Nutritional Aspects in Textured Soy Proteins

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ABSTRACT

Textured soy protein products have found extensive use in pet foods and many human foods. They extend and complement meats in formulated foods. Numerous feeding tests with people and experimental animals show that biological values are high and protein efficiency ratios compare favorably with pure meat products. By careful processing of the textured soy products, high quality, safe, low cost protein food can be prepared. Textured soy proteins are an excellent example of man's creative ability to engineer a supplementary food that is nutritious, palatable, and economical.

INTRODUCTION

The momentum of research and development in many disciplines generated by World War II carried through the 1960's. Knowledge of protein structure and essential amino acids stimulated interest in soybean proteins and their nutritional quality. Technology of polymer chemistry, of textiles, and plastics was tapped to utilize soy proteins. A classic publication by Satow (1), which covered his research since 1914, described the manufacture of plastics from soybean proteins. The development of fibrous and chewable structures from soybean protein was the key to the success of textured soy proteins. Animal or fish proteins have been extended with textured soy without sacrificing quality. In spite of the fact that during 1972-73, the price of 50% defatted soybean flour in the U.S. increased from \$.163 to \$.557/kg, textured soy proteins still are used to increase the yield of animal protein foods and reduce the latter's cost.

Knowledge of human nutrition has been developed in a defensive manner against the diseases that crippled man. Vitamins and their role in metabolism were discovered around the turn of this century. Protein-calorie malnutrition has been studied extensively since the second world war, particularly in poverty stricken populations. Meanwhile, affluent societies recognized the role of diet in coronary diseases. A school of thought is gathering momentum in the U.S. on the need for prudent diet foods which enourages use of complex carbohydrates with less sugars and more unsaturated fats with lower cholesterol intakes.

Soybeans, and oilseeds in general, are excellent bases for engineered foods because of the inherent nutritional quality plus the relatively low price. No wonder soybean proteins have been used extensively in foods to overcome both protein-calorie malnutrition and causes for heart ailments. The gap between the nutritional quality of soybean proteins and animal proteins is shrinking because we know how to compensate for the deficiencies in plant proteins. Table I shows a comparison between animal and plant proteins (2). If one examines the differences in essential amino acids (EAA) and net protein utilization (NPU) in plant and animal proteins, one can erase most of the per se differences by supplementing plant proteins with the limiting EAA, which in turn improves NPU.

Textured soy protein is intended as an extender to animal proteins and a supplementary source of protein in food. As an extender for meat, poultry, or fish, textured soy proteins ideally should not dilute the nutritional quantity or quality beyond levels that may develop malnutrition. This point will be explained further as we

TABLE I

Differences between Animal and Plant Proteins

Animal proteins	Plant proteins
Expensive	Cheaper
It is often difficult to keep animals	It is usually easy to grow protein-containing plants, such as legumes
Very like the proteins in our own bodies	Not very like the proteins in our own bodies
Very good for body-building, even if eaten alone	Very good for body-building, only if eaten together
Higher NPU's[a]	Lower NPU's
Contain more essential amino acids	Contain fewer essential amino acids

[a]NPU = net protein utilization.

TABLE II

Nitrogen Balances for Adult Men Fed for One Week Diets Containing Beef, TVP, and TVP with Methionine[a]

	Daily nitrogen intake					
	4.4 g			8.8 g		
Item	Beef	TVP	TVP + Met	Beef	TVP	TVP + Met
Range	-0.71 +0.46	-1.45 +0.02	-0.98 +0.02	0.11 1.24	-0.31 1.95	-0.61 1.84
Average	-0.30	-0.70	-0.45	0.74	0.78	0.72
ΔDeficit	0	0.40	0.15	0	0.04	0.02
Crude protein digestibility, percent	81.4	79.4	79.2	82.7	81.6	80.1

[a]See ref. 3.

TABLE III

Nitrogen Balances of Adult Patients Fed Animal and Plant Proteins with and without TVP[a]

Diet N source	N balance	Deficit
Animal and plant	4.49 ± 1.56	0
Animal and plant + TVP at 20 g protein	3.62 ± 1.54	0.87

[a]See ref. 4.

