Process B			Process C		
	NSP isolate	SP isolate	Residue II	NSP isolate	SP isolate	Residue III
			(g/16gN)			
Lysine	4.7	2.8	3.8	6.2	2.9	4.3
Tryptophan	1.3	1.1	1.3	1.6	1.0	0.9
Threonine	3.4	2.5	2.8	3.4	2.6	3.2
Valine	4.8	4.6	3.8	4.6	4.6	4.4
Methionine	1.9	1.1	1.4	1.9	1.1	1.4
Isoleucine	3.3	3.1	2.9	3.4	3.0	3.2
Leucine	6.8	5.7	5.4	6.4	5.6	6.2
Phenylalanine	5.3	6.6	4.7	4.1	6.3	4.9
Available lysine	4.7	2.8	3.8	6.2	2.8	4.1

TABLE III

Essential Amino Acid Content of Products from Pilot Plant Protein Isolation Using Liquid Cyclone Process Cottonseed Flour

Amino acids	Process B			Process C		
	NSP isolate	SP isolate	Residue II	NSP isolate	SP isolate	Residue III
			(g/16gN)			
Lysine	5.3	3.3	3.6	6.0	2.9	4.5
Tryptophan	1.5	1.8	1.1	1.6	1.0	1.1
Threonine	3.5	2.8	2.9	3.0	2.4	3.7
Valine	5.1	4.6	3.9	4.9	4.8	4.6
Methionine	2.1	1.2	1.1	2.9	1.0	1.3
Isoleucine	3.7	3.2	2.7	3.8	3.3	3.3
Leucine	7.0	6.0	5.2	6.8	6.0	6.4
Phenylalanine	5.4	6.2	4.3	4.7	6.5	4.6
Available lysine	5.2	3.1	3.6	5.6	2.7	4.2

protein" (SP) and the minor fraction is lower in molecular weight and is called "nonstorage protein" (NSP).

Repeated runs using these two isolation procedures were conducted in the pilot plant of the Food Protein Research and Development Center at Texas A&M University. Samples of the protein isolates were freeze-dried for amino acid analysis. The average values for the essential amino acid content of the products of these two processes are shown in Tables II and III. Most of these essential amino acids are present in higher amounts in the NSP than in the SP isolate. It should be noted that some differences exist in the essential amino acid content of the NSP isolates from Process B and C as compared with those given by Martinez and Hopkins (11). Several factors may account for these differences including different varieties of cottonseed as starting material, spray-drying versus freeze-drying of isolates, and analytical variation. However, probably the most important difference may lie in the fact that in Process C, the selective extraction process, the first extraction to produce the NSP isolate is made with tap water. The ionic content and concentration of municipal water supplies across the country varies widely. In College Station, Texas, the predominant cation is sodium while in many other parts of the country it is calcium. This can cause variation in the solubilization of protein fractions.

Of particular nutritional importance is the partitioning of the lysine content between the SP and NSP isolates. Note that the available lysine content of the glandless products is almost the same as total lysine while in the LCP products it is somewhat lower. This is probably the result of the presence of low levels of bound gossypol. Defatted glandless and LCP cottonseed flour have protein efficiency ratios (PERs) of around 2.5 (10) which is equal to casein. When oilseed proteins are fractionated to produce concentrates and isolates, the PER of the end products is frequently lowered, with concentrates being around 2 and isolates 1.7 or less. However, in the case of the NSP cottonseed protein isolate, the nutritional value is higher (2.7 to 3) (11) than the starting material as could be noted by the increase in essential amino acids. The purpose of the fractionation of oilseed proteins, however, is to produce materials with specific functional properties which will enhance some aspect of the food product in which they are sued. This improvement may be in the form of better tex-

