Protein Concentrate from Normal and High-Lysine Sorghums: Preparation, Composition, and Properties

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An alkaline extraction process gives protein concentrate and starch from ground sorghum. Optimum extraction was at pH 11.8–11.9 in 0.1–0.15 N sodium hydroxide with 150 g of sorghum/900 mL of solvent. The sorghum was extracted twice with sodium hydroxide solutions. After centrifugation, each of the two alkaline extractions was adjusted to pH 4.8–5.2 to yield a precipitate and a supernatant. Bran was removed from starch and protein by screening the second alkaline dispersion. Protein content (nitrogen × 6.25) of the concentrates varied between 48 and 60%, and the concentrates had from 3.1 to 5.4 g of lysine and 3.0 to 3.5 g of total sulfur amino acids per 16 g of nitrogen. The concentrates were insoluble in water between pH 3.5 and 5.8; solubility was 15 to 22% at pH 2.1 and around 90% from pH 8.7 to 10.8. All protein concentrates had good hydration capacity (4.0 to 4.5), and the two high-lysine concentrates had good emulsifying activity (53 to 54%) and good emulsion stability (40 to 47%).

Although protein from normal sorghum is deficient in lysine (Deyoe and Shellenberger, 1965), two floury lines of Ethiopian origin, IS 11167 and IS 11758, were exceptionally high in lysine at relatively high levels of protein (Singh and Axtell, 1973). Alcohol-soluble protein was sharply reduced in these Ethiopian lines while the salt-soluble fraction increased (Jambunathan et al., 1975). Another high-lysine sorghum, P-721 opaque, produced by chemical mutagen treatment of normal grain, has also been reported by Mohan and Axtell (1975).

Dimler et al. (1944) used an alkali process to prepare starch and protein from wheat flour, sorghum flour, and other cereal flours. Since whole sorghum has a better amino acid composition and a higher protein content than sorghum flour (endosperm), ground normal and high-lysine sorghums were used to produce protein concentrates and by-products by alkaline extraction.

MATERIALS AND METHODS

Sorghum. The two high-lysine sorghums, IS 11758 and P-721, were received from Dr. K. S. Porter, Department of Agronomy, Purdue University, West Lafayette, Ind. Both high-lysine sorghums have approximately twice the nutritional value as the normal sorghum based on protein efficiency ratio measurements (Singh and Axtell, 1973; Mohan and Axtell, 1975). In addition, the two high-lysine sorghums also had approximately 50% more protein than the normal sorghum. TE 77 is a common, full-season hybrid from Texas.

Each sorghum was ground twice in a hammer mill equipped with a screen containing $^1/_{16}$ in. diameter holes; 79, 85, and 39% of the twice-ground IS 11758, P-721, and TE 77 sorghums passed through a 100-mesh screen, respectively. Since all sorghums were ground under identical conditions, the larger particle size of the normal sorghum, TE 77, indicated it has harder endosperm than the two high-lysine varieties.

Protein Extraction. Each ground sorghum was mixed with a number of solvents at a specified weight-to-volume ratio, stirred for 25 min, and then centrifuged for 10 min at 3300*g* in a Sorvall laboratory centrifuge. A portion of the supernatant from centrifugation was analyzed for nitrogen in duplicate by micro-Kjeldahl, and a portion of the remaining supernatant was dried.

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Precipitation pH. An alkaline extract (7 mL) of each sorghum was pipetted into each of six centrifuge tubes, and hydrochloric acid solution was added dropwise to each tube until pH values ranged from 3.6 to 6.9. The mixture in each tube was stirred for 25 min and then centrifuged at 3300*g* in a Sorvall laboratory centrifuge for 10 min. A portion of each supernatant after centrifugation was analyzed for nitrogen. The amount of protein precipitated at each pH level was then calculated.

