

COOKING PROCEDURES FOR DIRECT CONSUMPTION OF WHOLE SOYBEANS¹

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SUMMARY

The purpose of this research was to determine adequate conditions for the preparation of soybeans at home level. In accordance with the results, soaking the soybeans for eight hours in a 0.25% bicarbonate solution, gives the appropriate hydration to the soybeans, which can then be easily cooked. Boiling them at atmospheric pressure during 20 minutes was required to destroy 80% of the soybeans antitrypsin activity, and a high PER was also obtained. Nevertheless, the soybeans texture was not satisfactory; therefore, longer boiling periods were tested so as to establish the most suitable time needed to achieve a softness similar to that of common beans as usually consumed. Softness was measured instrumentally, and the optimal conditions found were: 40 min boiling after 8 hr soaking in a 0.25% bicarbonate solution. Under these conditions, the PER and NPU values increased 18% and 33%, respectively, with respect to those of the casein PER and NPU.

It is concluded that with this procedure, large amounts of protein can become available at an equivalent price to US\$0.40/kg (\$ 80.00/kg).

INTRODUCTION

One of the most important public health problems in Mexico is the unsatisfactory nutrition of nearly 80% of the population (1-3), particularly with respect to the protein content and quality of their diet (4).

In recent years, soybeans have received considerable attention as a protein source because of their high-protein yield per cultivated area (5, 6), protein quality, and low cost. Nevertheless, apart from some Asian countries, soybeans are not consumed directly, due to several factors:

Manuscrito modificado recibido: 12-3-85.

1 This research was partially supported by a CONACYT grant.

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1) their hardness, which makes them require long cooking periods (7), and 2) unpleasant sensory characteristics (odor and taste), which are basically due to the lipoxygenase action (8, 9). Furthermore, crude soybeans have a relatively high content of thermolabile trypsin inhibitors which may be responsible for their relatively low digestibility and protein quality, and also cause pancreatic hypertrophy in rats (10, 11).

The existing industrial techniques eliminate most of the antitryptic activity and yield soy products of an acceptable sensory quality. In Mexico, however, industrial soybean products are sold to the public at prices three to ten times higher than those of the raw seed, thus making them inaccessible to the low-income population which should be the target group for the consumption of such products.

Direct consumption of soybeans and other legumes is an alternative approach to make low-cost protein available to the population. Home germination and fermentation techniques have been used for centuries in East Asia; these procedures eliminate some toxic factors and improve their nutritional value (12-15), as well as sensory quality. It is anticipated, however, that incorporation of these methods into the Mexican culinary and eating habits would be difficult in the short term, since they are complicated and exotic.

Therefore, to allow for direct consumption of soybeans, it is necessary to develop techniques which are both simple and in accordance with the culinary habits of the Mexican population.

One of the basic foods in the Mexican diet, and the main protein source in rural areas, is the common bean (*Phaseolus vulgaris*) prepared in different ways, most frequently by simple boiling. Being somewhat similar, soybeans could be prepared the same way, and utilized by the population as a partial or total substitute for common beans without confronting strong culinary and cultural barriers. Such a substitution would be advantageous with respect to protein quantity, quality and price.

Soybeans (Tropicana variety) usually require 10 hours of boiling in plain water so that they develop a soft texture similar to that of cooked common beans (16). This is an inconvenient and energy-expensive procedure, unable to compete with the boiling of common beans which takes less than four hours. It has been shown that pre-soaking decreases the cooking time for different seeds, including soybeans (7, 11). Berra (7), demonstrated that alkaline conditions further increase the effect of soaking. In some regions of Mexico, housewives add small amounts of sodium bicarbonate to the soaking water to speed-up cooking of common beans; this suggests that soaking in alkaline conditions could be accepted by the population.

If an acceptable procedure which reduces cooking time to that usually spent for cooking common beans is developed, the purpose of direct human consumption of soybeans might be achieved. However, it will also be necessary that such procedure render: a) soybeans with a soft texture, similar to that of common beans as usually consumed; b) a lowering of the trypsin inhibitors down to less than 20 TIU/mg of solids recommended by Rackis (11) as safe for consumption; and c) a decrease in protein quality not below 80% of that of casein, which is the value commonly obtained with industrial soy products.

