WHOLE SOYBEAN FOODS FOR HOME AND VILLAGE USE

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COLLEGE OF AGRICULTURE
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FOREWORD

The International Soybean Program (INTSOY) is a research, education, and development program with the general mission to expand the use of soybeans as a means of alleviating protein-calorie deficiencies and associated problems. The goal is exploitation of the potential of the soybean as an economic crop for the farmer and as a food source for the consumer. Research is oriented to increasing the soybean's potential under a wider range of producer and consumer environments; educational efforts are intended to expand the capacity of organizations and individuals to serve more effectively producers, marketers, input suppliers, processors, and consumers.

The soybean is well accepted as a food source under some conditions and cultures. Use outside of the Orient is primarily for oil and meal with most of the meal used for animal feed. Substantial effort has been devoted to improved commercial processes resulting in significant food use of the meal in such forms as soybean flours, concentrates, and isolates. There is increasing research on the various aspects of soybean cultivation under tropical and subtropical conditions; however, much less is being done on soybean food uses. There is tremendous need for expanded research on use of the soybean and the constraints to its wider use as a component of the human diet.

This publication reports on work of Professors Nelson, Steinberg, and Wei and their associates to develop concepts, methods, and processes for home use of the whole soybean directly for human food. The emphasis is on acceptability, quality of nutrition, and low cost of protein, calories, and other food nutrients. It is hoped that the work reported will serve as a foundation for expanded work with similar objectives.

INTSOY expresses appreciation to the many persons that contributed to this work and its publication, to the U.S. Agency for International Development and the Illinois Agricultural Experiment Station for financial support, and to Soybean Digest and World Crops for permission to reprint two of the papers included in this publication.

William N. Thompson
Director, INTSOY

DEVELOPMENT OF WHOLE SOYBEAN FOODS FOR HOME USE: RATIONALE, CONCEPT AND EXAMPLES

by

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Introduction

The diet of many millions of people in various parts of the world is deficient in protein and calories. Presently, one of the best answers to this shortage is whole soybeans.

The soybean contains about 40 percent protein. Since cow's milk is 3.5 percent and the common red bean is 25 percent, it is clear that the soybean does have a high protein content. This protein is characterized by a good balance of amino acids, better than any of the other common vegetable sources of protein. With the dietary addition of sulfur amino acids from cereals such as wheat or rice, the balance meets FAO standards, so the quality of this protein is high.

The soybean contains about 20 percent oil, while cow's milk is 3.5 percent and the common red bean is 1.5 percent, so the soybean is high in oil. Oil provides over twice the calories of carbohydrates and proteins. Furthermore, this oil is 85 percent unsaturated and is cholesterol-free, so it is highly desirable in the diet.

Almost the entire soybean crop produced outside the Orient is processed for oil extraction. All the oil is used for foods such as margarine. About 97 percent of the oil-free meal is sold as a protein supplement for animal and poultry feed. Thus, only 3 percent of the meal is used for food; examples are texturized vegetable protein used as a meat extender, and the soy protein concentrates and isolates used in baking. If both the oil and protein fractions of the soybean are to be consumed by humans, the process of separating them would be an unnecessary expense, especially in developing countries. Therefore, we should look at the whole soybean as a new food resource.

Economics is a powerful factor here. Animal protein is much too expensive for many peoples of the world. For instance, one of the most efficient animal converters of feed to gain is the broiler chicken, with a conversion of about two pounds of feed per one pound of gain. However, when protein conversion is considered, the relationship of vegetable protein consumed (5 lb.) to animal protein gained (1 lb.) is poor. Thus, this exercise strongly encourages direct food use of vegetable protein.

In contrast, the soybean is very inexpensive. The average male 23-50 years old requires 56 grams protein and 2700 calories per day. Considering that raw soybeans cost six dollars per bushel (60 lb.), that processing the raw soybeans into food may cost another six dollars per bushel, and that a person should eat 25 percent more soy protein to obtain the equivalent of animal protein, we calculate his protein needs would be satisfied for 7.7 cents per day, and almost 20 percent of his calorie requirement should be satisfied at no added cost.