Protein Concentrate. Ground sorghum (150 g) and 900 mL of 0.15 N sodium hydroxide were stirred for 25 min (Figure 1); the slurry pH was adjusted to pH 11.9 by addition of sodium hydroxide solution if needed. The slurry was centrifuged at 3300*g* in a Lourdes centrifuge for 15 min, and the supernatant was decanted and adjusted to pH 4.8 with 6 N hydrochloric acid to precipitate almost all the protein. The mixture was centrifuged at 3300*g* for 15 min to separate the precipitate from supernatant, which were freeze-dried separately as the first precipitate (protein concentrate) and first supernatant.

The alkaline residue from the first centrifugation was redispersed to original volume and pH by addition of water and sodium hydroxide solution (Figure 1). This alkaline slurry was stirred for 25 min and passed through 100-mesh bolting cloth to remove bran. The slurry that passed through the cloth was centrifuged at 3300*g* for 15 min to yield a supernatant, a starch layer, and a layer above starch. The supernatant was adjusted to pH 4.8 by adding 6 N hydrochloric acid to precipitate almost all the protein, and the mixture was centrifuged at 3300*g* for 15 min to give a precipitate and a supernatant, which were freeze-dried separately as the second precipitate and second supernatant. Starch, the layer above the starch, and the bran that remained on the bolting cloth were each neutralized with 6 N hydrochloric acid and freeze-dried.

For TE 77 sorghum, 0.1 N sodium hydroxide was used instead of 0.15 N, and the slurry pH was 11.8. For P-721 sorghum, the precipitation pH was 5.2, instead of 4.8.

Composition. Protein content was calculated from duplicate micro-Kjeldahl analyses by multiplying percentage of nitrogen by 6.25 and correcting to dry basis. Ash was determined according to AACC Approved Methods (1971), and starch was measured by a polarimetric method (Garcia and Wolf, 1972). Fat was determined by petroleum ether extraction. Although protein extracted without a precipitation step can be called "crude protein" and fat can be described as "crude fat", the terms protein and fat are used throughout for simplicity.

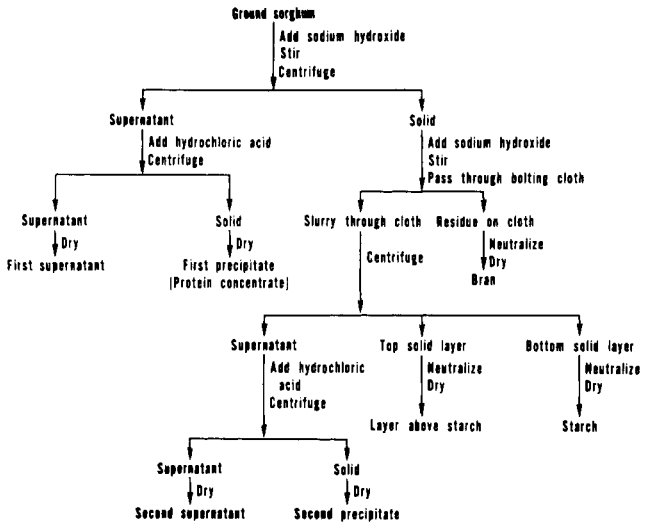

Figure 1. Schematic diagram for preparing protein concentrate and by-products from ground sorghum.

Samples for amino acid analyses hydrolyzed for 24 h by refluxing in 6 N hydrochloric acid. A portion of the acid hydrolysate solution was put in a Beckman Spinco Model 121 amino acid analyzer, and data were computed automatically (Cavins and Friedman, 1968).

Properties. Nitrogen solubility was measured by stirring 0.1 g of protein concentrate with 10 mL of water, and sodium hydroxide or hydrochloric acid solution was added dropwise to give a range of pH values from 2.1 to 10.8. The mixture was stirred for 25 min and centrifuged at 1300*g* (or 27 000*g*, if needed) for 20 min to separate solid and supernatant satisfactorily. The supernatant was analyzed for nitrogen and the percentage of nitrogen soluble was calculated at each pH value. Hydration capacity was measured according to AACC Approved Methods (1971). Emulsifying activity and emulsion stability were determined by the method of Yasumatsu et al. (1972) for a simple system, in which only soybean oil and water were added to the protein concentrate.

