SOYA MEAL

Soybean Meal Processing and Quality Control

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ABSTRACT

The quality of soya meal is the result of many factors, including bean variety, origin and storage. The various processing steps employed from the time the bean is received can affect the quality of the resulting meal and oil obtained. Heat treatment of the meal is essential to optimize its protein quality. The variables of moisture, temperature and time are interrelated and are important to achieve proper cooking conditions. The magnitude of these variables must be determined for each plant, preferably using a biological assay for evaluation. Many in vitro tests designed to measure protein quality in soya have been proposed and evaluated. The merits and limitations of some of the more widely used in vitro tests are discussed. Various processing conditions have been studied to improve utilization of soya products by infant calves and pigs. The manufacture of soya protein concentrate (70% protein, d.s.b.) has made products available that are suitable for a substantial replacement of milk protein in milk replacer formulations.

INTRODUCTION

The soybean has been cultivated and valued highly as a food for many centuries. Mendel and Fine (1) showed "special interest" in the unfavorable results obtained when soybeans were fed as early as 1911. Osborne and Mendel (2) first found that the poor biological value of raw soya protein could be markedly improved by heating under moist conditions. The growth-depressing properties of the soybean have continued to be the subject of intensive nutritional research for over 60 years. Much has been learned about the composition and structure of the soybean. This knowledge is now being used to produce one of the best and most uniform in quality protein sources available. Soybean meal is the primary protein concentrate source in feeds fed by the U.S. Livestock and Poultry Industry, and its use is rapidly expanding throughout the world. The availability of soya meal has made it possible for the livestock and poultry industries to grow at a rapid rate since 1940.

NONPROCESSING QUALITY FACTORS

The factors that affect the quality of meal and oil include variety, season, soil type and fertilization. Leng (3) reported that the range of protein content in soybean seed is 42.2-35.1%, of oil is 23.4-11.4%, of linoleic acid of the oil is 59.6-33.8%, of sugars is 16.5-6.2%. The composition of the sugars was found to be 67.5-41.3% sucrose, 15.8-5.2% raffinose and 35.2-12.1% stachyose. Clark and Hymowitz (4) and Yen et al. (5-8) found less trypsin inhibitor activity in certain commercial cultivars and reported that these variants were superior to other raw commercially grown cultivars (such as Amsoy, Clark, Harosoy) as protein sources for rats, swine and chicks. Orf and Hymowitz (9) reported that seed of PI 157440, a soybean line from Korea, did not contain the Kunitz trypsin inhibitor. With methionine supplementation (10), raw PI resulted in a significant improvement in gain and gain-to-feed over raw Amyso 71 when fed to chicks (Table I). Although PI (Kunitz inhibitor absent) caused the rate of gain and gain-to-feed to be significantly lower than that of soybean meal, its performance was approximately 45% better than Amsoy 71.

Krober and Cartter (11) observed that non-nodulating varieties grown on soils low in nitrogen gave low yields and were low in protein. The methionine content of the protein ranged from 1.1 to 1.5%, with a tendency for the higher protein seed to contain more methionine. To study environmental effects, a single variety, Hardee, was grown at the same location in the same season. The use of different strains of Rhizobium in inoculation, or lack of inoculation, caused the protein content to vary from 28.5 to 45.5%. The methionine content was found to range from 1.3 to 1.7% of the protein.

Weather damage lowers the quality of the soybean (12). Rain and dampness can cause molds to grow rapidly, turning them brown. A hard frost prematurely stops growth and causes freeze damage to the beans that generally remain green in color. The free fatty acid content of the oil was found to be higher under these conditions. Oil quality continues to decline during storage but at an accelerated rate in freeze-damaged beans. The trypsin inhibitor content of

TABLE I

Nutritional Value of a Trypsin Inhibitor (Kunitz) Variant Soybean for the Chick (10)

	DL-Methionine, % added	SMB	PI	Amsoy 71
Ave da. gain, (g)				
	0.0	9.2	5.25	4.7
	0.3	13.4	10.85	8.4
Gain/feed				
	0.0	.58	.43	.37
	0.0	.68	.57	.48
Pancreas, % of body wt				
	0.0	.12	.195	.19
	0.3	.125	.21	.27

damaged beans was reported to increase with storage beyond 6 months, which is contrary to undamaged beans. The lower oil quality and possible higher trypsin inhibitor levels after storage of weather-damaged beans increase processing costs and problems.