TABLE IV

Nitrogen Balances of Adult Males Fed Beef and TVP Mixtures for 5 Days at 4.8 g/Day[a]

Diet N source	N balance	Δ Deficit
100% Beef	-0.44	0
75% Beef and 25% TVP	-0.56	0.12
50% Beef and 50% TVP	-0.75	0.21
25% Beef and 75% TVP	-0.90	0.46
100% TVP	-1.11	0.67

[a]See ref. 5.

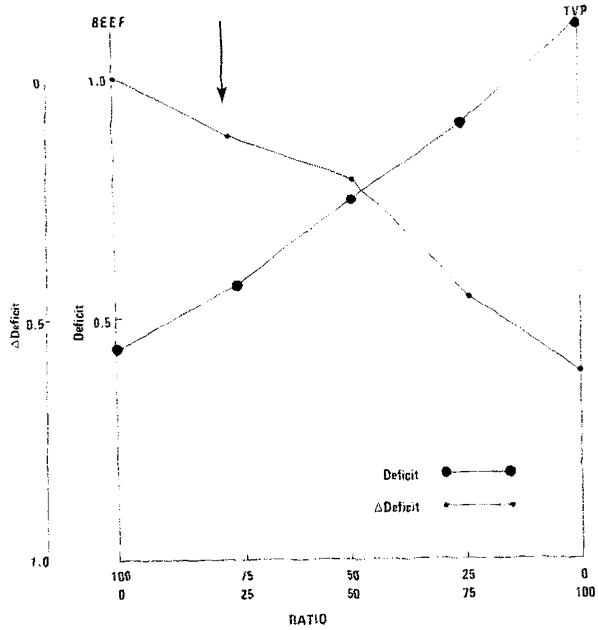

FIG. 1. Nitrogen balances and Δ deficit between beef, TVP, and their mixtures. See ref. 5.

evaluate the study on feeding meat-textured soy protein blends.

STUDIES ON THE BIOLOGICAL VALUE (BV) OF TEXTURED SOY PROTEINS

Generally speaking, all nutritional studies were carried out for periods of 6 days-6 months. Early in 1911, Mendel and Fine made the observation that soybeans produce positive nitrogen balance in human subjects. Kies and Fox (3) determined the nitrogen balance of TVP and TVP with 1% methionine vs. beef in adult males at 4.4 and 8.8 g nitrogen daily. Table II shows that at 4.4 g N intake, the deficit in N balance was highest in TVP-fed subjects, followed by TVP + methionine, and the lowest was in beef-fed subjects. The Δ deficits between TVP and beef and TVP + methionine and beef are 0.40 and 0.15, respectively. The subjects responded favorably to the higher nitrogen intake so that there was no significant difference between the three nitrogen sources. The authors concluded that since there was no pattern for each diet among the subjects fed 8.8 g N daily, the proteins in each diet had equal nutritive value. It may be significant to note that the subjects were conditioned on 50:50 blend of beef and TVP for 10 days prior to each experiment.

Poullain, et al., (4) published their study on the effect of textured soy protein on nitrogen balance in adult humans. They maintained 10 hospitalized patients for one week on diets containing 20 g TVP protein, which provided 21-32% total protein. As a control or reference, the same subjects were fed normal diet that contained a mixture of animal and plant proteins at 62-92 g protein daily. Table III shows the average nitrogen balance and deficit in the two diets. Positive N balance was obtained from the diets; however, the deficit in TVP from control was 0.87. This deficit is very high relative to 0.04 that is found in Kies and Fox data (Tables II and IV).

The nitrogen balance of beef and TVP blends were studied on adult males by Kies and Fox (5). Table IV and Figure 1 show the deficit in N balance in each diet and δ deficit between diets containing TVP and all beef. The N deficit almost follows a straight line as the ratio of TVP was

TABLE V

Effects of Vitamin Enrichments on Nitrogen Balance in Human Adults when TVP Was Fed at 4.4 g N Daily[a]

N source	N balance	Δ Deficit from beef	Δ Increase from TVP
Beef – no vitamins	-0.47	0	-
TVP – no vitamins	-0.93	0.46	0
TVP + niacin	-0.72	0.25	0.21
TVP + all vitamins	-0.67	0.20	0.26
TVP + vitamins less niacin	-1.08	0.61	0.15

[a]See ref. 5.

