TABLE II

Complementary Effect of Predigested Soybean Protein/Rice, Corn and Cheese Whey Protein

	Proportion of the products	PER	BV
Predig. soybean/rice	1:1	2.66 ± .15	74.63 ± .30
Predig. soybean/corn	1:5.66	1.67 ± .17	74.00 ± .42
Predig. soybean/cheese whey (dry basis)	1:1.03	2.31 ± .15	74.00 ± 0.17

(without experimental confirmation) that in some instances during fermentation, lactobacilus can produce lipases, which would liberate the fatty acid from the glycerides. This fact would explain the increase in the acid value for predigested soybean oil.

EFFECT OF COMPLEMENTS WITH PREDIGESTED SOYBEAN

As with soya products, predigested soybean protein is a good complement to rice, corn and cheese whey. Table II shows PER figures and biological values (BV) indicating that predigested soybean complements well with those products.

HUMAN ASSAYS

Experiments were made to confirm that predigested soybean does not have a beany flavor and does not produce flatulence after meals. Two studies were conducted with adults; one group of 258 were fed a diet containing whole predigested soybeans, and the other group of 229 were fed a diet containing broken predigested soybean (cotyledons) The results in Table III show that broken soybean has higher acceptance than whole soybeans. The medical report shows that flatulence was not detected and that a beany flavor was not found.

TABLE III

Results of Feeding Humans with Standard Dishes Prepared with Predigested Soybean

Number tested	Whole soybean	(%)	Broken soybean	(%)
Amount inquired	258	100	229	100
High acceptance	129	50	197	86
Medium acceptance	74	29	23	10
Low acceptance	45	17	9	4
Rejected	10	4	0	0

Nutrition Aspects of Fiber in Soya Products

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INTRODUCTION

The hypothesis that dietary fiber may act as a prophylactic agent with regard to certain diseases has attracted the interest of the scientific community. Consumption of diets low in dietary fiber by man has been correlated with increased incidence of colon cancer, coronary heart disease, diabetes, diverticular disease of the colon and various other maladies of the lower gastrointestinal tract. The current literature contains many research reports concerning the association of one or more types of fiber with one or more physiological effects. Few studies have dealt directly with the subject of this review: the nutritional effects of feeding soybean fiber to man or experimental animals.

CHEMICAL AND PHYSICAL PROPERTIES OF SOYBEAN FIBER

The fiber components in soya hull and in the cotyledon are distinct and thus should be considered separately. Soybean hulls have been analyzed (1-9; J. Ramon and B.P. Klein, personal communication) for crude fiber and components of dietary fiber. There is considerable variation in the reported values for individual fiber components (Table I). This variation is due to differences in methods used, laboratory-to-laboratory technique and perhaps to variety of bean analyzed. Variations in preparation and extraction conditions (10) result in large alterations in amount and physical characteristics of soybean hull fiber.

Soybean hulls are reported to contain about 87% dietary fiber, between 40 and 53% crude cellulose, 14 and 33% crude hemicellulose and 1 and 3% crude lignin (dry basis). In addition to the fiber, the soybean hull contains 7.0% protein, 0.9% oil, 4.3% ash and less than 1% starch (3).

Sparse published data were found for the fiber content of non-hull soya products. Dehulled soybean flour was reported to contain 6.2% NDF, 5.7% ADF, 4.6% crude cellulose, 0.5% crude hemicellulose and 1.3% lignin by the Van Soest method (J. Ramon and B.P. Klein, personal communication). Soya concentrates contain slightly higher levels of dietary fiber. A commercial soya bran source (ADM Co., Decatur, IL) was reported to contain 38.1% ADF and 50.8 NDF using similar methodology (11). In a practical sense, soya isolates have no fiber. In total, soya products certainly would not contribute a significant portion of American dietary fiber consumption.