The protein quality of a soy-cereal food is substantially better than the quality of products prepared solely from soybeans and should be as good as casein. Both the cost and acceptability of a food combination such as rice and soy could be substantially improved. Thus, especially in countries which are short of protein, human consumption of whole soybeans should be strongly encouraged.

The growth and development of a soybean plant is remarkably adaptable over a wide range of the earth's cultivatable land. Variety testing as well as field production studies have shown the soybean to be suitable for many tropical climates. These areas are generally considered to be the most lacking in protein and calories for the human population. It must also be considered, due to limited land availability as well as competition with other crops, that in some tropical countries the soybean will not be produced on a scale which would adequately supply raw material for a solvent extraction plant for oil and meal production. However, use of whole soybeans in the heme or in commercial processing operations, where the beans are processed alone or preferably combined with cereals, requires only modest amounts of soybeans and could result in a substantial tonnage of high protein content finished foods.

Utilization of soybeans in the home or village offers an ideal approach for improving the diet of those who are in need of more and better quality protein. Good concepts for home or village level preparation of soy products are required. The methods used for preparation of village products must be simple and easily followed. In addition, expensive equipment cannot be employed and the utilization processes should require only short cooking times to conserve scarce energy.

The above considerations led us to conclude that the whole soybean represents a tremendous potential for alleviating malnutrition around the world. Realization of this potential presented an equally great challenge. The concept generated to meet this challenge and the foods developed to implement the concept will be discussed below.

A Concept for Preparation of Whole Soybeans for Use in Human Food

The soybean presents problems in addition to promises. Raw soybeans contain a number of anti-nutritional factors which, if not eliminated, reduce the nutritional value. In addition, an off-flavor producing enzyme is present in raw soybeans. This enzyme must be inactivated at the proper time to prevent highly undesirable flavors from developing. These off-flavors render soybeans unacceptable to most people. This paper describes a concept for preparation or processing of soy foods in which the finished product is free from off-flavor, and of high nutritional value.

Inactivation of the Lipoxygenase Enzyme System

The flavor problem is the result of the action of the lipoxygenase enzyme system on the unsaturated fatty acids (the substrate). In the intact, dry, sound soybean, the sites of the lipoxygenase enzyme system and the substrate are separated in the cell tissue. Thus, the off-odors and off-flavors are not present in sound, dry soybeans. They are generated by subsequent manipulation.

Since the enzyme and substrate are in separate locations, breaking or damaging of the cell tissue exposes the sites, but as long as the tissue remains dry, the enzyme does not act. However, addition of water to the damaged tissue causes an instant reaction which results in a strong, beany odor and bitter flavor.

When sound, dry whole soybeans are soaked at room temperature in about a 5 to 1 water to bean ratio, they absorb water to about a 100 percent weight increase in approximately six hours. Hydrated, sound beans do not develop off-odor or off-flavor because the enzyme and substrate remain apart. However, rough handling of hydrated raw beans will damage the tissue and allow the enzyme and substrate to come together in the presence of water, which results in an instant reaction. Thus, hydrated, raw whole soybeans must be handled carefully to prevent tissue damage.

The lipoxygenase enzyme in soybeans can be readily inactivated by cooking in water as is commonly done in blanching vegetables. Soaked whole soybeans can be dropped into boiling water which will inactivate the enzyme in a few minutes. Dry whole soybeans can also be dropped directly into boiling water for simultaneous hydration and enzyme inactivation; however, blanching and hydration time is much longer.

Some soybean-containing food products are benefitted by a reduction in fiber content. This can readily be achieved by the removal of hulls or skins from the raw, dry beans. Even the best dehulling equipment causes some damage to the resulting cotyledons. Therefore, raw cotyledons should not be soaked at room temperature. However, they can be dropped directly into boiling water where the exposed enzyme is instantly inactivated by the hot water. Cotyledons are easily hydrated and blanched in this manner.