TABLE VI

Nitrogen Balances for Adolescent Boys Fed for 6 Days Diets Containing Beef, TVP, and TVP with Methionine[a]

Item	Daily N intake, 4.96 g		
	Beef	TVP	TVP + DL Methionine
Range	-0.55 + 1.43	-1.43 + 1.25	-0.63 + 1.36
Average	0.32	-0.08	0.48
ΔDeficit	0	0.40	+0.16
Crude protein digestibility, percent	82.0	79.0	80.0

[a]See ref. 7.

TABLE VII

Comparative Essential Amino Acids in Beef, TVP, and FAO Protein Pattern

Amino acid	XVP[a]	TVP[b]	Beef[b]	FAO Pattern
Isoleucine	4.3	5.24	4.82	4.2
Leucine	7.0	7.54	8.11	4.8
Lysine	6.1	5.88	8.90	4.2
Methionine	1.1	1.09	2.70	2.2
Cystine	1.2	1.47	1.28	2.0
Methionine, cystine	(2.3)	(2.56)	(3.98)	(4.2)
Threonine	3.7	3.78	4.59	2.8
Tryptophan	1.2	1.36	–	1.4
Valine	4.1	5.74	5.00	4.2

[a]Lauhoff data on textured soy protein.

[b]See ref. 4.

TABLE VIII

Biological Value, Digestibility, Net Protein Utilization, and PER of Beef and TVP[a]

Item	Humans[b] Beef	Humans[b] TVP
Biological value	43.6	35.7
Digestibility	89.5	87.7
Net protein utilization	39.3	30.9
	Rats[c] Beef	Rats[c] TVP
PER	2.37	2.1

[a]PER = protein efficiency ratio.

[b]See ref. 4.

[c]See ref. 3.

increased. When we examine the Δ deficit curve, we observe a significant break beyond the 50:50 ratio. These results support the general consensus not to exceed 50% textured soy proteins in meats and the choice of 75:25 ratio by most of meat processors in the U.S.

Kies and Fox (6) just completed a study to establish the effect of vitamin enrichment in TVP on nitrogen balance in human adults. Their data show that niacin level in TVP has the most crucial effect on nitrogen balance as shown in Table V. When one examines Δ N deficit between beef and TVP series, one concludes that niacin has a protein-sparing effect; furthermore, there is a sensitive balance between niacin and the other vitamins to achieve this effect. Under the column of Δ increase from TVP control, one observes that the addition of vitamins improves N balance by 16-23%.

Now after establishing the biological value of textured soy proteins in adult diets, one has to find out how they rate when fed to the fast growing young animals and humans. We will cite here three studies carried out on adolescent boys, 4-6 week old puppies, and 1 week old laboratory rats.

Korslund, et al., (7) fed 9 adolescent boys of 13-17 years textured vegetable protein TVP with 1% DL-methionine, and beef at 4.96 g nitrogen daily for 6 days. The nitrogen balance and crude protein digestibility are shown in Table VI. The difference between beef and TVP averages is 0.40 and is comparable to what Kies and Fox reported in human adults (3) while TVP with 1% DL-methionine resulted in higher positive nitrogen balance than beef. Crude protein digestibility was improved in TVP by DL-methionine addition; however, it was lower than in beef.

Puppies 4-6 weeks old were fed canned dog food in which textured soy protein and soy grits were the only source of nitrogen. Growth rate in size and wt and general health with blood and bone examinations showed that, after 16 weeks, the puppies enjoyed good health and normal growth (private communication).

Finally protein efficiency ratio (PER) bioassay on rats also supports the fact that textured soy proteins can maintain normal growth in young animals. Kies and Fox (3) reported PER on proteins in beef, TVP, and TVP + 1% DL-methionine of 2·37, 2·12, and 2·82, respectively. These results suggest the efficient manner that rats utilized DL-methionine relative to adult males.