Particle size, density, hydration capacity and ion exchange capacity are the four major physical properties of

TABLE I

Fiber Content of Soybean Hulls

Type of fiber	Dry basis (%)	Reference
Total crude fiber	47.0	1
	36.1	2
Total dietary fiber	88.0	3
	86.7	4
Acid detergent fiber	35.1	J. Ramon and B.P. Klein, personal communication
	43.9	5
	49.5	1
Buffered acid detergent fiber	54.1	6
Neutral detergent fiber	49.0	J. Ramon and B.P. Klein, personal communication
	56.7	7
	67.0	8
In vitro fiber	70.4	9
Crude cellulose	40.6	5
	45.8	1
	53	3
	53	4
Crude hemicellulose	13.9	J. Ramon and B.P. Klein, personal communication
	17.7	1
	33	3
	33	4
Crude lignin	0.7	4
	1.5	J. Ramon and B.P. Klein, personal communication
	2	3
	3.2	1
	3.3	5

dietary fiber (8). These properties not only are instrumental in the role a particular fiber source may play in the rheology of a food product, but they may also determine the physiological (nutritional) role of the specific dietary fiber source.

An important benefit of dietary fiber for humans is in increasing the water-holding capacity of the stools. Increased volume and softness of stools parallels the hydration or water-holding capacity. Increased stool bulk, softness and decreased transit time may reduce diverticular disease, hemorrhoids and possible other lower gastrointestinal problems.

Particle size of dietary fiber may well influence the water-holding capacity. For example, Heller and coworkers (12) reported that the daily fecal wet and dry weight in young adult men fed low-fiber diets supplemented with 32 g of coarse or finely ground wheat bran were significantly greater by 14 and 7% for the coarse bran diets.

When physical properties of fiber sources are to be compared, every effort must be made to use similar extraction techniques and particle sizes. Rasper (8,10) attempted to maintain standard procedures for his evaluation of the physical properties of fiber extracted from several cereals, soya hulls and peanut red skins. He used several techniques to investigate bulk volume (density), hydration capacity and cation exchange capacity of the fiber extracts. Upon grinding, the cereal bran particles had a tendency to form elongated flakes which passed through the screen along their smaller dimension. Soybean hulls and peanut red skins tended to disintegrate into a more uniform powder. Therefore, even though all products passed through the same screen, their sizes were different. This problem aside, the dietary fiber prepared from soya hulls had relatively low density and relatively high hydration capacity compared to fiber extracted from cereal sources. However, while heat treatment (110 C for 2 hr) had little effect on the water retention capacity of cereal samples, both noncereal materials, soybean hull and peanut red skins, demonstrated a significant reduction in water retention capacity. The hydration capacity of the tested fiber sources appeared to be correlated with the uronic acid concentrations in the extracted fiber.

A relatively high uronic acid content in soybean hull fiber (and in peanut red skins) may also offer an explanation for its distinctively high cation exchange capacity (Table II). Unsubstituted uronic acid groups, as well as other carboxyl groups, are presumably free to complex cations. Jones et al. (13) performed in vitro calcium binding studies with fiber extracted from 29 foods. They reported that dietary fiber from plants low in phytic acid bound calcium in proportion to their uronic acid contents.

From Table II, it is evident that cereal materials were highly heat-stable with respect to their cation exchange capacity, whereas both noncereal fibers were labile to heat. As both soya hulls and peanut red skin fiber are high in uronic acid, and these residues are related to exchange capacity, it would appear that reactive groups of uronic acid, and perhaps binding sites on other molecules, are sensitive to heat (10).

METABOLIC EFFECTS OF FEEDING SOYBEAN HULLS

The bioavailability of minerals such as zinc and iron from soybean foods has been of concern to nutritionists for years (14). Phytic acid, components of fiber or other components within the soya product may all bind metal ions to form stable complexes (15). Depending on food processing conditions (16) and the presence of other cations such as calcium in the diet (17,18), these stable complexes may be resistant to digestion and absorption in the gastrointestinal tract and, consequently, result in poor availability of bound minerals.