RESULTS AND DISCUSSION

The biological value of any particular variety of sorghum grain of low tannin content is directly proportional to its lysine content, but lysine is not the first limiting component of biological value for a group of high tannin sorghums (Axtell et al., 1974). Sorghum grain with brown seed color are characteristically high in tannin (1.3 to 2%) compared to a range of 0.2 to 0.4% in other common varieties (Chang and Fuller, 1964; Wall and Ross, 1970). IS 11758 has red seed color, low tannin, and high biological value (Singh and Axtell, 1973), P-721 has cream color and high biological value (Axtell et al., 1974), and TE 77 has red color. It is likely that both P-721 and TE 77 are also low in tannin, because they are not brown in color and P-721 has high biological value in addition. The influence of tannin on the three sorghums studied here is likely to be minimal and probably will not cause any complication in interpretation of results.

pH of Extraction. Water and sodium hydroxide solutions at various concentrations were used to extract the ground sorghums at a solid-to-solvent ratio of 1:6 (Table I). Water dissolved 6% of the protein from normal sorghum (TE 77), but 12 to 14% of the protein was extracted by water from the two high-lysine sorghums. As slurry pH increased from 9.9 to 11.9 in sodium hydroxide solutions, the percentage of protein dissolved increased from 16–29% to 41–46%. In general, the protein content of extracted solids (the supernatant from centrifugation which was then freeze-dried) increased with increasing pH, and the proteins of the two high-lysine sorghums were more soluble than that of the normal one at the same pH value. The highest percentage of protein dissolved was at pH 11.9 in 0.15 N sodium hydroxide for the two high-lysine sorghums; however for the normal sorghum, the best result was at pH 11.8 in 0.1 N sodium hydroxide. These conditions were used subsequently for making protein concentrate. Since the highest percentage of protein extracted from TE 77 (43%) is very close to the other two sorghums (44 and 46%), the larger particle size of TE 77 does not seem to influence percentage of protein extracted.

Table I. Extraction of Sorghum Protein with Various Solvents[a]

Solvent	Slurry pH			Total protein extracted, %			Protein in extracted solids, %		
	IS	P	TE	IS	P	TE	IS	P	TE
Water	6.5	6.5	6.3	14	12	6	23	29	19
0.03 N sodium hydroxide	9.9	9.9	10.0	29	24	16	31	36	33
0.05 N sodium hydroxide	10.8	11.2	11.5	33	33	28	33	41	42
0.075 N sodium hydroxide	11.4	11.6	11.7	40	36	35	36	41	45
0.1 N sodium hydroxide	11.6	11.7	11.8	41	38	43	35	42	44
0.15 N sodium hydroxide	11.9	11.9	11.9	46	44	41	33	40	39

[a] Solid-to-solvent ratio, 1:6, dry basis. IS 11758 (IS) and P-721 (P) are high-lysine sorghums, while TE 77 (TE) is a normal one.

Table II. Influence of Solid-to-Solvent Ratio on Extraction of Sorghum Protein[a]

Solid:solvent ratio	Solvent (sodium hydroxide) normality		Slurry pH			Total protein extracted, %		
	IS	P and TE	IS	P	TE	IS	P	TE
1:3	0.2	0.15	11.8	11.7	11.6	34	29	21
1:4	0.15	0.11	11.8	11.7	11.6	39	33	26
1:6	0.1	0.075	11.8	11.6	11.6	43	35	28
1:10	0.06	0.045	11.8	11.6	11.6	44	35	29

[a] IS 11758 (IS) and P-721 (P) are high-lysine sorghums, while TE 77 (TE) is a normal one.

Solid-to-Solvent Ratio. Ground sorghum was extracted with sodium hydroxide solutions at various solid-to-solvent ratios of 1:3 to 1:10 (Table II). Since the percentage of protein dissolved by sodium hydroxide solutions depends on pH of the slurry (Table I), normality of the sodium hydroxide was adjusted to give the same pH value for each sorghum slurry. The largest increase in percentage of protein extracted occurred when solid-to-solvent ratio rose from 1:3 to 1:4; the next largest was from 1:4 to 1:6. There was little or no increase when solid-to-solvent ratio went from 1:6 to 1:10. A solid-to-solvent ratio of 1:6 seems a good compromise between the highest percentage of protein extracted and minimum amount of extractant needed (Table II), and that ratio was always used unless otherwise specified.