Bicarbonate Blanch

One of the difficulties encountered in using whole soybeans for human food is the long cooking time required to develop an acceptable texture. Many recommendations for cooking soybeans have been made. Rice (1973) and Mueller et al., (1974) recommend cooking times up to three hours in order to develop an acceptable texture. However, such long cooking times are wasteful of energy and the long time often discourages soybean use.

The addition of sodium bicarbonate (baking soda) to the blanch or cooking water is highly effective for the tenderization of soybean tissue. Desirable sodium bicarbonate concentration in the cooking water ranges from about 0.05 to 0.5 percent, depending upon the size of particle being blanched; thus, whole beans require a high concentration and cotyledon pieces a low concentration. The addition of sodium bicarbonate to the cooking water generally reduces the cooking time needed to achieve a given tenderness, by at least fifty percent.

The use of a desirable concentration of sodium bicarbonate in the cooking medium also improves the flavor of the cooked beans. Beans cooked in low levels of sodium bicarbonate are invarlably more bland and better in flavor than beans cooked in tap water. However, the use of sodium bicarbonate in the blanch water tends to darken the beans. Fortunately, this color change is slight and is not noticed unless a direct comparison is available.

Elimination of Anti-nutritional Factors

Anti-nutritional factors include a number of components such as the trypsin inhibitor, hemagglutinin, phytic acid and other minor factors. Proteinase inhibitors of legumes, such as soybeans, have been studied in great detail because of their importance in animal nutrition (Rackis, 1972). Generally, very little has been done to relate their effect to human nutrition. However, it is generally considered that treatments of soybeans and other products that are suitable for animal nutrition are quite adequate for human nutrition. The trypsin inhibitor can be destroyed in soybean products by adequate heat treatment. It has been well established that the trypsin inhibitor can be eliminated in hydrated soybean tissue more rapidly than in dry tissue. An alkaline medium, such as a sodium bicarbonate blanch, also effects a more rapid destruction of the trypsin inhibitor during blanching. In addition, the trypsin inhibitor is considered to be the most heat resistant of the anti-nutritional factors in soybeans.

It is also known that the trypsin inhibitor requires more heating (cooking) to inactivate than the lipoxygenase system. Fortunately, both factors are completely eliminated when beans are cooked or blanched long enough to develop adequate tenderness or texture in the beans. This time would usually be about twenty to thirty minutes for whole soybeans.

Quality and Variety of Soybeans for Direct Food Use

Soybeans, to be directly used for human food, must be of good quality. Foreign material such as stems, pods, sticks and stones must be removed. Crushed beans and splits should be removed if possible. Of much greater importance is the use of mold-free soybeans. Moldy beans have little, if any, value for any purpose and may contain toxins.

All field varieties of soybeans are suitable for use in preparation of human food products. The so-called vegetable varieties have not been found superior to general field types.

Use of This Concept

Various applications of this concept are described in the four following papers. If soybeans are prepared according to the suggested procedures, very bland, better tasting products will result. These are believed to be excellent for incorporation into many different foods. Since the soybean is bland it can be flavored to suit local preference and offers an excellent source of high quality protein as well as unsaturated fat.

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HOME PREPARATION OF SOYMILK: A NEW CONCEPT

by

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Introduction

Cow's milk, since time immemorial, has made an incalculable contribution to the nutrition of mankind. However, in recent years it has been clearly documented that some people are intolerant or allergic to cow's milk. A large proportion of the world's population has hypolactasia (low level of lactase in the intestinal mucosa) resulting in lactose intolerance. According to the PAG Bulletin (1972), 50 to 100 percent of the population of Africa, Asia, Latin America and the Middle East show milk intolerance. In North America, blacks have a higher incidence (72 to 77 percent) of milk intolerance, as compared to whites, whose intolerance ranges from 6 to 19 percent. Only one percent of the European population suffers from milk intolerance. The major reason for these disparities is due to the fact that individuals lose their ability to metabolize lactose after weaning, due to low consumption of milk. Each of the two major components in cow's milk, protein and lactose, may produce clinical intolerance. The incidence of milk protein intolerance in the first two years of life has been estimated at 0.4 percent (Woodruff, 1976). Thus, for those people that are intolerant to cow's milk, a substitute such as soymilk is needed.