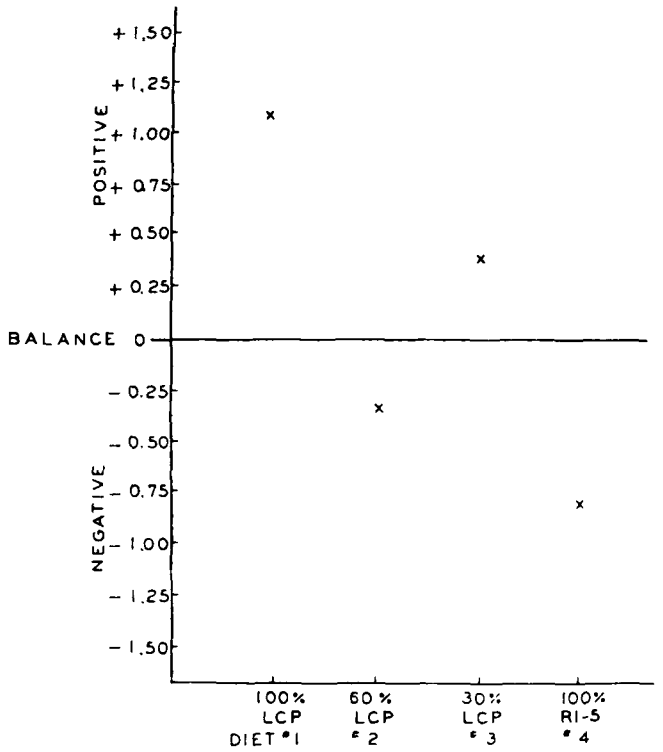

FIG. 1. The mean nitrogen balance for all subjects on each diet.

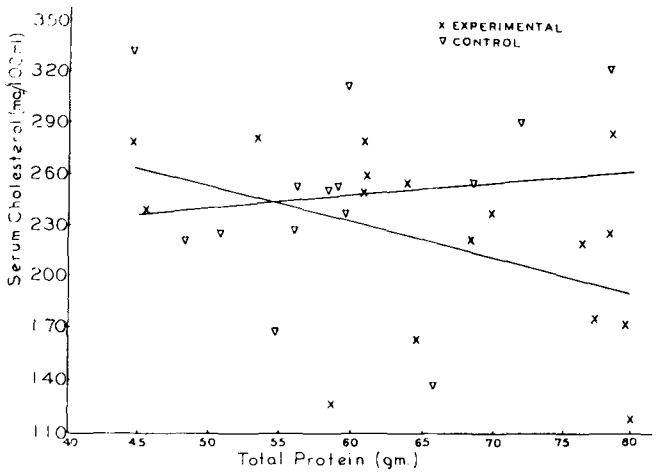

FIG. 2. Total protein intake vs. final serum cholesterol.

ture, flavor, moisture retention, fat emulsification or many other factors. The result is a food which consumers will buy repeatedly and consume readily. What must be remembered, in considering reductions in the nutritive value of specific food ingredients in the enhancement of their functional properties, is that these ingredients are not consumed individually as the sole source of protein but, instead, in combination with a number of other proteins. The overriding concern, therefore, must be for the nutritive value of the total diet rather than for individual ingredients. Adequate protein nutrition can be achieved in several ways from a variety of sources, for example: (a) all animal protein; (b) a mixture of animal and vegetable proteins; (c) a blend of vegetable proteins; (d) vegetable proteins supplemented or fortified with certain essential amino acids.

Investigations in the replacement of a portion of the animal protein with cottonseed protein in a typical American dietary pattern for two age groups have recently been completed by Dr. Betty B. Alford and coworkers at Texas Woman's University in Denton, Texas. This study was conducted under contract with the USDA Southern Regional Research Center and utilized LCP cottonseed flour produced at the Center in New Orleans and defatted glandless cottonseed flour prepared by the Food Protein Research and Development Center at Texas A&M University.

In order to determine the quality of the LCP cottonseed protein, 12 female college students were maintained on liquid formula diets containing different levels of this cottonseed protein for a period of 5 wk. Overall protein status was determined by assessing nitrogen balance of the subjects. Each subject consumed 15% of her total caloric intake as protein. Four experimental diets containing 100% (#1), 60% (#2), 30% (#3), and 0% (#4) of LCP cottonseed protein (CSP) were fed with the balance being made up of casein-based control protein of high biological value. Results indicated a significant difference between Diet #1 (100% CSP) with a positive result and Diet # (4) (100% control protein) with a negative result; however, both values were within the range of individual variation (Fig. 1). Larger and longer term studies will be required to confirm the apparent trend toward positive nitrogen balance with CSP.

