Defatted Soy Flour and Grits

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ABSTRACT

Defatted soy flour and grits are the most rudimentary forms of high protein products processed from the soybean, yet they are the soy products used in the largest volume by the food industry. To appreciate fully the contribution of defatted soy flour and grits to any food system, it is essential that a knowledge of the composition, nutritional value, and functionality of these products be well understood. Major emphasis is given to applications for defatted soy flour and grits with cereals.

INTRODUCTION

Man's investigations in the field of nutrition have never been more intensive than they are today. Perhaps this new concern is a result of a recognition that prophecies of a world food shortage may be at hand. Or, could it be that man's increasing insight into the relationships between diet and disease has stimulated him to research this area more aggressively? Maybe this concern has arisen from the rising cost of food, and it simply represents an effort by man to feed himself more efficiently and more economically. Whatever the stimulus may be, we have all learned to appreciate more fully the value of products produced from the soybean. The soybean is an efficient means of producing a low cost protein. It is a rich source of high quality protein. Soy protein products can be processed to have functional properties which are highly compatible with traditional food ingredients in today's food products.

The protein products produced from the soybean which are used in the largest volumes by food manufacturers are defatted soy flour grits. Defatted soy flour and grits are the most economical source of soy protein available. Yet, the nutritional value of these products is superior to that of the refined protein products processed from soybeans. In addition, defatted soy flour and grits have functional properties which make them versatile food ingredients. To comprehend the total contribution of defatted soy flour and grits in foods, it is essential that we have good understanding of the composition, nutritive value, and functionality of these products.

PRODUCTS AND PROCESSING

Defatted soy flour and grits are processed from cleaned, whole soybeans which have been dehulled, then defatted by solvent extraction techniques. The general steps involved in the production of defatted soy flour and grits are illustrated in Figure 1. Precise control of the degree of heat treatment given the defatted soy flakes during the desolventizing process and during subsequent steps is critical in that both the nutritive value and functionality are directly dependent upon the degree to which the product is heat treated. The standard indices used to measure the degree of heat treatment given defatted soybean products are listed in Table I. Soy flour and grits are differentiated only on the basis of particle size. Soy flour is milled to have a particle size finer than 100 mesh, U.S. Standard Sieve Size, while soy grits have a particle size larger than 100 mesh, U.S. Standard Sieve Size. A list of commercially available forms of defatted soy flour and grits is presented in Table II. These products are differentiated on the basis of particle size and degree of heat treatment.

COMPOSITIONAL INFORMATION

The protein fraction of the soybean has been studied intensely while other components have been, for the most part, overlooked. Information on the content of both major and minor constituents of defatted soybean products is presented here.

Because of variables, such as the variety of seed planted the weather, the soil, the growing season, and the farming practices, the content of each component in the soybean varies (1,2). Therefore, only typical values or ranges of values are presented here to describe the composition of defatted soy flour and grits.

A proximate analysis of defatted soy flour and grits is presented in Table III. Researchers have questioned the accuracy of using a nitrogen to protein conversion factor of 6.25 (3,4). There is general agreement that a smaller conversion factor would more accurately represent the protein content of soybean products though the 6.25 factor continues to be used by agronomists, commercial handlers and processors of soybeans, and by various technical associations. A profile of the amino acid content in defatted soy flour and grits is shown in Table IV. Considerable efforts have been made to compare the amino acid content of different varieties and strains of soybeans, with special emphasis on methionine, the first limiting essential amino acid in soy protein (1,5). Unfortunately, no varieties or strains of soybeans have been found yet which contain a significantly higher concentration of methionine.

The carbohydrate content of untoasted, defatted soy flour is presented in Table V. The oligosaccharides, raffinose and stachyose, have been implicated as causative factors for the flatulence often experienced when consuming foods containing soybean products (6). Recent investigations by Wuhrmann and coworkers (7) indicate that verbascose, a pentasaccharide of the raffinose family, also may contribute to the production of intestinal gas. Results obtained from Cargill's Research Center indicate that heat treatment reduces the quantity of free oligosaccharides in defatted soybean products.