Precipitation pH. The effect of precipitation pH on alkaline extract of sorghum was determined at six pH values between 3.6 and 6.9 (Table III). The amount of protein precipitated ranged from 9 to 86%; this large difference demonstrated the importance of proper pH value for precipitating sorghum protein from the alkaline extract. The maximum amounts of protein precipitated were 84% for IS 11758 between pH 5.1 and 3.6, 82% for

Table III. Effect of Precipitation pH on Alkaline Extract of Sorghum[a]

pH			Protein precipitated, %		
IS	P	TE	IS	P	TE
6.2	6.3	6.9	74	35	9
5.5	5.8	6.2	82	79	74
5.1	5.3	5.4	84	82	84
4.6	4.8	4.9	84	81	86
4.1	4.2	4.4	84	80	86
3.6	3.7	4.0	84	80	84

[a] IS 11758 (IS) and P-721 (P) are high-lysine sorghums, while TE 77 (TE) is a normal one.

Table IV. Products from Sorghums IS 11758 (IS), P-721 (P), and TE 77 (TE)[a]

Product	Yield, %			Total protein, %		
	IS	P	TE	IS	P	TE
Protein concentrate (first precipitate)	12	8	6	38	31	35
First supernatant	10	7	3	7	7	3
Second precipitate	3	2	1	6	6	6
Second supernatant	3	3	2	1	2	1
Bran	34	42	50	29	39	50
Layer above starch	14	13	9	16	14	4
Starch	28	26	28	2	0	2
Total	104	101	99	99	99	101

[a] Solid-to-solvent ratio was 1:6, dry basis.

P-721 at pH 5.3, and 86% for TE 77 between pH 4.9 and 4.4. The pH values chosen for precipitating the sorghum protein from the alkaline extract were 5.2 for P-721 and 4.8 for IS 11758 and TE 77.

Products from Sorghum. All figures in Table IV for the seven fractions from alkaline extraction of ground sorghum have been rounded off to the nearest percent. Protein concentrate yield increased from 6% for normal sorghum to 8–12% for the high-lysine ones. The total protein accounted for by the concentrate ranged from 31 to 38%. The yields of first supernatant, second precipitate, and layer above starch were higher for the high-lysine sorghums than for the normal one. However, the bran yield was considerably higher for the normal sorghum and this higher yield of bran may be due to the larger particle size of this sorghum. When the two high-lysine sorghums were compared, the yields of protein concentrate and first supernatant were higher for IS 11758 than for P-721. Also, the IS 11758 protein concentrate accounted for a higher percentage of total protein than that of P-721. Therefore, IS 11758 gave better result than P-721, which in turn gave better result than TE 77. The total yields of 99–104% were based on the starting sorghum, and the sodium chloride formed by the neutralization of sodium hydroxide and hydrochloric acid accounted for a few percent of the total yield for each sorghum.

Composition. The protein, fat, ash, and starch contents of protein and by-products from ground sorghum appear in Table V. In addition to protein, fat, ash, and starch, sorghum also contains fiber (Bressani and Rios, 1962), sugars, and pentosans (Edwards and Curtis, 1943). The sugars include raffinose, stachyose, sucrose, fructose, and glucose (Nordin, 1959). The sorghum protein concentrates had 48–60% protein, 26–32% fat, and 2–4% ash compared with 10–15% protein, 3–7% fat, and 1–3% ash for the starting ground sorghums. The second precipitates had lower protein content and higher fat in general compared with the corresponding protein concentrates. The first and second supernatants had 6–14% protein, low fat, and high ash contents. These supernatants contained albumins, globulins, salt, sugars, minerals, and other water-soluble materials; their high ash content is partly due to sodium chloride formed by neutralizing the sodium hydroxide solution with hydrochloric acid solution. The bran fractions after alkaline extraction were similar to the ground sorghums in protein and starch contents but had considerably less fat. Bran from dry milling without solvent extraction had considerably higher protein and fat than ground sorghum (Jones and Beckwith, 1970). The layer above starch had higher ash than the corresponding brans. The starch fractions were low in protein, fat, and ash.