Soybean breakage (13) increased the free fatty acid content from 0.65% for whole beans to 1.79% for halves, 3.04% for pieces, and 9.46% for fines (by differences).

Soaking and cooking times required for various beans have been studied by Burr and Kon (14). In their study, Sanilac beans containing 16.7% moisture were soaked and cooked both shortly after harvest and after storage for one year at 21 C. Cooking time at harvest was 32 min vs 94 min after storage for one year. Saio et al. (15) reported on the effect of time, moisture and temperature of storage on the change in color, acid value and nitrogen solubility index (NSI) of soybeans. They found that color darkened, NSI decreased and acid value increased with time, temperature and relative humidity. Total reducing substances significantly increased in the extraction of soybeans from water immersion after storage. The interaction of proteins with carbohydrates is therefore another possibility during storage and processing and may ultimately effect protein quality.

Temperature and relative humidity are both related to overall changes during storage, but relative humidity seems to be more important. Relative humidity is a function of temperature and moisture. Webb et al. (16) studied the relation of interparticle relative humidity to the growth of molds and/or spontaneous heating in various feed ingredients. No feed ingredient or mixed feed became moldy or heated during 6 weeks of storage at a relative humidity of 72.0% or less. Saio et al. (15) observed that beans molded during storage at 25 C and 80% relative humidity.

BIOLOGICALLY ACTIVE FACTORS

Biologically active factors were recently reviewed by Liener (17) and Anderson et al. (18). Some biologically active factors are trypsin inhibitor, lipase inhibition, goitrogenicity, allergenicity, flatulence and hemagglutination. The role that protein digestibility plays in assessing the nutritive value of soya protein sources is important. The trypsin inhibitors do not appear to account fully for the growth inhibition caused by raw soybeans (Table II) (19). Kakade et al. (20) removed the trypsin inhibitor activity of a crude extract of soybeans and found the inhibitor-free extract still caused growth inhibition and pancreatic hypertrophy in rats (Table III). Approximately 40% of the growth inhibition and pancreatic hypertrophy could be attributed to the trypsin inhibitors removed. Although removal of the trypsin inhibitor improved digestibility of the protein, a much greater increase was effected by heat treatment.

TABLE II

Effect of Adding Partially Purified Soybean Trypsin Inhibitor (STI) to Diets Containing Heated Soybean Meal in the Presence and Absence of Methionine (19)

Diet	Protein efficiency ration (PER)	
	- Meth	+0.6% Meth
Raw soybeans	1.3 ±.15	2.42 ±.10
Heated soybeans[a]	2.63 ±.10	2.99 ±.03
Heated Soybeans + 1.8% STI	1.95 ±.09	2.63 ±.07

[a]Autoclaved at 15 lb pressure (115) for 20 min.

TABLE III

Contribution of Trypsin Inhibitors to the Growth Inhibition and Pancreatic Hypertrophy Induced in Rats by Diets Containing Unheated Soybean Protein (20)

Dietary protein	PER	Wt of Pancreas, g/100 g body wt
Soya flour extract, unheated	1.4	0.71
Soya flour extract, heated	2.7	0.57
Soya flour extract, minus inhibitor	1.9	0.65
Change due to removal of inhibitor	+38	-43

Evans and St. John (21) reported on the distribution of soya albumins, globulins, prolamines, glutelins and residual protein in solvent-processed soybean flakes autoclaved at 121 C. for 5, 15, 30, 60 and 120 min (Table IV). Heating decreased the percentage of albumins and globulins present in soybean meal. The glutelins were first increased and then decreased by heat treatment. The residual or insoluble protein was increased by heat treatment. The glutelins and residual protein fractions were composed largely of denatured proteins. Dry heat was less effective than wet heat in causing heat denaturation.