The relatively high cation exchange capacity of soya hull fiber (Table II) suggests that this fiber source may have the capacity to reduce mineral bioavailability if the fiber is consumed in high enough quantities in the diet. In the author's laboratory, experiments have been made to investigate the effect of soybean hull on the bioavailability of zinc from and of calcium added to soya flour-based diets. Weingartner et al. (19) fed diets based on dehulled or whole (hull included) soybean flour to rats and measured growth and zinc deposition in bone after 3 weeks' feeding. The soya hull contains at least half of the total dietary fiber of the whole soybean and practically no phytic acid. Results of the zinc study showed that inclusion of soybean hulls, at least at low levels in the diet, had no effect on the bioavailability of zinc native to the bean.

The bioavailability of calcium added to whole soya or dehulled soya flour-based diets as calcium carbon carbonate was also tested (19). Rats were fed calcium-supplemented diets for 33 days and, after sacrifice, their total femur calcium was measured. Again, the presence of soybean hulls in diets did not affect bioavailability of the added calcium.

Recently, we investigated the effects of the presence of insoluble fiber material from soybean cotyledons in rat diets on the zinc bioavailability. For some diets, the soya fiber (insoluble material) was removed from dehulled beans by soaking the beans overnight in distilled water, heating the beans to 81 C, hot grinding and using a filter press. The filtered soya extract retained 97% of the original phytic acid of the dehulled bean, but little of the dietary fiber (70). Results of the zinc bioassay with rats comparing bioavailability of zinc from the dehulled flour (including the insoluble fiber material) with the dehulled soya without the fiber showed no effect of the cotyledon fiber on zinc bioavailability.

Kornegay (1) investigated the energy value and digestibility of various levels of soybean hulls in swine diets. The gross energy of hulls was calculated to be 4.32 kcal/g. As the proportion of hulls increased in the diet, daily feed intake increased whereas average feed per gain was similar for diets up to 6% hulls. Feed per gain was increased for diets containing 12 and 24% hulls. As soybean hulls were substituted for the basal diet, digestion coefficients for dry matter, energy, crude protein, ether extract and ash decreased whereas digestion coefficients for ADF, cellulose and lignin were increased.

A series of papers (3,4,21,22) have reported on the biological effects of feeding moderate supplements (25-26 g) of various sources of bran fiber to human subjects. Dintzis and coworkers (3) investigated changes in composition and morphology of brans of AACC soft white wheat, dry milled corn and soybean hulls (hulls from A.E. Staley Co., Decatur, IL) after passage through the human alimentary tract. They found that soybean hulls could be greatly disrupted by the human gastrointestinal tract depending on individual transit times. In a person with short transit time, cellulose and lignin were almost fully recovered, and half of the apparent hemicellulose was recovered. In a constipated individual, recovery of lignin was ca. 33%, and cellulose and hemicellulose were only ca. 10% recovered in the stool.

The same workers (4,21,22) fed healthy men 26 g of one of several cereal brans, soybean hulls or textured vegetable protein daily for periods of 23-30 days. The fiber sources were added to breads and were part of a nutritionally adequate diet similar to diets of many adult American males. Mean fecal weight increased from 68 to 128 g ($p < 0.01$) when soya hulls were fed. Total plasma cholesterol decreased 14% with soya hulls ($p < 0.05$) as did plasma triglycerides. All other fiber sources except textured vegetable protein decreased plasma triglycerides, but only hard red spring wheat bran and soya hulls reduced plasma cholesterol. Soya hulls tended to decrease low density lipoprotein (LDL) cholesterol, but had no significant effect on high density lipoprotein (HDL) cholesterol. Feeding the men finely ground soybean hulls (and most other fiber sources) improved glucose tolerance. No adverse effects of any individual fiber sources were noted on mineral balances of zinc, copper or iron. However, when all fiber sources were grouped and apparent requirements of minerals were calculated by regression analysis of intake vs balance, ingestion of fiber sources significantly increased apparent requirements for calcium, phosphorus, iron and copper, but not of zinc or magnesium.