Amino Acid Composition. The essential amino acid compositions of protein concentrate and by-products from the three sorghums (Table VI) were corrected to 100% nitrogen recovery and expressed in gram of amino acid/16 g of nitrogen recovered. Only significant differences in amino acid composition are discussed here. The two high-lysine sorghums had approximately 50% more lysine than the normal hybrid, TE 77. Since lysine is the first limiting amino acid in sorghum protein, this increase in lysine level approximately doubled the protein efficiency ratio of these two sorghums compared with normal lines (Singh and Axtell, 1973; Mohan and Axtell, 1975). The protein concentrates (Table VI) had 50% more lysine than the starting sorghum for both high-lysine and normal lines. The lower lysine content of normal sorghum was carried over to all fractions compared with those from high-lysine lines, except that the first supernatants were approximately equal in lysine for the three sorghums. Since the first supernatant contains albumin and globulin which are generally rich in lysine, this fraction is high in lysine. The second precipitate also had considerably higher lysine content than the corresponding ground sorghum, although at a somewhat lower level than was found for protein concentrate and first supernatant. The bran fraction, however, had considerably lower lysine content than the corresponding ground sorghum. The bran fractions from conventional dry milling without solvent extraction (Jones and Beckwith, 1970; Shoup et al., 1969) had 3.7 to 3.8 g of lysine/16 g of nitrogen. Our bran fraction after solvent

Table V. Composition of Protein Concentrate and Byproducts from Sorghum (% Dry Basis)[a]

Material	Protein (nitrogen × 6.25)			Fat			Ash			Starch		
	IS	P	TE	IS	P	TE	IS	P	TE	IS	P	TE
Ground sorghum	14.9	14.3	9.6	7.1	4.9	3.4	2.8	1.9	1.2	55.7	67.3	64.0
Protein concentrate (first precipitate)	48.3	56.6	60.3	32.2	29.3	25.8	4.0	3.9	2.2			
First supernatant	10.7	14.1	11.3	0.7	0.6	0.5	32.0	47.4	71.8			
Second precipitate	29.4	45.6	50.9	39.3	40.6	26.0	3.6	4.3	3.2			
Second supernatant	5.6	8.3	6.0	0.7	0.4	0.6	42.6	83.8	85.0			
Bran	12.7	13.3	11.2	2.5	1.7	0.9	3.0	2.6	3.1	57.4	67.4	67.0
Layer above starch	17.6	15.3	5.2	2.6	2.3	1.0	4.5	7.5	7.2	59.6	64.6	84.2
Starch	1.0	0.0	0.6	0.3	0.4	0.2	1.4	1.3	1.3	99.6	100.6	98.0

[a] IS 11758 (IS) and P-721 (P) are high-lysine sorghums, while TE 77 (TE) is a normal one.

Table VI. Essential Amino Acid Composition of Protein Concentrate and By-Products from Sorghum (g/16 g of Nitrogen Recovered)[a]

Amino acid	Ground sorghum			Protein concentrate (first precipitate)			First supernatant			Second precipitate			Bran			FAO/WHO (1973)
	IS	P	TE	IS	P	TE	IS	P	TE	IS	P	TE	IS	P	TE	
Isoleucine	4.5	4.4	4.3	4.4	4.7	4.1	2.8	2.7	2.7	4.7	5.2	4.2	4.7	4.7	4.8	4.0
Leucine	13.1	13.6	15.1	9.9	9.8	12.3	3.8	5.4	4.2	12.2	12.5	13.0	17.1	16.9	17.5	7.0
Lysine	3.2	2.9	2.0	5.4	5.1	3.1	5.4	5.1	5.0	4.2	3.9	2.5	1.7	1.3	0.9	5.5
Methionine + cystine	3.1	3.3	3.1	3.4	3.5	3.0	4.9	3.7	4.2	3.2	2.5	3.5	2.0	2.2	2.5	3.5
Phenyalanine + tyrosine	10.1	10.1	10.9	9.9	9.5	9.7	4.8	5.3	4.5	10.7	10.3	9.9	11.8	10.8	11.8	6.0
Threonine	3.7	3.7	3.6	4.4	4.5	3.5	5.0	4.4	4.4	4.2	4.5	3.6	3.3	3.1	3.0	4.0
Valine	5.5	5.5	5.8	6.7	7.1	6.0	4.4	4.6	5.3	6.3	7.1	5.3	5.4	5.7	5.4	5.0

