RATE STUDIES ON ATMOSPHERIC STEAMING AND IMMERSION COOKING OF SOYBEANS[1]

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ABSTRACT

Simple methods for adequately cooking soybeans to produce a full-fat flour would enable populations in many of the developing countries to have a food that would provide needed protein in their diet. Rate studies were made on two such cooking procedures — atmospheric steaming and immersion in boiling water. Variables of initial moisture, particle size, and hull removal were correlated with rate of cooking as defined by change of urease activity and nitrogen solubility index (NSI). Trypsin inhibitor assays were correlated with urease enzyme activity. Conditions were established for both methods that enabled rapid cooking of soybeans. The experiments demonstrated that initial moisture of the soybean fraction is a major factor influencing cooking rate. High initial moisture (62–65%) promotes rapid decrease in both NSI and urease. Small particle size influences the reduction of urease activity, but has little influence on the rate of NSI reduction. Therefore, by steaming a soybean fraction of small particle size (under 20-mesh) and low moisture (8%), it is practicable to destroy urease activity and retain high NSI if this is desired in the cooked product. Restricted timing (5–7 min.) of the immersion cooking of soaked whole soybeans can also retain high NSI value while destroying urease. Trypsin inhibitor activity is destroyed at approximately the same rate as urease by both cooking methods.

In many of the developing countries a deficiency of protein in the diet is a major nutritional problem. The need for concentrated forms of protein for growing children has been well established by many world food organizations. A good source of concentrated protein being proposed to improve nutrition in the diets of the developing countries is full-fat soybean flour.[2] A beverage or porridge made from this flour is an ideal way of serving protein to children. In addition to its protein content, full-fat flour contains lipids that also have good nutritive value.

Under the sponsorship of the Agency for International Development (AID), research has been undertaken to develop a process that would be suitable for making full-fat soybean flour in village communities in protein-deficient areas.

Flour produced from the process should have high nutritive value, acceptable taste, and storage stability. Processing should be simple

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[2]Milner, M. Unpublished report. International Symposium on Oilseed Protein Foods. Mt. Fuji, Japan, May 1964.

and easily adaptable anywhere. As an initial requirement, a cooking step is needed to inactivate growth inhibitors and to attain full nutritive value. Atmospheric steaming and immersion in boiling water are two cooking methods that were investigated. Rate studies were made on these two methods to obtain preliminary data for selection of an optimum process.

Materials and Methods

Materials. Hawkeye soybeans, 1963 crop, were used exclusively. For the atmospheric steaming experiments, a variety of physical forms of soybeans of varied moisture were prepared (Table I). For immersion

TABLE I

SOYBEAN FRACTIONS USED IN ATMOSPHERIC STEAMING EXPERIMENTS
(All mesh sizes are U.S. standard sieve series)

PHYSICAL FORM	MOISTURE	PHYSICAL FORM	MOISTURE
	%		%
Whole beans	8	Whole beans	20
Dehulled whole beans	8	Half beans	20
Dehulled half beans	8	Meats − 6+10 mesh	20
Meats − 6+10 mesh	8	Meats −20+40 mesh	20
Meats −10+20 mesh	8	Whole beans	62–68[a]
Meats −20+40 mesh	8	Dehulled whole beans	62–68[a]
Meats −40+80 mesh	8	Meats +6 mesh	62–68[a]

[a] Beans were soaked overnight.

cooking, only whole beans were used, since the high loss of solubles in the cooking water from soy meats would make this method unfeasible.

Analyses. Nitrogen solubility index (NSI) was determined by the method of Smith and Circle (1) modified as follows: 2.5 g. of sample (less than 100-mesh) was added to 100 ml. water and the pH adjusted to 7.2 with sodium hydroxide. The sample was agitated at 125 r.p.m. with a flat-bladed agitator for 2 hr. at 30°C. After centrifugation for 15 min. at 1,060 r.c.f. at tip, nitrogen was determined on the supernatant. Urease was determined by the official AACC method (2), and trypsin inhibitor according to the method of Wu and Scheraga (3).