At this time, we have no long range studies on textured soy proteins. The problems involved with such studies are obvious, particularly the necessity of keeping the subjects in confinement and under constant supervision.

FACTS ON NUTRIENTS IN TEXTURED SOY PROTEINS

Proteins

Being the major component in defatted soy flour and with such desirable functional characteristics as texturization, proteins in soy were extensively studied during the past 20 years. Several parameters have been adopted to express soy protein's nutritional quality, most of them in comparison to standardized animal proteins, such as casein or whole egg. A few are based upon absolute values. We will not cover in detail the methodology of protein evaluations but rather analyze pertinent theories and data that correlate protein composition with its biological value.

Table VII shows the essential amino acids in beef, textured soy proteins, and FAO protein pattern. The only limiting amino acids are methionine and cystine. To improve soy protein to match FAO, one has to add L-methionine from any acceptable source. Whole egg protein has been accepted as the reference protein since 1946 when Block and Mitchell (8) published their chemical score of proteins. Kofranyi (9) reported that in a nitrogen balance study on human males, a mixture of 36% egg nitrogen and 64% potato nitrogen yielded better results than whole egg alone. He maintained that the biological value (BV) of a protein is dependent upon amino acid pattern rather than the absolute amounts of essential amino acids supplied. Bujard, et al., (10) presented data from a different angle to support Kofranyi's work. In their effort to correlate between total amino acid content, amino acid enzymatic degradation in vitro, digestibility, BV, and NPU in rats, they established good correlation between pepsin-pancreatin-digest-dialyzate (PPDD) index and BV and NPU. PPDD index reveals the pattern of EAA released in vitro digestion and the undigestible residue. These hypotheses can explain the reasonably close BV and PER of beef and textured soy proteins in spite of the significant differences in the sulphur amino acid content (Table VIII).

Changes in soy protein digestibility and PER during and after thermoplastic extrusion are minor. Defatted soy flour averaged 89% in digestibility in comparison with 80% for textured soy proteins. Cumming, et al., (11) reported that water soluble soy proteins became insoluble after thermoplastic extrusion and were broken into subunits with lower mol wt.

Lipids and Associated Components

Defatted soy flour contains between 0.7% and 1.5% residual fat depending upon the method of analysis. Details on the composition of residual lipids and associated components will be reported somewhere else. It is sufficient to say here that ca. 19% petroleum ether-solubles in defatted flakes are phosphatides and the rest are neutral glycerides (12). Changes that may develop during thermoplastic extrusion are not known yet. However, if we follow the observations in toasting soy flakes, we expect an increase in neutral glycerides and fatty acids, which, in turn, generates hydroperoxides. We realize the significance of hydroperoxides and degradation products on the taste and odor of textured soy proteins but have no information

TABLE IX

Carbohydrates in Textured Soy Proteins[a]

Carbohydrate	Source		Percent
Monosaccharides			
Glucose	Cotyledons		0.3
Arabinose	Hull		Trace 0.1
Ribose	Nucleic acids		Trace 0.1
Pligosaccharides			
Sucrose	Cotyledons		8.1
Maltose	Cotyledons		0.6
Raffinose	Cotyledons		1.1
Stachyose	Cotyledons		4.9
Polysaccharides			
Arabinan	Cotyledons		15.0[b]
Arabinogalactan	Cotyledons		
Xylan (hemicellulose)	Hulls		3.5[c]
Galactomannans	Hulls		
Cellulose	Hulls		
		Total	33.5

[a]Data calculated from private communication.
[b]See ref. 14.
[c]See ref. 11.

on their nutritional significance.

Wolfram and Zöllner (13) reported that 6.5 g linoleic acid are required daily to keep normal level of linoleic acid in blood cholesterol of adults. Textured soy proteins in Poullain's, et al., (4) experiment would have supplied 0.2 g linoleic acid based upon the fact that 20 g TVP protein contained 0.4 g lipids, of which 50% was linoleic acid. This amount of linoleic acid is ca. 3.1% minimum daily requirement reported by Wolfram and Zöllner (13).