[a] IS 11758 (IS) and P-721 (P) are high-lysine sorghums, while TE 77 (TE) is a normal one.

extraction had only 0.9–1.7 g of lysine/16 g of nitrogen. Apparently our procedure selectively extracted some of the high-lysine proteins from bran and resulted in protein concentrates with considerably higher lysine than the starting sorghums.

The last column in Table VI lists the suggested level of essential amino acid (FAO/WHO, 1973). The two high-lysine sorghum concentrates meet or exceed all amino acid requirements except that P-721 concentrate is a little low in lysine. The normal sorghum protein concentrate is still deficient in lysine, although lysine content had increased 50% compared with the starting ground sorghum. The normal protein concentrate is also a little lower in methionine + cystine and in threonine than the FAO/WHO pattern.

The question may arise as to whether lysine in sorghum protein is modified by the alkaline treatment and becomes unavailable. The amount of lysine from protein concentrate, first supernatant, second precipitate, and bran for each sorghum was added and compared with the amount of lysine from ground sorghum. The amount of lysine from these four fractions was 101, 94, and 100% of the ground sorghum for IS 11758, P-721, and TE 77, respectively. However, these four fractions only accounted for 80, 83, and 94% of the total protein of the IS 11758, P-721, and TE 77 sorghum, respectively. In addition, two sorghum protein concentrates were hydrolyzed and analyzed for lysinoalanine, and no lysinoalanine peak is visible in any of them. Therefore, it appears that lysine is still available after alkaline extraction.

Nitrogen Solubility of Protein Concentrations. The percentages of nitrogen soluble at a number of pH values from 2.1 to 10.8 for sorghum protein concentrates are shown in Figure 2. In general, there is no great difference in nitrogen solubility among the high-lysine and normal concentrates. The concentrates were insoluble between pH 3.5 and 5.8. Solubility below pH 3.3 increased as pH decreased and reached values of 15 to 22% at pH 2.1. Nitrogen solubility above pH 6.2 increased rapidly as pH increased, passed through a region of very rapid increase between pH 7.7 and 8.4, and reached values of around 90% from pH 8.7 to 10.8.

Hydration Capacity. Hydration capacity (weight of sediment per unit weight of sample) was good for all three concentrates (Table VII), but the high-lysine lines (4.4 to 4.5) were better than the normal one (4.0).

Emulsifying Activity and Emulsion Stability. Both high-lysine concentrates had good emulsifying activity of 53 to 54% and good emulsion stability of 40 to 47% (Table VII); however, the IS 11758 concentrate had better stability than the P-721 concentrate. The normal sorghum concentrate had poor emulsifying activity and poor emulsion

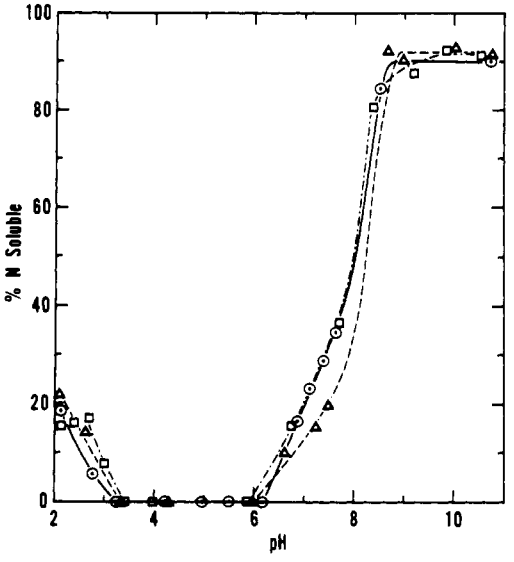

Figure 2. Nitrogen solubility of sorghum protein concentrate at various pH values. Protein concentrate (0.1 g) was stirred with 10 mL of water to which either hydrochloric acid (below pH 4.5) or sodium hydroxide (above pH 5.6) solution was added to arrive at desired pH. (○) IS 11758, solid curve; (△) P-721, dotted curve; (□) TE 77, -----.