The vitamin and mineral content of defatted soy flour and grits is shown in Tables VI and VII.

NUTRITIONAL INFORMATION

Defatted soybean products are used widely in animal

Cleaned whole soybeans
↓
Crack
↓
Dehull → Soy hulls
↓
Temper
↓
Flake
↓
Solvent extraction → Soybean oil
↓
Desolventize
↓
Heat treatment
↓
Mill
↓
Size classification
↓
Soy flour–Soy grits

FIG. 1. Production of defatted soy flour and grits.

TABLE I

Standard Methods for Measuring Heat Denaturation of Soy Flour and Grits

Abbreviation	Term	Definition
PDI	Protein dispersibility[a] index	Percentage of total protein which is dispersible in water under controlled conditions of extraction
NSI	Nitrogen solubility[b] index	Percentage of total nitrogen which is soluble in water under controlled conditions of extraction

[a]AOCS method BA 10-65.
[b]AOCS method BA 11-65.

TABLE V

Carbohydrate Content of Untoasted Soy Flour

Carbohydrate	Quantity (Percent)
Hexose	Trace
Sucrose	5.7
Stachyose	4.6
Raffinose	4.1
Neutral arabinogalactan	8-10[a]
Acidic polysaccharide	5-7[a]
Arabinan	1[a]

[a]Source: Aspinall personal communication.

TABLE II

Commercial Types of Defatted Soy Flakes, Grits, and Flours

Product	Granulation (U.S. Standard Sieve Size)	Heat treatment (PDI)[a]		
		20-40	60-75	85+
Flakes	+5 mesh	X	X	X
Coarse grits	−5/+20 mesh	X	X	
Medium grits	−20/+40 mesh	X	X	
Fine grits	−40/+80 mesh	X	X	
Standard flour	−100 mesh	X	X	X
Fine flour	−200 mesh	X	X	X

[a]PDI = protein dispersibility index.

TABLE III

Proximate Analysis of Defatted Soy Flour

Component	Quantity
Protein (N x 6.25)	51.5
Nitrogen	8.2
Moisture	7.0
Fat (ether extract)	1.0
Fat (acid hydrolysis)	3.5
Fiber	3.0
Ash	5.8
Carbohydrates	30.0

TABLE IV

Amino Acid Content of Defatted Soy Flour and Grits

Amino acid	Quantity (mg/16 g N)	Quantity (g/100 g flour)
Essential amino acid		
Cystine	1.22	0.62
Isoleucine	4.69	2.39
Leucine	7.90	4.03
Lysine	6.25	3.19
Methionine	1.27	0.65
Phenylalanine	5.27	2.69
Threonine	3.86	1.97
Tryptophan	1.27	0.65
Valine	5.08	2.59
Nonessential amino acid		
Alanine	4.39	2.24
Arginine	7.06	3.60
Aspartic acid	11.78	6.01
Glutamic acid	19.61	10.00
Glycine	4.33	2.21
Histidine	2.84	1.45
Proline	5.22	2.66
Serine	4.92	2.51
Tyrosine	3.78	1.93

TABLE VI

Vitamin Content of Defatted Soy Flour

Vitamin	Quantity
Vitamin A	0.7-40 International units
Vitamin C	0
Thiamin	1.10-1.50 mg/100 g
Riboflavin	0.24-0.44 mg/100 g
Niacin	4.09-6.70 mg/100 g
Vitamin D	0
Vitamin E	1.5 International units
Vitamin B_6	0.48-1.20 mg/100 g
Folic acid	0.03-0.09 mg/100 g
Vitamin B_{12}	0.06-0.20 mg/100 g
Biotin	0.17-0.66 mg/100 g
Pantothenic acid	1.3-5.1 mg/100 g
Choline	2.2-3.8 mg/100 g