One of the practical ways to utilize soybeans is for soymilk preparation. Soymilk is the name given to the aqueous extracts from soybeans or to the fine emulsion of soy flour because of its milky appearance. Soymilk is reported to have been developed in China, before the Christian Era, by philosopher Whi Nain Tze (Piper et al., 1943). Although soybeans have been an important source of food for humans in the Orient for centuries, their use as a human food in non-oriental countries has been nominal due to the objectionable flavor that is generally developed during preparation.

Wilkens et al. (1967) reported that grinding unsoaked, dehulled soybeans with water at temperatures between 80 and 100°C, and maintaining the temperature for ten minutes completely inactivated the lipoxidase enzyme that is responsible for causing off-flavors in soy products. Blain and Styles (1959) found that these enzyme-induced off-flavors in soymilk could be prevented by heat inactivation of the lipoxygenase enzyme. Lao (1971) suggested that more than one component contributes to the beany, painty, oxidized flavor in soymilk. Studies by Mattick et al. (1966) reported that the volatile off-flavors of soymilk arose predominantly from the lipid fraction through an oxidative mechanism, which is catalyzed by the lipoxygenase system. Farkas and Goldblith (1962) indicated that the thermal inactivation of lipoxygenase was pH dependent. Kon et al. (1970) reported off-flavor development was suppressed in legumes at pH 3.85 and below. Lao (1971) extracted soymilk at pH 2 and found there was no lipoxygenase activity even when the product was neutralized to pH 6.5.

Nelson et al. (1976) described a method for preparing soymilk from whole or dehulled raw soybeans which resulted in a colloidally stable, bland product of very good acceptability. With this method, no filtering or desludging is used so protein recovery is essentially 100 percent, and the beans are hydrated and blanched to eliminate the off-flavor producing enzymes and growth inhibitors. However, industrial equipment such as a homogenizer is required.

A need exists for a soymilk that can be prepared in the home with simple equipment and that will not have the painty flavor of the traditional Oriental process. The concept for preparation of such a soymilk is described in this paper. With this process raw whole beans are blanched for ten minutes, ground into a slurry and filtered. The filtrate is simmered for twenty minutes and the flavoring ingredients are added. The resulting soymilk is very good in flavor and texture, and contains nearly 3 percent protein.

Experimental

Initially, Wayne, Bragg, Clark 63, Corsoy and Bonus varieties of the 1973 crop were used in various preparations of soymilk. Soymilk prepared from the Bonus variety contained more total solids and protein. Therefore, the Bonus variety of 1973 and 1975 crops were used. One hundred grams of raw material were used for each extraction.

Soymilk was prepared by a number of different methods. In all the methods, the raw material was heat treated at the very beginning to prevent off-flavor development. Also, sodium bicarbonate was incorporated both in the blanching and extraction water. After considerable preliminary work the following methods were established:

Method 1. One hundred grams of whole soybeans were dropped into 500 ml of boiling water containing 0.05 percent $NaHCO_3$ and boiled for five minutes. This blanch water was discarded. The partially blanched soybeans were dropped into 1000 ml of boiling water containing 0.04 percent $NaHCO_3$ and the beans were blanched for an additional five minutes. The blanched beans were ground into a slurry with the second blanch water, at the highest speed in a Waring blender for one minute. The slurry was cooked for 20 minutes and filtered.

Method 2. Same as Method 1 except the slurry was filtered and then the extract was cooked for 20 minutes.

Method 3. One hundred grams of hammer-cracked or broken whole soybeans were used and the preparation procedure was as in Method 1.

Method 4. Whole raw soybeans were ground with a hand grinder into a flour fine enough to pass through 20 mesh (Molino Corona, Landers, Mora and CIA Ltd. , Colombia). One hundred grams of soy flour were sprinkled into 500 ml of boiling water containing 0.05 percent $NaHCO_3$. The resulting slurry was cooked for five minutes. Then the 500 ml boiling water containing 0.04 percent $NaHCO_3$ was stirred into the slurry, and cooking continued for another 15 minutes. The slurry was then filtered.