Table VII. Some Functional Properties of Sorghum Protein Concentrates Compared with Soy Isolate

Protein concentrate	Hydration capacity	Emulsifying activity, %	Emulsion stability, %
IS 11758	4.5	54	47
P-721	4.4	53	40
TE 77	4.0	3	3
Soy protein isolate		45	44

stability. A commercial soy protein isolate tested for comparison gave an emulsifying activity value of 45% and an emulsion stability value of 44% under the same experimental conditions as sorghum concentrate. The emulsifying activity of the high-lysine concentrates is better than that of the soy isolate, and the emulsion stability of the two concentrates approximately equals that of the soy isolate.

Potential Uses of Protein Concentrate and By-Products. Sorghum concentrate may be used in foods as a protein ingredient. The attractive hydration capacity suggests possible use as a water-absorbing agent in food. The two high-lysine sorghum concentrates have good emulsifying activity and stability and may be used as fat emulsifiers in food. Since sorghum grits or meal have been successfully extruded (Sanderude, 1967; Wall, 1967; An-

derson et al., 1969), the alkaline residue after one protein extraction presumably can be neutralized and extruded into breakfast food, snacks, or other textured convenience foods. This residue may also be used as a starch source for fermentation. Starch can also be produced according to Figure 1.

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Protein Quality of Wild Rice

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Protein quality of wild rice has been studied by rat assay method and amino acid composition. Wild rice has relatively high protein content (15.2–17.0%, dry basis) and protein efficiency ratio (1.77) for a cereal. Wild rice proteins consist of a very low proportion of alcohol-soluble prolamines and a high proportion of glutelins. They are relatively rich in essential amino acids, especially lysine and methionine. Neither the rice variety nor the fermentation step that is unique in wild rice processing affects the nutritional value of wild rice.

Wild rice (*Zizania aquatica*) is an annual aquatic grass that for many centuries has grown naturally in shallow lakes and marshes, especially in the upper Great Lakes region of the United States and Canada (Rossman et al., 1973). Historically, wild rice was a principal vegetative food of the American Indians who lived in an area where agriculture was limited. However, for the last 50 years or so, Indians have sold most of the wild rice they harvested, and the grain is now widely appreciated because of its unique color and flavor characteristics.

In recent years, wild rice fields or "paddies" have been built in the region where wild rice grows naturally. Today, about 12 000 to 13 000 acres of paddies are seeded with newly developed strains of wild rice having desirable growing characteristics, and mechanical devices have replaced the hand labor used by the native Americans to harvest and process the rice. The Indians, however, continue to harvest natural stands in traditional ways.

Wild rice freshly harvested is moist (35–50% moisture) and flexible, and it must be processed before marketing. The present methods of processing wild rice vary greatly among the processors. Generally, wild rice goes through the following steps before it appears on the market shelf: fermenting, parching, hulling, aspirating, grading, and packaging.

The literature contains relatively little information on the nutritional value of wild rice. Earlier investigators (Kennedy, 1924; Capen and LeClerc, 1948) found that wild rice has a higher content of protein and vitamin B_1 than many cereals, and it contains common minerals in amounts comparable to other cereals. Recent studies (Lindsay et al., 1975), in addition to confirming earlier findings, indicated that fermentation has little effect upon the protein and mineral content of the wild rice and that the amino acid composition of wild rice compares favorably with the FAO Provisional Pattern (FAO–WHO, 1973). They also found that the lipid content of wild rice is low compared to some cereal grains, but it contains high levels of linoleic and linolenic acids. These compositional qualities have recently been reviewed by Anderson (1976).

This study was undertaken to investigate the protein quality of wild rice by rat assay method and amino acid

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