Procedure. For atmospheric steaming, each sample was spread in a single layer on a stainless-steel screen. A jacketed autoclave was preheated with atmospheric steam in both the jacket and chamber until the condensate leaving the chamber was essentially 100°C. The sample screen was then placed in the center of the chamber and the door closed but not locked. Steam escaping around the door assured absence of pressure build-up in the chamber; steam on the jacket kept condensation within the chamber at a minimum. After steaming was

completed, the door was opened with the steam still on and the sample screen removed. After drying at room temperature overnight, the samples were ground and then defatted with hexane for chemical analyses.

For immersion cooking, beans were placed in folded cheesecloth and then immersed in a quantity of boiling water about ten times the weight of the beans. After draining, the beans were treated in the same manner as the steamed samples.

Results and Discussion

Atmospheric Steaming. The urease activity of selected samples from the soybean steaming experiments is shown in Table II. Comparison of

TABLE II
EFFECT OF MOISTURE AND PARTICLE SIZE ON UREASE ACTIVITY
(Atmospheric steaming 15 min.)

INITIAL MOISTURE	UREASE ACTIVITY, pH INCREASE				
	Whole Beans	Dehulled Whole Beans	Half Beans	Meats: U.S. Standard Sieve Size	
				−20+40	−40+80
%					
8	1.6	2.1	1.7	0.1	0.1
20	0.2	..	0	0	..
62–68 (soaked)	0.1	0	..	..	..

the urease values for whole beans uniformly steamed for 15 min. at three levels of initial moisture shows the influence of initial moisture on reducing urease activity. Increasing the moisture level from 8 to 20% had a pronounced effect in destroying urease activity. Further increasing the initial bean moisture to 62–68% by overnight soaking reduced the urease even more effectively in the whole bean. Ground meats (20- to 80-mesh) were reduced in urease activity much more rapidly when the initial moisture was 8% than were whole or half beans.

Reduction of urease activity with steaming time for whole beans at three moisture levels is shown in Fig. 1. Dehulled kernels of 8% moisture are also included to show the effect of hulls on urease change.

Rate of urease enzyme deactivation was much more rapid with high initial moisture than with the 8% moisture. No urease was detected at either moisture level after 30 min. of steaming. Urease activity in the soaked bean was probably destroyed before that in the bean with 20% moisture, but steaming times between 15 and 30 min. were not evaluated.

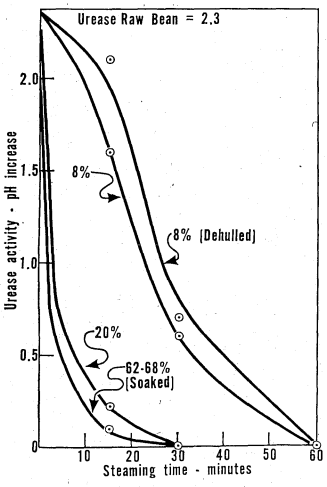

Fig. 1. Effect of initial moisture on urease activity of whole soybeans when steamed at 100°C.

The two curves at 8% moisture comparing whole beans with and without hulls reveal that urease activity falls off rapidly for both conditions. Apparently soybean hulls do not slow the cooking rate as determined by urease inactivation.

Figure 2 shows the effect of particle size on urease activity when

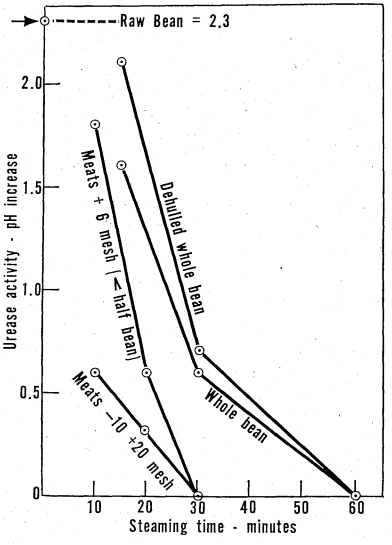

Fig. 2. Effect of particle size on urease activity of soybean fractions with 8% initial moisture, steamed at 100°C.

initial moisture was held at a constant value of 8%. Up to 15 min. of steaming, the urease activity for the smallest particle size decreased most rapidly. The slower drop in urease with larger particle size appears correlated with moisture and heat penetration. Effect of particle size was most significant during the first 15 min. of steaming.