The purpose of this research, therefore, was to determine the most appropriate conditions for soaking (time, pH) and cooking (time) of soybeans, so as to fulfill the previously described requirements of texture, trypsin inhibitors inactivation, and protein quality, in order to develop simple, specific recommendations for the direct consumption of whole soybeans.

MATERIALS AND METHODS

Materials

Whole soybeans (*Glycine Max*, Tropicana variety), cultivated in the southern area of Tamaulipas, Mexico, were processed according to the procedure shown in Figure 1. Beans were soaked in either a 0.50% or 0.25% aqueous sodium bicarbonate solution, or in plain water (control). The water-to-soybeans ratio was 6:1; solution temperature was 20°C in all cases; and the pHs of the solutions were 8.4, 8.2 and 7, respectively. Other variables tested were soaking time (0, 6, 8 and 10 hr) and cooking time (0, 10, 20, 30, 40 and 50 min).

Analytical Methods (17)

Proximal analyses — Crude protein measured by the Kjeldahl method (18) was expressed as N x 5.71, which is the conversion factor recommended for soybeans. Ether extract, crude fiber, ash and moisture (19-21), were determined according to the AOAC methods, and moisture, as recommended by Pearson (23). Carbohydrates were calculated by difference.

The hydration ratio was determined by the technique of Steinkraus *et al.* (24), and defined as g of hydrated sample/g of the original, while the trypsin inhibitor activity was established by the spectrophotometric technique of Kakade *et al.* (25).

Texture was determined according to Breene and Braker (26), a technique which is based on compressing the sample until it breaks. Chewiness resistance index (CRI), an indication of hardness, is defined as the integrated area under the pressure curve applied against time. This was determined using an Instron Universal Testing Machine.

Biological quality of the protein — Protein efficiency ratio (PER) and net protein utilization (NPU) were determined by the methods of Campbell (27) and Miller (28), respectively. For each experiment, nine Wistar albino rats from the Institute's colony were housed in individual cages and fed the test diet for 28 days. Protein level was 100% by weight; other components of the diet were: corn oil 200%, starch 200%, sucrose 200%, dextrose 200%, cellulose 40% and Teklad³ vitamin and mineral mixture.

Sensory evaluation was done by 20 untrained panelists using a hedonic

3 Trade name: Teklad test diets ARS/SPRAGUE-DAWLEY Div. of Mogul Corp. Madison, WI. Casein was used as the protein source for the control diet.

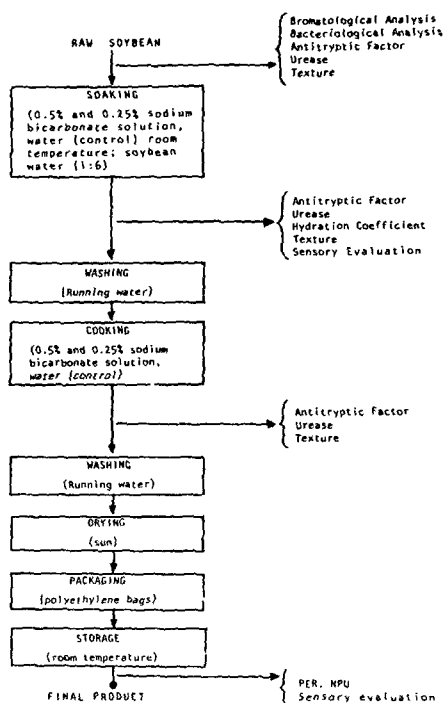


FIGURE 1

Soybean soaking and cooking treatment

scale (29); the test comprised texture, appearance and taste of the different samples.

RESULTS AND DISCUSSION

The proximal analyses and trypsin inhibitor activity of dehulled raw soybeans are depicted in Table 1.