Boonvisut and Whitaker (22) reported on the effect of heat, amylase and disulfide bond cleavage in the in vitro digestibility of soybean proteins. Through trypsin and successive pepsin-trypsin treatment, they found the in vitro digestibility was affected by the presence of trypsin inhibitors, the native structure of the proteins, and the presence of starch (shown to be present in soybeans). Trypsin inhibitors were destroyed by heating at 100 C. for 30 min at pH 1, but not at pH 7. The native structure of the proteins could be destroyed by heating (particularly at a low pH), by digestion with pepsin at pH 1, or by cleavage of the disulfide bonds. Prior amylase treatment increased the

TABLE IV

Influence of Heat Treatment on Protein Distribution in Solvent Process Soybean Flakes (21)

Treatment	Time (min)	Albumins[a] (%)	Globulins[a] (%)	Prolamines[a] (%)	Glutelins[a] (%)	Insol. prot.[a] (%)
None	0	75.6	5.7	3.5	6.0	9.2
Autoclaved (121 C)	5	49.6	6.3	2.7	19.8	21.6
↓	15	8.8	6.4	3.4	45.8	35.9
	30	6.4	1.6	3.2	38.6	49.6
	60	7.5	1.2	2.6	22.6	65.4
	120	8.6	1.0	2.7	10.0	77.3
Dry heat (121 C)	60	64.4	6.8	2.3	10.1	16.5
Boiling H_2O	60	15.2	3.6	3.6	38.2	38.6
Autoclaved (110 C)	60	6.1	2.2	3.0	44.2	43.6

[a]Percentage of total protein.

trypsin digestibility of most protein fractions. Almquist et al. (23) heated raw soya meal in an autoclave at 15 psi in the presence of paper containing lead acetate solution. In the first 30 min a very distinct deposition of lead sulfide took place. A further 30 min liberated a relatively small amount of sulfide, indicating that the release of sulfur was

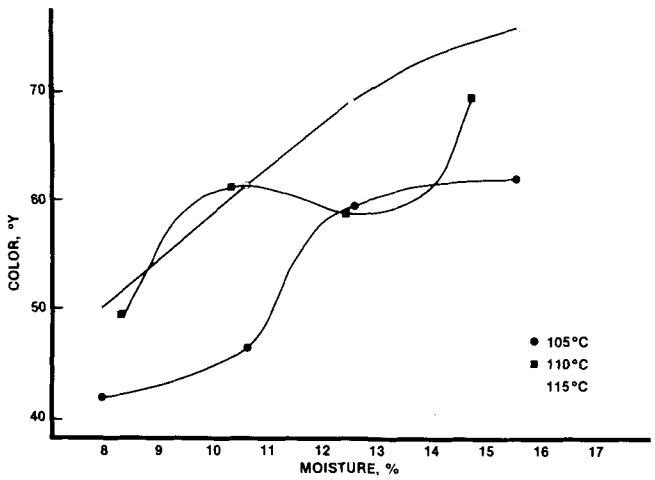

FIG. 1. Relationship of color to moisture and temperature.

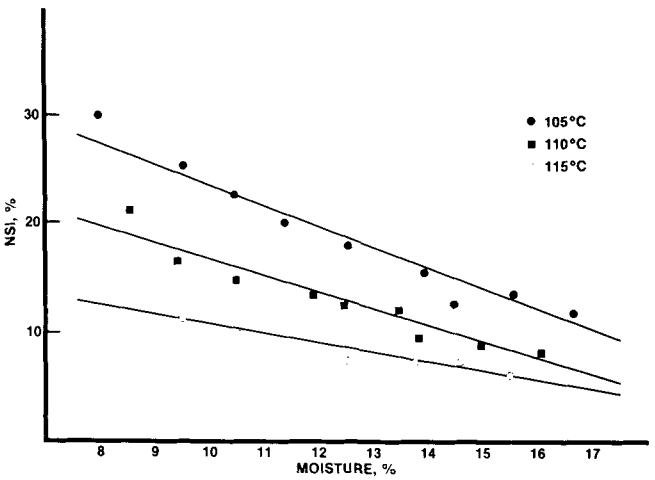

FIG. 2. Relationship of NSI to moisture and temperature.