An extended feeding study was conducted utilizing as subjects children, ranging in age from 8 to 17 yr, who resided in childrens' homes. Fifty percent of animal protein was replaced by cottonseed protein in the experimental diets. The study consisted of an experimental and a control group and was divided into two phases, each lasting at least 6 mo. Experimental and control groups were paried as closely as possible for height, weight, age, sex, etc. Menus for the control group corresponded closely with those of the experimental group except for the omission of CSP. The studies were conducted under clinical supervision and medical records maintained. Anthropometric and biochemical measurements were utilized to evaluate nutritional status.

Study of a summary of percentile ranking for height for subjects revealed increased growth in a number of the CSP group. Although a larger sample would be necessary to say with confidence that CSP was responsible for the increase in height, the trend was evident. What is more important, however, is that CSP did not have a deleterious effect on growth as exhibited by height.

When ranked according to weight of subjects during both phases, there were essentially no differences between the experimental and control groups. Also, no differences were observed in skeletal maturation or bone density.

Biochemical testing failed to show any statistically significant differences in hemoglobin or hematocrit. Plasma Vitamin A value differences were not significant. No differences were found in serum carotene, ascorbic acid, or urinary B vitamins.

Although there was an increase in both total protein and albumin in Phase II, this held true for both groups with no significant differences between them. All values were within the normal range. Serum calcium and phosphorus values were within normal ranges and showed no differences.

Differences in serum cholesterol between groups were not signifcant.

Another study to investigate the nutritional value of glandless cottonseed protein in the diets of older subjects was conducted with residents of two nursing homes. The incentives for this study were: (a) to provide a source of low-cost, good quality protein for the low-income elderly; and (b) to determine if this source of protein has any serum cholesterol-lowering effect.

The experimental group on CSP maintained their weight better than the control group. Data on total protein and albumin indicated no significant differences resulting from the substitution of 25% CSP in their diet for conventional proteins.

Serum cholesterol concentrations versus total protein intake were also evaluated for this group (Fig. 2). Although

no statistically significant differences in the means of serum cholesterol levels existed at either the start or the end of the study, the trend in mean of serum cholesterol level of the experimental group was a decrease in relation to the levels of the control group.

One of the areas of greatest immediate market potential for food use of cottonseed proteins is that of extrusion textured protein (ETP) for extending ground meat. Preliminary investigations at Texas A&M with a Wenger Model X-5 Laboratory Extruder have produced ETP products from LCP and glandless cottonseed flours as well as from soy products processed in the same equipment. Although a degree of texturization of these cottonseed products has been achieved, under the same conditions of temperature, screw speed, feed-rate, and screw and extruder barrel configuration, products with different characteristics from those of soy were initially produced. There was a greater degree of expansion as the extrudate exited from the die, resulting in a more porous structure of lower bulk density than extruded soy products. Subsequent studies with the Wenger X-5 and a larger Prodex Torquemaster Model extruder have revealed that modifications in the conditioning of cottonseed protein prior to extrusion and changes in the internal geometery of the extruder produce products equal in density and texture to soy products. This work was reported at the Institute of Food Technologists Meeting in Anaheim, California, in June, 1976.

Evaluation of Wenger X-5 processed cottonseed and soy products in comparison with commercial soy products as extenders in ground meat patties produced the results tabulated in Table IV. All patties containing cottonseed or soy ETP had significantly less shrinkage than the all-meat control. The various soy and cottonseed products were generally similar in their performance. Organoleptic testing of these products produced scores equal to or greater than the all-meat patties.

There are many other possible uses for cottonseed protein products in a wide variety of food systems. Martinez et al. (12) have reported that the SP isolate may be used to fortify bread at levels up to 10% without adversely affecting loaf volume or quality. This same isolate is soluble in the acidic pH range, thus offering the possibility of acid-beverage fortification. It is also heat coagulable and will form gels. Lawhon et al. (13) have demonstrated the high solubility and whippability properties of the cottonseed whey proteins for which they have developed membrane processing technology to recover them from the waste water of cottonseed protein isolate production.