The overall results from these USDA studies (3,4,21,22) suggest beneficial effects for humans of moderate intakes of dietary fiber (soya hulls) on glucose and lipid metabolism. On the other hand, some reduction in mineral balance was observed. Consumption of larger quantities of dietary fiber might prove more harmful to mineral balance. The reduction of serum cholesterol with the feeding of hulls is of interest. Other researchers reported that soya protein, in contrast to animal protein, results in reduced serum cholesterol in various animals (23), and in hypercholesterolemic

TABLE II

Cation Exchange Capacity of Dietary Fiber (Acetone Dietary Fiber and Enzymatic Dietary Fiber) Treated at Normal (below 35 C) and High Temperature (110 C for 2 Hr) (10)

Origin of dietary fiber	Method of dietary fiber preparation			
	Acetone washing		Enzymatic digestion	
	Temperature of drying (C)			
	<35	110	<35	110
	meq 0.1 N NaOH/g			
Soybean hull	0.57	0.26	0.67	0.36
Peanut red skins	0.54	0.37	0.55	0.32
Hard wheat bran	0.13	0.14	0.14	0.15
Corn bran	0.16	0.16	0.20	0.19
Rice bran	0.14	0.15	0.15	0.14
Oat bran	0.11	0.11	0.18	0.15
Rye middlings	0.08	0.09	0.12	0.09
Rice hull	0.07	0.07	0.07	0.07
Barley hull	0.11	0.10	0.10	0.10
Oat hull	0.06	0.06	0.07	0.06

humans (24).

CONCLUSIONS

Investigations into the biological effects of specific types of dietary fiber are in their infant stages. Progress is hampered by the dramatic effects that the type of isolation technique has on physical and physiological properties of the isolated fiber. Development of uniform procedures for isolation and analysis of types of fiber must precede major progress in ascertaining physiological roles of fiber components. However, there is little argument that the components of plant fibers will be shown to have a much greater effect on animal and human nutrition than was previously realized (25).

For soya products specifically, consumption of moderate amounts of hulls has been shown to produce beneficial effects on glucose and lipid metabolism in man. Both animal and human feeding trials suggest that soya hulls in moderate levels in the diet have little effect on mineral bioavailability. Little is known about the biological effects of the fiber contained within the cotyledon.

Americans are receiving little of their total dietary fiber from soybeans. Few soybean hulls are consumed and soya isolates have had the bulk of the fiber removed during processing. Insoluble, spent soya flakes and hulls are largely used in animal rations. These soya processing by-products seem to be well utilized by animals. For man, the metabolic effects of soya fiber is a scientific curiosity, not a practical question.

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Review of Earlier Soya-Protein-Fortified Foods to Relieve Malnutrition in Less Developed Countries

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INTRODUCTION

Alleviation of malnutrition has become a national priority in many less developed countries (LDC). An adequate diet is believed to be a basic right of every human being. Governments have also come to realize that proper nutrition plays a key role in socioeconomic development, i.e., that of providing citizens with improved physical and mental capacities (1).

Nutrition intervention programs to relieve protein-calorie malnutrition (PCM) have three population targets: infants (0-6 months), preschool children (7 months-3 years) and pregnant and lactating mothers.

The Consultative Group on Maternal and Young Child Nutrition of the Advisory Group on Nutrition, United Nations, has recently recommended that, because the first 6 months in a child's life are the most critical for nutrition, breast milk should be the exclusive food source during this time. In the case of infants who cannot be breast fed, the Group recommends that milk-based mixtures be used preferentially to cereal-protein mixtures (2). Besides supplying some unique biochemical substances that protect the infant against certain infectious diseases, maternal feeding involves a natural contraceptive effect, is hygienic and economic compared to formulas, and allows a satisfying psychological interaction between mother and child (3).

According to Scrimshaw and Underwood (4) infant malnutrition in LDC occurs because of inadequate complementary feeding practices during the weaning period as breast feeding alone becomes insufficient. The introduction of complementary foods presents many problems including timing, quality and quantity, sanitation in preparation and delivery of the food to the infant, and the danger of premature adoption of commercial formulas. This last point has