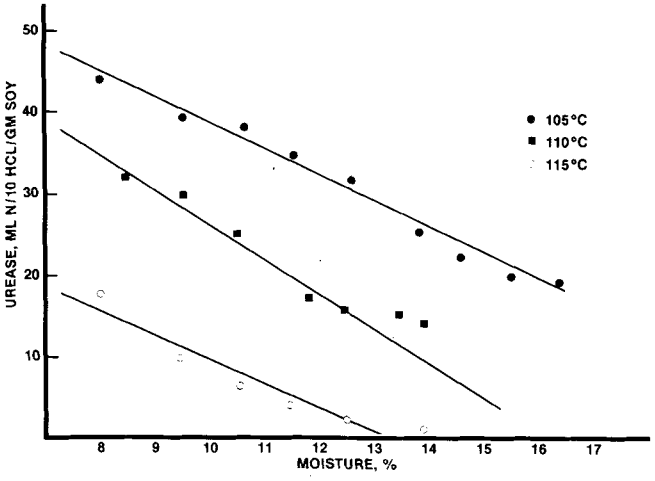

FIG. 3. Relationship of urease activity to moisture and temperature.

essentially complete in 30 min. The proteolytic enzyme inhibitors of beans contain disulfide bonds that reportedly contribute to the stability of the tertiary structure of proteins (24,25). The Bowman-Birk inhibitor contains 19.8% sulfur containing amino acids and has seven disulfide bonds per mole (26).

The effect of moisture, temperature and time on the denaturation of protein, color development and inactivation of urease has been reported by Wright (27). Figures 1, 2 and 3 indicate that an interrelationship exists between nitrogen solubility index (NSI), urease activity (UA) and color with the application of heat and moisture for different lengths of time. The heat treatment process must, therefore, be adjusted to optimize the nutritional value of the protein and is at best a compromise between denaturation or destruction of the undesirable properties and retention of the nutrients present in available form.

Tables V, VI and VII indicate the effects of various heat treatment conditions on rat and chick performance. The data indicate that with improved performance, a reduction in NSI and UA has occurred, but at lower levels little, if any, correlation exists. For example, the protein efficiency ratio (PER) and gains were obtained for rats (Table V) and chicks (Table VI) with soya meals having a urease activity as high as 5.2-6.06 mls N/10 HCl per gram of meal. This corresponds approximately to 0.5-0.6 units change in pH using the modified Kaskey-Knapp procedure (Table VIII) (28). The results are not unexpected since urease plays no physiological role in the monogastric animal.

The relationship of UA to NSI is shown in Figure 4. The significance of this relationship lies in the fact that the trypsin and lipase inhibitors, hemagglutinins, and probably the allergens are proteins or derivatives, as is the enzyme urease, and they are also denatured by heat. Albrecht et al. (31) reported that adequate cooking of whole soybeans can be accomplished by atmospheric steaming or immersion in boiling water in less than 15 min, as judged by trypsin inhibitor and urease activity. High initial moisture is the most important factor favoring rapid cooking. As shown in Figure 5, a comparison of the destruction of trypsin inhibitor and urease activity indicates that the inhibitor is destroyed as readily as urease.

Renner and Hill (32) have shown that the cooking of soybeans and extracted flakes to optimize growth also increased the metabolizable energy value. Nesheim et al. (33) found that fat absorption by chicks was low up to 2 weeks of age but was not affected by the addition of a Kunitz inhibitor preparation. Sambeth et al. (34) reported that the gall bladder of chicks contract when fed certain raw soybean whey fractions. Garlich and Nesheim (35) reported that the reduction in ability to absorb fat by chicks receiving raw soybean meal can be overcome by feeding sodium taurocholate or soybean lecithin.

A protein-inhibiting pancreatic lipase activity was isolated from a soybean extract by Mori et al. (36). Purification and properties of a lipase-inhibiting protein was reported by Satouchi and Matushita (37). The inhibitor was found to have a molecular weight of 77,000 and to be active in the pH range of 6.5 to 9.5, but to be unstable below this pH. Activity was almost completely lost above 50 C. in the absence of substrate emulsion, but was still stable at 60 C. in the presence of substrate. The mode of action was found to be caused by an interaction between the inhibitor and substrate rather than lipase and the inhibitor.

Rackis et al. (38) observed that with destruction of as little as 54% of the trypsin inhibitor activity, pancreatic hypertrophy was prevented in rats, but a destruction of 80 percent was required for optimum PER (Table IX).