In all the methods the slurry was filtered with six folds of cheesecloth. The slurry was poured on the cloth and liquid filtered through until the cloth became saturated with soy particles. At this point four corners of the cloth were raised and the remaining slurry was filtered by twisting the cloth above the slurry. This exerted considerable pressure on the slurry, forcing the liquid through the cloth. The extract prepared by each method was formulated with 0.2g salt, 4g sugar and 17.6 microliter artificial cream flavor manufactured by Fritzsche, NY, U.S.A., for every 100 ml of soymilk.

The volume, pH, viscosity, protein and solids content of each soymilk sample were measured before the addition of salt, sugar and flavorings. The volume was measured with a graduated glass cylinder. The pH was determined with a Beckman Research pH Meter. Nitrogen content of all the samples was analyzed by the Micro-Kjeldahl method (A.O.A.C., 1970) and the protein was calculated as N x 6.25. Solids were determined by drying, first in an air oven and then in a vacuum oven, for a total of 48 hours. Total and free fat contents of all the samples were determined by chloroform-methanol extraction and hexane extraction, respectively. Ash was determined by Method 14.007 (A.O.A.C., 1970) and calcium by the wet ashing method (Stone, 1976).

Results and Discussion

The quality and acceptability of soymilk prepared by any of the four methods are closely dependent upon several factors. These include blanching time, treatment of beans, dehulling, addition of sodium bicarbonate and incorporation of blanch water.

When whole, raw beans were blanched for 5, 7, 10 and 20 minutes, the final soymilk was different in each instance. Soymilk from five minute blanched soybeans had a total solids content of 6.6 percent, and the product from seven minute blanching contained 6.2 percent solids; both products contained 2.9 percent protein. However, they were unacceptable due to an odor and flavor reminiscent of freshly cut grass. Soymilk prepared from 20 minute blanched beans showed a drastic reduction of protein and total solids to 1.37 percent and 4.66 percent, respectively. Thus, it was clearly evident that 20 minutes exceeded the optimum blanching time. Ten minute blanched soybeans produced a bland flavored, smooth textured soymilk that was free from bitterness and chalkiness. This soymilk contained 2.87 percent protein and 6.4 percent total solids. Thus, ten minutes was established as the standard blanching time for all treatments.

The quantity of water used for blanching had no effect on the final product as long as the beans were blanched for only ten minutes and not soaked before grinding. The ten minute blanch was performed in two steps of five minutes each; the first five minute blanch water was discarded and the second five minute blanch water was incorporated with the beans during grinding into a slurry. The objective was to effectively clean the beans and to reduce the amount of solids leaching from the beans. This method of blanching also helped impart a slightly alkaline pH to the final product when sodium bicarbonate was added to the second blanch water.

In Method 1 the slurry was cooked and then filtered to obtain soymilk, while in Method 2 the slurry was not cooked before filtering but the extract was cooked after filtering. The final products from both methods were bland flavored, smooth textured and showed good acceptability.

Cracked or broken soybeans were used in Method 3. For experimental purposes the whole beans were either hand-cracked with a hammer or broken with a Buhr mill. Soymilk from cracked beans with hulls contained 2.3 percent protein as compared to 2.2 percent protein in soymilk prepared from dehulled cracked beans. However, both cracked soybean preparations yielded low viscosity products that contained less protein and total solids than products prepared with whole soybeans. Also, the cracked soybean products were generally inferior as compared to the products obtained from either whole or finely ground soybeans.

In Method 4, a flour, made from whole raw soybeans ground to pass 20 mesh, was used as starting material. The final product contained more than 3 percent protein and 7 percent total solids. However, this soymilk had a cooked-cereal flavor which was considered poor in acceptability.