Table 2 presents the hydration ratios after soaking for 6, 8 and 10 hrs, either in plain water (control) or in 0.25% and 0.50% sodium bicarbonate solutions. It is obvious that the hydration ratios increased both with time and with bicarbonate concentration.

The effect of soaking conditions on the trypsin inhibitor activity is shown in Table 3. Soaking in plain water for 6 hr produced no changes in TI activity (113 TIU/mg) from initial non-soaked soybeans. Prolongation of the soaking time resulted in a slight decrease (7%) in activity. We do not have any explanation for this phenomenon which, evidently, needs further research. Soaking in bicarbonate solutions produced some TI inactivation for the three soaking times; the highest occurred in the more concentrated solution (sodium bicarbonate 0.50%; pH 8.38) which,

TABLE 1

COMPOSITION AND TRYPSIN INHIBITOR CONTENT OF DEHULLED SOYBEAN GRAINS (TROPICANA VARIETY)

Component	g/100 g of product
Crude protein (N x 5.71)	38.6
Ether extract	18.6
Crude fiber	5.9
Moisture	8.2
Ash	5.0
Carbohydrates (by difference)	23.7
TIU/mg*	113.5

* mg of sample (deffated and dried).

TABLE 2

HYDRATION RATIOS* OF SOYBEANS SOAKED IN WATER AND IN DIFFERENT SOLUTIONS OF SODIUM BICARBONATE

Soaking time hours	Soaking solution		
	Water control	NaHCO ₃ (0.25 ^o /o)	NaHCO ₃ (0.5 ^o /o)
6	1.4	2.0	2.5
8	1.8	2.2	3.0
10	2.0	2.2	3.4

* g of hydrated sample/g of original dry sample.

at 10 hr, was 37^o/o. Reduction of TI activity by soaking alone has not been reported by other authors (30-33), but both the variety of the soybeans and the pH of the solutions used were different. After soaking, each sample was cooked during 0, 20 and 30 min, respectively, by boiling in the soaking solution at atmospheric pressure, after which times trypsin inhibitor activity was measured. Findings are presented in Figure 2.

According to Rackis (11), from the toxicological point of view, inactivation of 80^o/o of the antitryptic activity in raw soybeans is adequate, since it prevents the decrease in protein quality which results from further thermal processing. Figure 2 shows that inactivation of 80^o/o or more of the trypsin inhibitor was obtained with all solutions and soaking times applied when the soybeans were cooked for 20 min or more. Soaking in 0.5^o/o sodium bicarbonate solution for 6, 8 or 10 hr increased the inactivation efficiency during boiling and, in the three cases, more than 80^o/o inhibition of activity was obtained even after boiling for only 10 min. TI activities for the three soaking times were similar when the bicarbonate solutions were used both for soaking and cooking, and

TABLE 3

TRYPSIN INHIBITOR ACTIVITY IN SOYBEANS SOAKED IN WATER AND IN DIFFERENT SOLUTIONS OF SODIUM BICARBONATE (TIU/mg)*

Soaking time hours	Soaking solution		
	Water (control)	NaHCO ₃ (0.25 ^o /o)	NaHCO ₃ (0.5 ^o /o)
6	113.5	99.6	90.7
8	107.0	94.5	91.5
10	105.5	94.8	71.5

* Per mg of sample (deffated and dried).

indicate that a period of 6 hr of soaking suffices. Thus, to achieve 80^o/o inactivation of TI, soybeans should be soaked for six hours and cooked for 20 min, using a 0.25^o/o bicarbonate solution, or for 10 min using a 0.5^o/o bicarbonate solution (30, 31).