In summary, the array of protein products which can be produced from cottonseed represents a desirable addition to the currently available supply of food proteins. As the demand for food proteins increases, research must keep pace with a supply of acceptable products to meet these needs.

TABLE IV

Shrinkage of Meat Patties Cooked by Oven Broil Method

Patty formulation[a]		Shrinkage[b]
All Meat		39.0
CSF ETP, Wenger[c]:	20%	28.5
	30%	29.9
Soy ETP, Wenger[c]:	20%	26.8
	30%	25.2
Soy ETP, Industrial:	20%	26.2
	30%	29.2
Soy ETP, Industrial:	30%	26.3
LCP ETP, Wenger[c]:	30%	28.3
Soy ETP, Wenger[d]	30%	27.1
CSF ETP, Wenger[e]	30%	23.3

[a]20% fat raw basis; frozen prior to boiling.

[b]All patties had significantly less shrinkage ($P<.05$) than all meat control.

[c]Prepared from undenatured flours. CSF = cottonseed flour, ETP = extrusion textured protein, LCP = liquid cyclone process.

[d]Prepared from denatured (low protein solubility) flour.

[e]Prepared from CSF autoclaved for 15 min at 15 lb steam pressure.

ACKNOWLEDGMENT

Appreciation is expressed for the data on the Texas Woman's University Feeding Studies which were provided by Dr. Betty B. Alford, Associate Professor, Texas Woman's University, and were derived from the final report on USDA Contract No. 12-14-100-11056 (72), with the Southern Regional Research Center in New Orleans, LA.

REFERENCES

1. Butz, E.L., JAOCS 51:57A (1974).
2. Scrimshaw, N.S., M. Behar, D. Wilson, T. Viteri, G. Arroyani, and R. Bressani, Am. J. Clin. Nutr. 9:196 (1961).
3. Scrimshaw, N.S., and R. Bressani, Publication 1-160, INCAP, Guatemala.
4. Gastrock, E.A., Proc. of Conf. of Protein-Rich Food Products From Oilseeds, New Orleans, LA, May 15-16, 1968, p. 26-31.
5. Martinez, W.H., Ibid. p. 33-39.
6. Martinez, W.H., L.C. Berardi, and L.A. Goldblatt, J. Ag. Food Chem. 18:961 (1970).
7. Lawhon, J.T., L.W. Rooney, C.M. Cater, and K.F. Mattil, J. Food Sci. 37:778 (1972).
8. Berardi, L.C., C.J. Fernandez, and W.H. Martinez, Cottonseed Protein Isolates: Selective Precipitation Procedure, Presented at the 32nd Annual Meeting of the Institute of Food Technologists, Minneapolis, MN, May 22-24, 1972.
9. Berardi, L.C., W.H. Martinez, and C.J. Fernandez, Food Technol. 23:75 (1969).
10. Ridlehuber, J.M., and H.K. Gardner, Jr., JAOCS 51:153 (1974).
11. Martinez, W.H., and D.T. Hopkins, Cottonseed Protein Products: Variation in Protein Quality with Product and Process in 14th Nutritional Quality of Foods and Feed. Part II. Quality Factors: Plant Breeding, Composition, Processing and Anti-Nutrients. Ed. by M. Friedman, Marcel Dekker, New York, NH 1975, pp. 355-374.
12. Martinez, W.H., W.G. Bechtel, and T.T. Lehman, Glandless Cottonseed Protein Products in Bread. In abstracts of papers, Am. Assoc. of Cereal Chem., 54th Annual Meeting, Chicago, April, 1969. Cereal Sci. Today, Abstract No. 163, March 1969.
13. Lawhon, J.T., S.H.C. Lin, L.W. Rooney, C.M. Cater, and K.F. Mattil, J. Food Sci. 39:183 (1974).

[Received May 27, 1976]