TABLE V

Relationship of Nitrogen Solubility Index (NSI), Urease Activity (UA), and Color to Protein Efficiency Ratio (PER) (60)

Treatment	NSI	UA[2], ml N/10 HCl/g, by titration	Color ° Y	PER
Raw flakes	50.0	45.93	36.1	1.64
104.4 C – 108 min				
7.97% H_2O	23.69	32.96	36.8	1.76
11.88% H_2O	15.41	25.94	48.8	1.78
14.98% H_2O	11.67	10.52	50.8	1.69
110 C – 108 min				
8.35% H_2O	17.85	26.04	37.5	1.67
12.10% H_2O	11.47	6.06	46.9	1.87[a]
14.96% H_2O	8.88	0.16	59.3	1.79
115.6 C – 108 min				
7.95% H_2O	13.48	13.15	41.7	1.71
12.19% H_2O	8.75	1.08	55.0	1.99[a]
14.98% H_2O	7.95	0.65	58.0	1.90[a]
100 C – flowing steam				
15 min	29.44	17.03	37.0	1.94[a]
30 min	21.51	4.08	35.9	1.94[a]
60 min	12.12	0.54	–	1.96[a]
Commercial SBM	15.25	4.11	50.0	1.89[a]

[a]Values are significant over raw flakes ($P < .01$).

TABLE VI

Effect of Heat Treatment on Growth-Promoting Qualities of Soybean Meal (29)

Treatment	UA, ml N/10 HCl/g	Gain (g) 0-4 wk	Gain (g) 0-8 wk	Feed/gain 0-4 wk	Feed/gain 0-8 wk
Raw	41.4	287	853	2.4	2.7
10 min	5.2	359	1030	2.0	2.4
20 min	2.9	342	1000	2.1	2.4
30 min	1.5	382	1069	2.0	2.4
180 min	0.2	375	1023	2.0	2.4
Commercial	0.1	375	1011	2.0	2.4
Raw + 0.15% meth	41.4	318	927	2.2	2.5
30 min + 0.15% meth	1.5	380	1078	2.0	2.4

TABLE VII

Plasma Amino Acids and Protein Efficiency of Chicks Fed Autoclaved Commercial Soybean Meal (30)

Heating time (hr)[a]	% lysine in meal	g gain/g protein cons.	Plasma lysine (mg/100 ml)	Plasma lysine/leucine
0	3.1	2.95	13.6	4.9
0.5	2.8	2.66	12.3	3.6
1	2.6	2.57	8.8	2.8
1.5	2.4	2.16	5.4	1.6
2	2.2	1.77	4.6	1.5
4	1.6	0.54	2.3	0.8

[a]Autoclaved at 15 lb layered 2.54 cm thick.

Liener (39) reported on a hemagglutinin in raw soybeans and found this material to depress the growth of rats. Turner and Liener (40), however, concluded that the soybean hemagglutinin plays a relatively minor role in the deleterious effects of unheated soybean flour. Hemagglutinating activity is readily destroyed by moist heat.

The cooking of raw soybean meal has been demonstrated to reduce the need for vitamin B_{12} (41). Ershof (42) reported on the antithyrotoxic activity in soybeans. Konijn et al. (42) found that the goitrogenic material in soya flour inhibited iodine uptake by the thyroid in vivo and in vitro and decreased organification by the gland. Suwa et al. (43) reported on studies of soybean factors which produced goiter in rats, and reported that goiter was prevented relatively easily when iodine was added to the diet (Table X).

Carlson et al. (44) reported the rachitogenic effects of isolated soybean protein in turkeys. The addition of an eight-fold level of vitamin D_3, or autoclaving the protein source, could largely overcome the effect. Jensen and Mraz (45) reported that supplementing chick diets with soybean meal, autoclaving the isolated protein, or reducing the level of soy protein improved bone ash.

Factors capable of producing an estrogenic response in

TABLE VIII

Relationship of Results Obtained by Titration and Modified Caskey-Knapp Urease Methods (28)

Soybean meal	Titration method, ml N/10 HCl/g	Change in pH units
A (Blank)	0.0	0.0
A	12.2	1.23
B	5.5	0.55
C	2.5	0.25
D	1.3	0.13
E	0.7	0.07
F	0.2	0.02
G	0.1	0.01

animals occur naturally in soybeans; this activity was estimated by Carter et al. (46). Hexane-extracted soybean flakes were found by Walter (47) to contain 0.1% of the glucoside of genistein (genistin). Genistein was found to be 4.44×10^{-6} times as potent in estrogenic activity as diethylstilbestrol. It is doubtful that normal consumption of soybean products would provide sufficient amounts of the various estrogenic compounds present to be of practical importance.