TABLE VII

Mineral Content of Defatted Soy Flour and Grits

Mineral	Quantity	
Aluminum	2.33	mg/100 g
Arsenic	0.01	mg/100 g
Calcium	220.00	mg/100 g
Chlorine	132.0	mg/100 g
Cobalt	0.05	mg/100 g
Copper	2.3	mg/100 g
Fluorine	0.14	mg/100 g
Iodine	0.001	mg/100 g
Iron	11.0	mg/100 g
Lead	0.02	mg/100 g
Magnesium	309.0	mg/100 g
Manganese	2.8	mg/100 g
Phosphorous	680.0	mg/100 g
Potassium	2360.0	mg/100 g
Selenium	0.06	mg/100 g
Sodium	25.4	mg/100 g
Sulfur	250.0	mg/100 g
Zinc	6.1	mg/100 g

TABLE VIII

Relationships between Heat Treatment, Nutritive Value, and Activity of Selected Antigrowth Factors

Heat treatment		PER[a]	Antigrowth factor activity[b]		
Degree	PDI[c]		SBTI	Urease	Hemagglutinin
Untoasted	85+	1.31	500 Units	2.10	52 Units
Lightly toasted	60-75	1.59	150 Units	1.70	51 Units
Fully toasted	20-40	2.19	15 Units	0.10	14 Units

[a]PER = protein efficiency ratio. Values corrected so that casein standard has a PER of 2.50.

[b]SBTI = soybean trypsin inhibitor. Assay performed by Cargill method. Urease–assay by pH rise AOCS method BA 9-58. Hemagglutinin–method of Liener, Arch. Biochem. Biophys. 54:223 (1955).

[c]PDI = protein dispersibility index. AOCS-MOCS method 10-65.

feeds and human foods primarily because they are a rich source of high quality protein. To optimize the nutritional value of defatted soybean products, they must be subjected to a heat treatment process. The heat treatment partially or wholly destroys factors which interfere with the digestion and utilization of soy protein. The beneficial effect of destroying antigrowth factors by heat treatment outweighs the adverse effects of heat denaturation of the protein, as shown in Table VIII. Excessive heat treatment will result in damage to the protein. Of greatest significance is the damage done to the sulfur-containing amino acids and to lysine. Palatability also is decreased by overtoasting. Rat feeding tests conducted at the Cargill Research Center indicate that the nutritional value of the protein in toasted soy flour is improved markedly by the addition of methionine. By adding 0.60% dl methionine to toasted soy flour, the protein efficiency ratio (PER) was raised from 2.17 to 2.69, with the casein control having a corrected PER of 2.50.

Most applications for defatted soy flour and grits involve their combination with cereals. Their addition raises both the quantity and quality of the protein in cereal products. The quantity of the protein is raised because defatted soybean products contain more protein than do cereal products, as shown in Table IX. The quality of the protein is improved in soy-cereal mixtures because soy protein is a rich source of lysine, the first limiting essential amino acid in most cereal proteins. Table X illustrates the nutritional improvement in pasta when soy flour is mixed with durum wheat flour.

High percentages of soy flour have been incorporated successfully into white bread (8,9). By the addition of 12% soy flour in wheat bread, the lysine content of the bread is more than doubled, and the protein content is increased by 30%.

Similar improvements in the nutritive value of corn flour and rice flour by the addition of soy flour are well documented (10,11). A recognition of the need for better nutrition in cereal-based foods has prompted the development of several types of soy-cereal mixtures of which the most widely known is CSM. CSM is a mixture of corn meal, soy flour, nonfat dry milk, soybean oil, and a vitamin-mineral premix. This protein enriched mixture has an amino acid pattern which closely conforms to the 1965 FAO reference pattern which is based upon whole egg protein. Other examples of commercially developed mixtures based on soy flour are wheat-soy blend (WSB), soy fortified bread wheat flour (containing 6% and 12% soy flour), soy fortified bulgar, and soy fortified rolled oats. The U.S. Department of Agriculture has permitted the use of a soy fortified macaroni as a nutritional alternate for meat in federally supported child feeding programs. This decision recognizes that protein mixtures can be formulated to have about the same nutritional value as animal proteins.