The effect of moisture and particle size on NSI when the various soybean fractions were treated with atmospheric steam for 30 min. is shown in Table III. The protein in soaked beans of 62–68% moisture

TABLE III
EFFECT OF MOISTURE AND PARTICLE SIZE ON NSI
(Atmospheric steaming 30 min.)

Initial Moisture	Nitrogen Solubility Index (NSI)					
	Whole Beans	Dehulled Whole Beans	Half Beans	Meats: U.S. Standard Sieve Size		
				+6	−6+10	−10+20
%	%	%	%	%	%	%
8	40	44	49	36	..	43
20	28	..	27	..	29	..
62–68 (soaked)	15	17	..	14	..	..

was denatured more rapidly than in beans of 20% moisture. With urease activity, these two moisture levels showed only slight differences. At constant moisture, particle size did not greatly influence NSI value. As shown previously, small particle size favored more rapid destruction of urease.

The effect of initial moisture on NSI values of whole and dehulled beans steamed at 100°C. is illustrated in Fig. 3. Straight lines were fitted to these data by the method of least squares. A 95% confidence limit for a predicted NSI value is given by ± 3 NSI units.

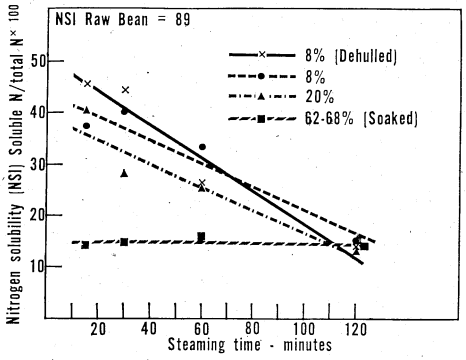

Fig. 3. Effect of initial moisture on NSI value of whole beans steamed at 100°C.

The lines for beans with 8% moisture, with and without hulls, show that hull removal had little or no influence on the change in NSI. Soybeans steamed at 20% moisture had a lower NSI than the beans with 8% moisture during the early steaming period. This similarity means that the higher moisture increased the rate of protein denaturation during the first 15 min. of steaming but did not affect the rate between 15 and 120 min. High-moisture soaked soybeans cooked very rapidly as judged by their low NSI values. The NSI was no lower after continued steaming. After 2 hr. of steaming, all the beans regardless of initial moisture had a NSI of approximately 15.

Immersion Cooking. Immersion cooking of soaked whole soybeans in boiling water for 7 min. resulted in a solids loss of 5% of the dry bean weight in the cooking water. This loss was not considered excessive enough to preclude immersion cooking from consideration as a simple, practical cooking method.

Table IV shows the urease and NSI values for whole soybeans, immersion-cooked at two respective levels of initial moisture, 8% and 62–68% (soaked overnight).

Soybeans presoaked overnight had all urease activity destroyed after 5 min. of immersion cooking, whereas the low-moisture bean still had residual urease activity after 30 min. The protein denaturation of soaked beans after 5 min. of cooking is equivalent to that in a low-moisture bean after 20 min. of cooking, as indicated by NSI values of 34 and 35. The change in NSI with immersion time for presoaked soybeans is shown in Fig. 4.

The drop in NSI is relatively slow after the first 2 min., when destruction of urease activity is essentially complete. Therefore, restriction of the immersion time during cooking would avoid excessive decrease in NSI.