ALLERGENICITY

It has been reported that calves are particularly sensitive to certain soybean proteins. Attempts to substitute more than 30% or 40% soya resulted in diarrhea, weight loss and occasional deaths (48,49). Smith and Sissons (50) provided evidence of disturbances in intestinal function, which may be linked with a gastrointestinal allergic response. Barratt et al. (51) studied serum antibody responses to ingested aqueous alcohol extracted-soy proteins and showed them to be predominantly a complement-fixing IgGl precipitin. No evidence of tolerance was seen. Previously sensitized calves responded to reintroduction of a soya diet with marked increases in antibody levels. Biopsies revealed morphological disturbances to the villi and lamina propria of the intestine. A significant inhibition of flow rate in the intestine was demonstrated in the pig.

Diser (52) observed that when calves were given successive feeds prepared from heated soy flour, mean rates of digesta flow increased markedly between the first and fifth feed, which confirmed other observations. Ileal flow, polyethylene glycol recovery and net N absorption obtained for heated soya flour were significantly different ($P < 0.05$) from those for casein or ethanol extracted soy meal. It appeared that hot aqueous ethanol treatment of soybean products for calf feeding had a beneficial effect by inactivating toxic factors responsible for disturbances of digestive processes. The beneficial effect that ethanol extraction of soya meal had in calf diets in preventing digestive disorders and in improving growth may have been partly due to the removal of ethanol-soluble oligosaccharides. Sucrose, a major disaccharide in soybeans, is not digested by the calf, nor are the polysaccharides stachyose and raffinose.

SOYBEAN PROCESSING

The discussion so far has focused on some of the important factors to consider in the processing of soybeans. Generally, the knowledge important in processing lies in the areas of dehulling, extraction and the cooking of protein products to optimize their nutritive value for food and feed uses. The processing of soybeans has been reviewed in detail (51,53,54,55).

The preparation of beans for processing is important to achieve good hull removal. This step is critical for manufacture of high-protein dehulled soya meal. McDonald (55) states that beans should be dried rapidly (79 C.), lowering the moisture to a range of 12.5-13.0%; then dried at a lower temperature of 65 C. to a range of 9.0-10.0% moisture. The beans should be conditioned for a minimum of 2 weeks (preferably 30 days) before processing for good dehulling.

After storage, the beans are cleaned to remove any tramp iron and foreign matter present. They are then dried to shrink the kernel from the hull, and sent through cracking rolls, reducing the beans to sizes of one-sixth to one-eighth bean particles. These fragments are graded and passed through aspirators, where the hulls are separated from the meats. The separated hulls are toasted and ground for animal feed. The cleaned, cracked meats pass to a conditioner-cooker, which raises their temperature to about 77 C, with a moisture content in the range of 10%. The conditioned particles are then flaked, using flaking rolls, to a thickness of .005-.010 in. The cell walls are broken down and surface area is increased for extraction. The flakes are extracted with a solvent, usually hexane, to remove the oil, forming a mixture called miscella. The oil is recovered from the miscella and refined, and the spent flakes are desolventized to remove the residual hexane. If the product is destined for food use, the solvent is usually removed under mild conditions. The desolventized flakes are then processed to produce the desired product specifications, such

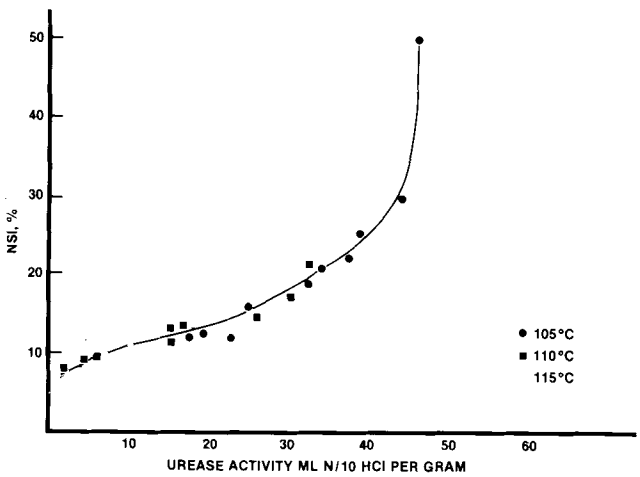

FIG. 4. Relationship of urease activity to NSI.