FUNCTIONAL PROPERTIES

Functional properties refer to those characteristics which describe how a product performs in a defined application. For defatted soy flour and grits, functionality relates to such properties as water absorption capacity, emulsifying capacity, and adhesiveness. These properties are primarily dependent upon the degree to which the protein is denatured and, secondarily, on the particle size. Functionality is greatest in untoasted products and is reduced in proportion to the degree of heat treatment. The ability of undenatured flour and grits to absorb water, emulsify fat, and bind is significantly greater than for lightly toasted products and vastly greater than for fully toasted flour and grits. Products with finer particle sizes tend to have slightly more functionality than do coarse products.

To optimize the way a soy ingredient performs in a food system, it is, therefore, necessary to consider both the degree of heat denaturation in the soy flour and the granulation. Having the ability to select the desired functionality in a soy product enables the food technologist to produce mixtures of soy and cereals which closely resemble the cereal alone with respect to most handling and cooking properties. Now, it is possible to reformulate traditional foods with soy flour without causing a significant change in

TABLE IX

Proximate Analysis of Defatted Soy Flour and Several Cereal Products

	Soy flour	Durum flour	Degermed corn meal	Polished rice	Rolled oats
Item	Percent				
Protein[a]	47.0	12.7	7.9	6.7	14.2
Moisture	8.0	13.0	12.0	12.0	8.3
Fat	0.9	2.5	1.2	0.4	7.4
Fiber	2.3	1.8	0.6	0.3	1.2
Ash	6.0	1.7	0.5	0.5	1.9

[a]Protein conversion factors–soy (N x 5.71), durum (N x 5.83), corn (N x 6.25), rice (N x 5.95), and oats (N x 5.83); source: USDA Handbook No. 8.

TABLE X

Effect of Addition of Soy Flour to Durum Flour in Macaroni Products

Durum flour	Soy flour	Protein content Uncooked	Protein content Cooked	PER[a]
Percent				
100.0	0	15.1	13.9	1.27
87.5	12.5	22.1	22.4	1.94
83.0	17.0	24.1	26.7	—
75.0	25.0	28.0	30.5	2.39
67.0	33.0	30.6	34.5	—

[a]PER = protein efficiency ratio. Corrected values, basis PER of 2.50 for casein.

the processsing characteristics, appearance, and flavor of the product.

Since both the functionality and nutritional value are influenced by heat treatment, it would appear that the food technologist who wants functionality from his soy ingredient must sacrifice nutrition, since soy products which have maximum functionality have minimal nutritive value. Fortunately, it is possible to capitalize on both properties. Functionality is of primary concern in the formulation, fabrication, and processing steps of a food. By the time the food is consumed, it likely will have been subjected to an additional heat treatment. For example, the functionality of the soy component in bread is crucial to the preparation and processing of the dough. But, bread is baked before it is consumed. Similarly, pasta is boiled, doughnuts are fried, and meat patties are broiled. These heat treatments will substantially improve the nutritional contribution of the soy component in these foods.

Certainly, the addition of defatted soybean products to cereals is an effective, yet inexpensive way to improve the nutritional value of food. Intensive research programs are exploring other ways of utilizing defatted soy flour and grits in the development of new foods which are highly nutritious and highly acceptable. Remarkable progress has been made in the development of meat-like and milk-like products from the soybean. The incentives for successfully developing these products are both economic and humanitarian. Recently, the United Nations published a document (12) which deals directly with the humanitarian incentive. If present and future populations are going to satisfy their protein requirements, they will have to implement one or more of the alternatives presented in this document. One of the alternatives proposed involves an increase in the use of oilseed meals as direct sources of protein in human diets. The humanitarian incentive, thus, relates to our survival when the supplies of dietary protein become inadequate.

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