Carbohydrates

Carbohydrates compose ca. one-third components in textured soy proteins. Table IX shows semiquantitative list of these carbohydrates. The presence of raffinose and stachyose causes flatus to a variable degree of discomfort. Textured soy proteins may generate, in physiological testing, 23.5 cc/g relative to 18.1 to 27.6 cc/g for pulses (private communication). When textured soy proteins were

TABLE X

Indispensable and Toxic Elements in Unflavored and Uncolored Textured Soy Proteins[a]

Element	Content	
Indispensable	Mg/100 g	Percent RDA in 20 g protein[b]
A. Bulk		
Sodium, Na^+	0.9	—
Potassium, K^+	2090	—
Calcium, Ca^{2+}	252	10.0
Magnesium, Mg^{2+}	302	30.2
Phosphorus, PO_4^{2-}	740	29.6
Chloride, Cl^-	0.07	—
B. Trace		
Iron, Fe^{3+}	9.6	21.0
Cobalt, Co^{2+}	0.0000001	—
Copper, Cu^{2+}	1.6	32.0
Manganese, Mn^{2+}	3.6	—
Zinc, Zn^{2+}	5.6	14.9
Aluminum, Al^{2+}	0.9	—
Boron, B^{2+}	3.8	—
Iodine, I^-	<0.000005	1.0
Toxic	ppm	
Arsenic, As^{2+}	<0.05	
Cadmium, Cd^{2+}	0.07	
Lead, Pb^{3+}	0.1	
Mercury, Hg^{2+}	<0.05	
Selenium, Se^{2+}	0.15	

[a]See ref. 15.
[b]RDA for adults and those 4 years of age or older.

TABLE XI

Provisional Tolerable Weekly Intake (PTWI) of Heavy Metals from Food[a]

Element	Mg/kg wt	PTWI,mg	Mg/280 gm TSP/week[b]
Mercury	0.005	0.3	<0.002
CH_3Hg^+	0.0033	0.2	
Lead	0.05	3.0	0.028
Cadmium		0.4-0.5	0.002
Arsenic	—	—	<0.002

[a]See ref. 16.
[b]Calculated from data in Table IX and for daily consumption of 20 g protein from textured soy protein.

blended with minced meat at 30:70 ratio, gas production increased from 2.2 to 6.7 cc/g.

The fate of reducing sugars and sucrose in textured soy proteins depends upon the heat treatment at the extrusion and drying steps. Extrusion temperatures that range from 150-155 C are used widely in manufacturing textured soy proteins. Higher temperatures will cause browning in the product and detectable scorched flavor. Drying conditions, if not well regulated, may add to the browning reactions.

Minerals

Mineral content in textured soy proteins varies with cultural practices, particularly soil, climate, and fertilizer applied to the growing soybeans. Table X shows a selected list of the quantities of indispensable and toxic elements present in unflavored and uncolored textured soy proteins. The classification of bulk or macro- and trace or micro-elements is based upon the quantity required by the human body to maintain and develop healthy tissues. The bulk elements Na^+, K^+, Ca^+, Mg^{+2}, and anions PO_4^{3-}, and Cl^- are required in blood plasma and red cells to build skeletal and transport tissues. Trace elements, Fe^{+3}, Cu^{+2}, Co^{+2}, Mn^{+2}, I^-, are essential in the function of enzymes and coenzymes.

The quantities of both bulk and trace elements here allow good source for human requirements; however, iron has been supplemented to the level of 10 mg/100 g in textured soy proteins.

The toxic elements, As^{+2}, Cd^{+2}, Pb^{+2}, Hg^{+2}, are present at levels below the sensitivity of the current analytical methods and are shown in Table X. These elements compete with the indispensable ones, and their accumulative effect on body metabolism is lethal. The poisonous effect of mercuric salts on enzymes and nucleic acids is known. The World Health Organization (WHO) published in 1972 provisional tolerable weekly intake (PTWI) of heavy metals, as listed in Table XI). We included in the same table the calculated amounts of Hg^{+2}, Pb^{+2}, and Cd^{+2} that will be ingested with 20 g protein supplied daily for 1 week from textured soy proteins. It is evident that the amounts of heavy metals are negligible to cause any concern at this time.