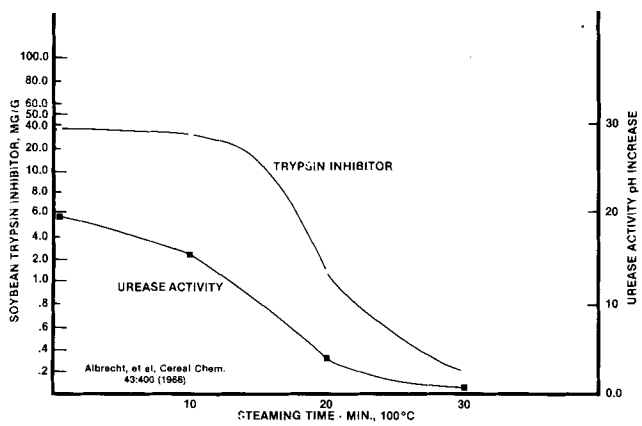

FIG. 5. Relationship of urease activity to trypsin inhibitor.

as a given NSI. If they will be used for feed purposes, the spent flakes may be desolventized, then cooked, or desolventized and cooked in one operation.

Many levels of moisture and temperature, at given times, will adequately reduce trypsin inhibitor to a safe limit and denature the protein to achieve good digestibility for most purposes, except as feed for infant animals. The temperature should be at least in the range of 100 C or above; the time will be dictated by the temperature chosen and the moisture content of the product. It does not make any difference if the cooking is done at atmospheric or elevated pressures, as long as all criteria are satisfied to optimize product performance.

LABORATORY TESTS FOR QUALITY

Many attempts have been made to correlate improvement in protein quality with in vitro laboratory tests. The most widely used methods measure urease activity (28), trypsin inhibitor (56), water and alkali-soluble protein, fluorescence, available lysine (57) and enzyme digestibility. Cravens and Sipos (58) studied all these methods and found a good correlation within a given process between processing conditions and in vitro tests. Unsatisfactory correlation was found between the tests and nutritive value, and no correlation existed between laboratory results and nutritive value when samples came from different processors. Wright (27) observed that the only known reliable method for determination of soya protein quality is the animal feeding test. Plant conditions must be adjusted to optimize nutritive value. Once these conditions are established, in vitro tests such as urease activity, trypsin inhibitor activity, NSI and available lysine are valuable in helping to produce a high-quality product consistently. Urease activity is probably best for this purpose if only one test must be used.

UREASE ACTIVITY

The interpretation of UA values is important in respect to an evaluation of a soya product. The enzyme serves no practical physiological function in the mono-gastric, but is important if present in ruminant feeds that contain urea. High UA values, above pH increases of 0.6 in soy products, strongly indicate that the product has received a mild cook. The absence of UA in a product such as an isolate does not provide any information on the nutritional status of that isolate in regard to heat treatment. A low UA, in the range of 0.05 pH change or less, suggests that the product may have been overheated, but this conclusion may not necessarily be correct (Tables V and VI).

A UA value of 0.2 pH increase (maximum) is accepted by many to be the level of safety in soya meal products. This should be considered as the maximum level to be safe, when the meal is used in ruminant feeds at normal levels in the presence of urea. The 0.2 pH increase value may be too low in many cases for poultry, since some unnecessary protein damage may have taken place to achieve this goal. DeSchrijver (59) obtained several commercial samples of soya meal in Europe that ranged in UA from 0.01 (probably overcooked) to 1.1 (probably undercooked). These samples were used in chick rations at levels of 38%. The results obtained are given in Table XI. Interestingly, the UA values ranged as high as 0.65 pH increase with good performance, which confirms the data given in Tables V and VI.