Sensory determinations of texture and flavor were conducted on samples soaked from 6 to 8 hr in the three different solutions and boiled for 20 min. All samples were judged as "unacceptably hard" in compar-

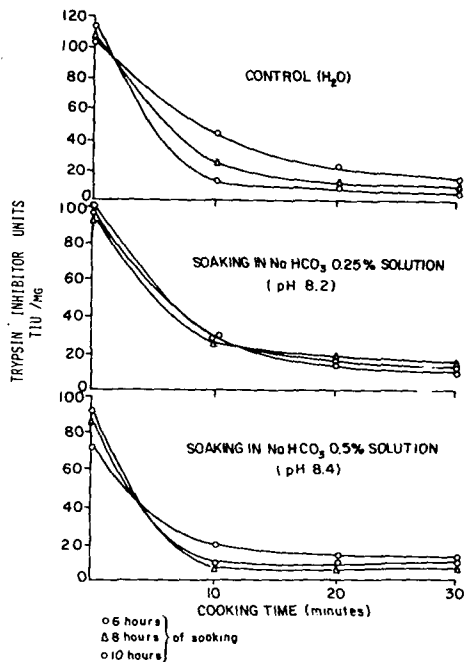


FIGURE 2

Activity of the trypsin inhibitor in soybeans at different cooking and soaking times in different solutions

ison to common cooked beans. Flavor was "poor", especially for the samples soaked in the 0.50/o sodium bicarbonate solutions, which exhibited a "very unpleasant salty taste". It was evident that, even though 20 min of cooking is enough to inactivate the trypsin inhibitor, longer cooking periods were required to improve the texture of soybeans. Samples, soaked initially in the three solutions for each of the three soaking times, were boiled for 0, 20, 30, 40 and 50 min and then, chewiness (CRI) was measured. Results are depicted in Figure 3. Samples of boiled common beans, considered by the panel as having a good texture, were used as control; these samples had chewiness resistance index (CRI) values between 10 and 20, values which were set as the goal to be achieved for soybeans (32, 33).

Soaking in plain water failed to lower the CRI below 30. Soaking in either bicarbonate solutions, at any of the three soaking times, produced a continuous reduction of the CRI with cooking times up to 40 min, after which time reduction was negligible. At 40 min, the indexes were 22 and 18 for samples soaked and cooked in the 0.25 and 0.50/o bicarbonate solutions, respectively.

Since the only advantage of using the 0.50/o bicarbonate solution was to reduce the time necessary for TI inactivation from 20 to 10 min and provided that with this solution, sensory characteristics were the poorest, it was eliminated from the rest of the study.

Once the conditions to achieve the best sensory characteristics (flavor and softness) and safe antitrypsin values were established, the protein quality of treated soybeans was evaluated by the PER and NPU tests. For comparison purposes, these indexes were also determined for raw, non-soaked soybeans, and for soybeans soaked during 8 hr in a 0.250/o

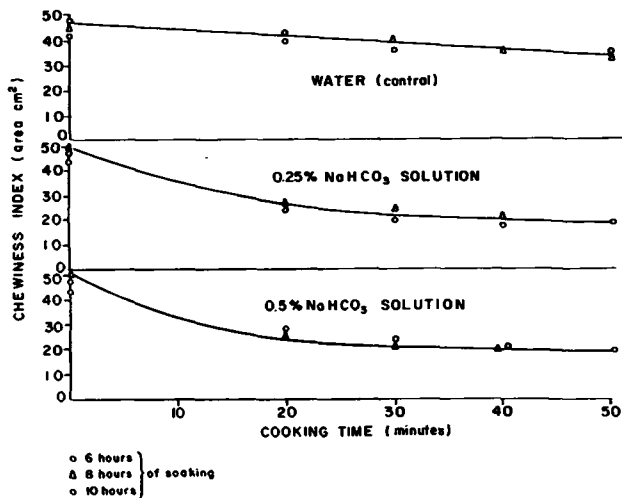


FIGURE 3

Chewiness index of soybeans under different soaking and cooking times

TABLE 4

**PER AND NPU OF SOYBEANS SUBJECTED TO DIFFERENT CONDITIONS
OF SOAKING* AND COOKING**

Source of protein in the diet	PER	PER as % of casein's	NPU	NPU as % of casein's	TIU/mg
Casein	2.5 ± 0.61	100.0	60.0 ± 11.9	100.0	—
Soybeans					
Unsoaked raw	0.66 ± 0.56	26.4	22.0 ± 6.7	36.7	113.43
Soaked raw	1.17 ± 0.32	46.8	29.3 ± 4.1	47.13	94.51
Soaked + cooked 20 min	2.77 ± 0.12	110.8	64.5 ± 11.5	107.6	17.5
Soaked + cooked 40 min	2.82 ± 0.24	112.8	58.0 ± 8.5	96.8	11.2