Vitamins

Their organic nature differentiates them from trace elements. Table XII lists the levels of vitamins in textured soy proteins and their ratios to the U.S. RDA. The levels of vitamins A, C, and D are too negligible to be reported here; on the other hand, all the other vitamins supply 8-40% U.S. RDA in 20 g protein. The level of vitamin enrichment in textured soy protein is not finalized yet, because under consideration is the increase in folic acid to 0.3 mg/g protein and in vitamin A to 15 IU/g protein.

THE BIOCHEMICAL AND PHYSIOLOGICAL EFFECTS OF TEXTURED SOY PROTEINS IN HUMANS

One of the methods to assess nutritional status is by evaluating the changes in the biochemical and physiological

TABLE XII

Vitamins in Textured Soy Products

Vitamin	Level, mg/100 g		Percent U.S. RDA in 20 g proteins[c]
	As is[a]	Enriched[b]	
A	—	—	—
D	—	—	—
B_1, Thiamine	0.3	0.3	8.0
B_2, Riboflavin	0.3	0.6	14.1
B_6, Pyridoxine	0.4	1.4	28.0
B_{12}, Cyanocobalamin, mcg	<0.1	6.0	40.0
Folic acid	0.2	0.2	20.0
Pantothenic acid	2.5	2.5	10.0
Niacin	2.3	16.0	32.0
C, Ascorbic acid	<1.0	<1.0	—

[a]Data from Lauhoff Co.

[b]Data from Lauhoff Co. on textured soy protein that has vitamin levels specified by U.S. Department of Agriculture.

[c]RDA for adults and children 4 years of age and older.

indices relative to a norm. Blood, urine, feces, and sometimes milk analyses reveal data that can be used with reasonable accuracy in determining human or animal general state of health. We will discuss some of the biophysiological data reported on feeding textured soy proteins that support the facts mentioned earlier under feeding studies. Kies and Fox (3) reported on the blood components of subjects maintained on 4.4 g nitrogen daily. Table XIII shows their findings which can be discussed under three groups: protein components, minerals, and nitrogenous waste materials. The ranges in total protein, albumin, globulin, hemoglobin, and hematocrit were comparable among the three diets. Calcium, phosphorus, and, indirectly, iron in hemoglobin in subjects fed TVP or TVP with methionine were normal when compared to the beef fed subjects. Uric acid and urea nitrogen did not vary significantly among the three treatments.

These results prove that: (A.) Soybean protein was adequate to supply the essential amino acids to the nitrogen pool to maintain the build up of blood protein components; (B.) Iron is absorbed from the textured soy protein and other components in the diet to supply a normal hemoglobin level; (C.) Calcium was readily available from the diets with TVP or TVP with methionine, and the presence of phytates did not interfere with calcium bioavailability; and (D.) Uric acid levels in the subjects fed the three diets were comparable, which indicates that the purine level in textured soy proteins did not affect uric acid. Urea nitrogen average increased slightly in the subjects fed TVP or TVP + methionine and the range was larger than in subjects fed beef.

These results also suggest that no antimetabolites that may be present in textured soy protein interfered with the assimilation of nutrients by human or animal bodies. It is our contention that, under the moist-heat-pressure conditions of processing textured soy proteins, antimetabolites in soybeans are inactivated to have practically no effect on the latter's nutritive value.