TABLE IX

Effect of Soya Flour Containing Various Levels of Trypsin Inhibitor on Growth and Size of Pancreas of Rats (38)

% TI Destruction	Body wt (g)	PER	Pancreatic wt (g/100 g body wt)
0	79	1.59	0.70
40	111	2.37	0.56
68	121	2.78	0.50
82	134	2.97	0.49
87	148	3.08	0.47
92	142	3.03	0.45
Casein	145	3.35	0.55

TABLE X

Effect of Iodine Supplements in Diets Containing Raw Soybeans on Thyroid Weight of Rats (43)

Iodine supplement[a] (mg/100 g diet)	Thyroid (mg/100 g body wt)
0.0	26.4 ± 4.0
5.0	12.7 ± 1.3
10.0	9.4 ± 0.5
20.0	8.9 ± 0.3

[a]Diet contained 40% raw soybeans.

TABLE XI

Comparison of Biological Value and Urease Activity of Commercial Samples of Soybean Meal (59)

Sample no.	Urease activity	Chick gain (g)	FCE
2	0.01	1305	1.92
6	0.04	1318	1.85
9	0.08	1345	1.83
5	0.11	1345	1.86
12	0.25	1331	1.87
3	0.27	1341	1.83
11	0.33	1317	1.88
4	0.37	1323	1.88
8	0.43	1319	1.84
10	0.45	1326	1.83
7	0.65	1336	1.89
1	1.10	1285	1.93

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Critical Processing Factors in Desolventizing-Toasting Soybean Meal for Feed

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ABSTRACT

Even though it is well established that both underheated and overheated meals are of inferior nutritive value, comparatively little is known of the fundamental nature of the changes brought about in the protein and how these correlate with the processing conditions during toasting. In the present study we examined the interrelation of several factors in the commercial desolventizing-toasting process for toasting soybean meal and determined how these relate to protein quality of the meal. A total of 48 test runs were made in the pilot plant from two cultivars of soybeans (one high and one low in protein) that were dehulled, flaked, and defatted in a continuous extractor using hexane. The solvent-wet flakes were desolventized and toasted under a variety of conditions. In a simulation of commercial operation, independent variables such as moisture, temperature and time of toasting were mathematically converted to equations for computer fitting of the data, which were used to predict several dependent measurements. Quality of the meal was improved by increasing heating time, jacket steam pressure and moisture content. Moisture level in the toasting operation was directly affected by the hexane level in the feed material to the toaster.

INTRODUCTION

Solvent extraction is the preferred method for processing soybeans; more than 90% of the soybeans crushed in the U.S. are handled by this procedure. The most sensitive step in the process for controlling protein meal quality is the desolventizing-toasting (D-T) operation. During the past few decades, the heating or toasting of soybean meal to improve nutritional value has been studied, but little work has been reported with a commercial D-T.

Design and operation of the D-T has been reported by Kruse (1,2), Cravens and Sipos (3), Sipos and Witte (4) and Milligan (5). A preliminary study on a pilot-plant D-T process has been reported by Moulton et al. (6). A major consideration during the various processing steps of desolventizing-toasting is the relationship between time, temperature and moisture, and the effect of that relationship on protein denaturation and protein quality.

The purpose of this study was to define the processing steps and conditions that control nutritional quality. These conditions become important upon translation to D-T operations in the soybean industry. Working with two soybean cultivars in a series of 48 experimental runs, we determined conditions for toasting soybean meals to low urease activity and trypsin inhibitor levels. Other quality criteria such as nitrogen solubility index, available lysine and meal color were also studied.

EXPERIMENTAL

Milling and Extracting

Two soybean cultivars, namely Essex and York, were grown in Maryland and supplied by the University of Maryland for the tests. The beans were milled and extracted for oil at a rate of 50 lb/hr according to the flow procedures shown in Figure 1. The soybeans were cracked through 6 in. diameter (15.24 cm) corrugated rolls set for 0.075 in. (0.19 cm) clearance. As the cracked beans passed onto the double screen shaker, the hulls were removed by an aspirator and collected. The larger pieces of cracked soybeans passing over the top screen [3/16 in. (0.48 cm) perforated round hole] of the double screen shaker were recycled into the cracking process. Bottom screen was 14-mesh black wire screen. The dehulled beans (meats) retained on the bottom screen passed to the tempering conveyor, where they were heated to 165 F (73.9 C) by indirect steam. Tempered meats were flaked through 12 in. (30.48 cm) diameter smooth rolls to a thickness of approximately 0.010 in. (0.025 cm).