* Each datum represents the mean value of nine rats ± standard deviation.

sodium bicarbonate solution, either raw or cooked for 20 or 40 min. Results are summarized in Table 4. In general, as expected, there was a good correlation between the PER and NPU. Raw soybeans had a low protein quality, roughly one-third that of casein; soaking for 8 hr in a 0.25% bicarbonate solution without cooking, increased both PER and NPU to 47% of casein values, but the increase was not statistically significant. Cooking for 20 or 40 min after 8 hr of soaking further increased both indexes to levels statistically similar to those of casein. Both the PER and NPU of cooked soybeans were statistically higher ($p < 0.001$) than those of uncooked-unsoaked beans, but no difference could be demonstrated between those submitted to 20 and 40 min cooking ($p < 0.01$). It is concluded that optimum levels of protein quality are obtained for domestic preparation of soybeans with the procedure selected (34, 35).

Two vegetable soups and a salad were prepared using soybeans cooked for 40 min after soaking in 0.25% bicarbonate solution for 8 hr as substitutes for common beans. These dishes were offered informally to a group of 20 persons working in the laboratory; more than 80% considered them to be "satisfactory".

In summary, soaking alone was ineffective in decreasing TI activity to safe levels, and it was necessary to apply a heat treatment by boiling for 20 min; this treatment, however, was not enough to produce a texture similar to that of common beans as customarily eaten. For an acceptable texture, 8 hr soaking in a 0.25% bicarbonate solution and 40 min boiling were required. The presence of bicarbonate was effective, but the use of plain soaking water did not achieve adequate texture when the soybeans were boiled for 40 min; this period was considered too long. Protein quality of boiled soybeans substantially increased when cooked for 20 or 40 min. The developed procedure enables direct consumption of soybeans, improving their protein quality and eliminating the trypsin inhibitor activity

problem. Furthermore, the method is simple enough to be followed by most people.

The cost of the product using the procedure described (considering the cost of soybeans, bicarbonate and energy needed), was slightly less than the equivalent of US\$ 0.40 per kg, which, in Mexico, is considerably lower than the price of industrial soybean products that cost from US\$ 0.80 to 2.00 per kg. This advantage, in terms of cost, makes possible soybean consumption by the low socio-economic strata of the population, but direct consumption of soybeans will require intensive education measures; nevertheless, since the Mexican population eats common beans frequently, this may be a favorable factor of achieving the proposed objective.

RESUMEN

PROCEDIMIENTOS DE COCCION PARA EL CONSUMO DIRECTO DE LA SOYA ENTERA

Este trabajo tuvo como objetivo determinar las condiciones adecuadas para la preparación de soya a nivel del hogar. De conformidad con los resultados, el remojo de soya durante ocho horas en una solución de bicarbonato de sodio al 0.25%, proporciona la hidratación apropiada que permite una fácil cocción de la soya. Para destruir el 80% de la actividad antitripsina se requirieron 20 minutos de ebullición a presión atmosférica, con lo que se logró un PER alto. Sin embargo, para lograr una textura similar a la del frijol común, se necesitaron mayores tiempos de ebullición. La textura se midió mediante equipo instrumental, encontrándose como condiciones más adecuadas el remojo durante ocho horas en una solución de bicarbonato de sodio al 0.25% y, posteriormente, ebullición durante 40 min. Bajo estas condiciones, los valores de PER y UPN ascendieron en 180% y 330%, respectivamente, en relación a los valores de PER y UPN de la caseína.

Se concluye que con este procedimiento se puede disponer de grandes cantidades de proteína a un precio equivalente de \$80.00 el kilo (US\$0.40/kg).

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