QUALITY ASSURANCE ASPECTS IN TEXTURED SOY PROTEINS

We recall the time when one's only concern on food safety was whether it contained poisons. Now our concern extends to several areas as a result of man's knowledge and insatiable desires for new food and variety. Table XIV shows, in general, the areas of concern to food processors and to consumers. Specific measures taken by the processors of textured soy proteins in the U.S. to assure quality control are as follows: (A.) Examination of the defatted soy flour or other base material for infestation and extraneous materials, so that it contains no more than one insect fragment/50 g sample. The low moisture levels in textured soy protein will not sustain infestation. (B.) Processors realize the economic loss because of microbial contamination; therefore, microbial load is controlled throughout processing textured soy proteins. The following standards are representative: total plate count/g, 5000 (max.); coliform/g, 50, thermophilic spores/g, 15; coagu-

TABLE XIII

Effect of Feeding Beef or TVP Nitrogen on Blood Components[a]

Blood component	Beef	TVP	TVP + Methionine
Total protein g/100 ml	7.0 (6.3-7.6)	6.9 (6.8-7.2)	7.0 (6.6-7.6)
Albumin, g/100 ml	4.5 (4.1-4.9)	4.5 (4.2-4.7)	4.5 (4.2-4.9)
Globulin, g/100 ml	2.5 (2.2-2.9)	2.5 (2.1-3.2)	2.5 (2.2-2.8)
Hemoglobin, g/100 ml	15.0 (11.3-16.6)	15.4 (13.7-16.6)	15.1 (11.9-17.7)
Hematocrit, ml/100 ml	44 (35-48)	46 (40-50)	45 (38-50)
Calcium, mg/100 ml	10.1 (9.6-11.4)	10.2 (9.7-11.4)	10.0 (9.5-10.8)
Phosphorus, mg/100 ml	4.2 (3.6-4.7)	4.2 (3.6-6.0)	4.2 (3.8-4.7)
Uric acid, mg/100 ml	6.5 (3.7-10.1)	6.1 (4.8-7.8)	5.8 (4.1-7.7)
Urea N, mg/100 ml	8.6 (4-12)	9.0 (4-16)	9.1 (5-15)

[a]See ref. 3.

TABLE XIV

Food Safety Area of Concern to Processors and Consumers

1.	Extraneous material Filth
2.	Microbial contamination A. Loss in quality and value B. Acquired toxicants–aflatoxins
3.	Natural toxicants and antimetabolites Trypsin inhibitor
4.	Environmental threats Pesticide residues Toxic elements: Hg^{2+}, Cd^{2+}
5.	Nutritional imbalance Addition of vitamins and minerals
6.	Food additives Absolute safety

lase-positive staphyloccus, negative; and *Salmonella*, negative.

No aflatoxins or ochratoxins have been detected in textured soy proteins. Thousands of soybean samples were checked by the Food and Drug Administration's laboratories, and the occurrence of aflatoxins was rare.

Antimetabolites, such as trypsin inhibitors and hemagglutinins, are virtually eliminated by inactivation during processing of base material, as reported earlier, and during the manufacture of textured products.

Environmental threats indicated in pesticide residues and in the levels of toxic heavy metals are the most serious, since the tragic reports on cadmium and mercury poisoning in Japan in 1968. Pesticide residues in soybeans are monitored by the U.S. Department of Agriculture and Food and Drug Administration agencies. Spot check analyses on heavy metals in textured soy proteins proved the levels are safe, as shown in Table XI.

Consumer concern on the nutritional imbalance in textured soy proteins is manifested in the response of consumer groups, academic and research institutions, and nutritionists in publishing new regulations on nutritional standards for textured soy proteins. Enrichment with vitamins and minerals is on provisional basis, because we need to know more on the effects of adding nutrients, such as calcium, iron, zinc, vitamin A, or others on the nutritional quality of textured soy proteins.

Processors of textured soy proteins for school lunch programs in the U.S. guarantee the minimal levels of vitamins and iron in their products. Daily checks on iron and one or more of the vitamins assure that products meet the standard.

Food additives are probably the least threat to the majority of consumers. The great efforts of the joint FAO/WHO Codex Alimentarius Commission to set international food standards can surely eliminate some of the road blocks on the diverse usage of food additives in textured soy proteins.

Textured soy proteins are undoubtedly an excellent example of man's creativeness when he applied knowledge to engineer a new supplementary food that is nutritious, palatable, and last, but not least, economical.

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