TABLE IV

EFFECT OF INITIAL MOISTURE ON UREASE ACTIVITY AND NSI OF WHOLE SOYBEANS IMMERSION-COOKED IN BOILING WATER

Cooking Period	Urease Activity, pH Change: Initial Moisture		NSI: Initial Moisture	
	8%	62–68% (soaked)	8%	62–68% (soaked)
min.			%	%
0	2.3	2.3	89	89
2	..	0.1	..	40
5	..	0	..	35
7	..	0	..	23
10	1.9	0	49	13
20	0.8	0	34	11
30	0.1	0	24	11

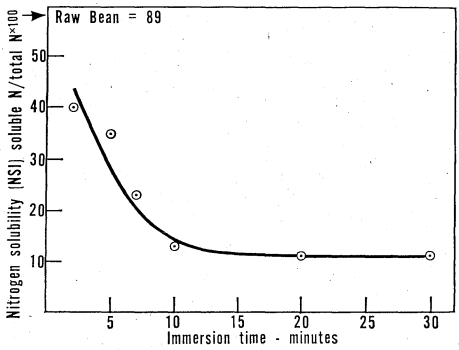

Fig. 4. Protein denaturation as measured by nitrogen solubility during immersion cooking of presoaked soybeans.

Trypsin Inhibitor. The presence of trypsin inhibitor activity in soybeans is indicative of undercooking and low nutritive value. Table V gives trypsin inhibitor values for several samples selected from both steam and immersion cooking. These samples were selected on the basis of their relatively high NSI value accompanied by low urease activity. Comparison of the trypsin inhibitor destroyed with urease activity reveals that the inhibitor is destroyed as readily as the urease by either cooking method. To compare the relative rates of destruction for trypsin inhibitor and urease, values were determined on a series of samples (+6 mesh, 8% moisture) from the steaming experiment that started with high urease activity. These values (Fig. 5) indicate that the trypsin inhibitor and urease activity are destroyed at about the same rate. Therefore, a low urease value should be accompanied by low trypsin inhibitor concentration in the cooking methods described in this paper.

TABLE V

TRYPSIN INHIBITOR ASSAYS OF SELECTED COOKED SOYBEAN SAMPLES

SAMPLE DESCRIPTION	INITIAL MOISTURE	COOKING TIME	UREASE ACTIVITY, pH CHANGE	NSI	TRYPSIN INHIBITOR DESTROYED [a]
	%	*min.*		%	%
	Atmospheric steam				
Whole beans	20	15	0.2	40	99
Half beans	8	30	0.1	49	99
Meats −10+20 mesh	8	30	0	43	99
	Water immersion				
Whole beans	62	5	0	35	100
Whole beans	65	7	0	23	99

[a] Based on 35 mg. standard trypsin inhibitor per g. raw bean.

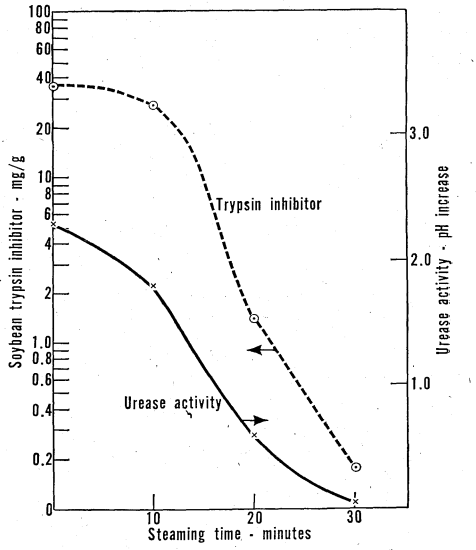

Fig. 5. Comparative data showing trypsin inhibitor concentration and urease activity of selected samples steamed at 100°C. for various periods.

Conclusions

Adequate cooking of soybeans can be accomplished by atmospheric steaming or immersion in boiling water in less than 15 min. as judged by inactivation of trypsin inhibitor and urease. High initial moisture in the bean is the most important factor favoring rapid cooking. Small particle size increases the rate of destruction of urease activity but has little influence on the rate of decrease in NSI. Removal of soybean hulls does not speed cooking rate. Relationships developed in this study will be the basis for establishing optimum conditions for simplified cooking methods to produce full-fat soy flours. Taste and nutritive value are also important properties of the flour that need to be evaluated in the future.

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