The proximate analyses of the soymilks prepared using the four methods are presented in Table 1. The soymilk prepared from soy flour contained the highest percentages, 3.33 and 7.32 of protein and total solids, respectively. This may be attributed to the fact that the product was high in suspended material and no protein was lost during blanching. In descending order of merit, the total solids and protein were 7.25 and 2.82 percent, respectively, for soymilk prepared from whole beans when the slurry was filtered before it was cooked, and 5.64 percent solids and 2.59 percent protein in soymilk obtained from cooking the slurry for twenty minutes and then filtering. Soymilk from cracked soybeans contained 2.04 percent protein and 4.88 percent total solids.

The filtrate-cooked soymilk (Method 2) had a higher total fat content, 1.62 percent, as compared to 0.92 percent for the slurry-cooked product (Method 1). As is evident from Table 1, the filtrate-cooked soymilk contained higher percentages of other constituents such as calcium, ash and carbohydrates.

As shown in Table 2, the yield of soymilk was affected by the method of preparation. Each value represents the average of six trials or replications. In all four methods, water equal to ten times the weight of raw material was used. The yield was better when the slurry was cooked for twenty minutes and then filtered (Method 1), as compared to the product obtained by filtering the slurry before cooking (Method 2).

To compare protein yield of the soymilks prepared by different methods, the protein content was corrected to a 600 ml yield. The results are presented in Table 2. Soymilk prepared from soy flour (Method 4) contained 3.24 percent protein, whole bean soymilks (Methods 1 and 2) both contained 2.74 percent protein and soymilk prepared from cracked beans (Method 3), 2.04 percent protein.

Soymilks were organoleptically evaluated by a panel of seven members of the Food Science Laboratory for color, flavor, off-flavor, chalkiness, bitterness, mouth-drying and viscosity using a nine point hedonic scale. A score of 9 indicates the product to be excellent, 5 acceptable and 1 very poor and unacceptable.

Table 1. Composition of soymilk prepared from different forms of soybeans

Component	Method 1 Whole Bean Slurry Cooked	Method 2 Whole Bean Filtrate Cooked	Method 3 Cracked Bean	Method 4 Soy Flour
		(percent)		
Water	94.36	92.75	95.12	92.68
Total solids	5.64	7.25	4.88	7.32
Protein	2.59	2.82	2.04	3.33
Total fat	0.92	1.62	1.21	1.51
Free fat	0.67	0.68	0.96	1.14
Calcium	0.14	0.16	0.11	0.15
Ash	0.68	0.73	0.61	0.66
Carbohydrate (by difference)	1.31	1.92	0.91	1.67

Table 2. Yield, total solids and protein contents of soymilk prepared by four methods

Method	Product	Yield ml	Total solids in soy-milk,	Protein	
				Liquid sample	Corrected to 600 ml
			(percent)	(percent)	
1	Soymilk from whole beans (slurry cooked)	635	5.64	2.59	2.74
2	Soymilk from whole beans (slurry filtered and filtrate cooked)	585	7.25	2.82	2.74
3	Soymilk from cracked beans	600	4.88	2.04	2.04
4	Soymilk from soy flour	590	7.32	3.33	3.24

The results of the organoleptic evaluation are presented in Table 3. A statistical analysis of variance (not given) showed that only color and viscosity gave significant differences within treatments; full-fat soy flour resulted in superior color and cracked beans gave inferior viscosity. Other organoleptic characteristics exhibited some variation in scores; however, these differences were not significant.

Examination of these data (Table 3) shows that all organoleptic scores, for all product characteristics and all treatments, were well above the acceptable range; the lowest mean score was 6.2 while acceptable was 5.0.

Soy milk prepared from whole beans was superior to similar products from cracked beans and full-fat soy flour in all organoleptic characteristics except color. Ratings for defects such as chalkiness, bitterness and mouth-drying in soy milk from whole beans averaged about 8, which is exceptionally high for soy milk. Thus, when all factors were considered, the soy milk procedure which utilized whole beans was considered as the superior method.

Summary and Conclusions

Heat treatment is the most important step in the preparation of soymilk. It is absolutely necessary to moisten and heat raw soybeans before grinding into a slurry in order to prevent development of the typical beany or painty flavor.

Incorporation of sodium bicarbonate both in the blanching and grinding waters effects higher protein extraction in the final product. However, concentrations higher than 0.05 percent in the blanch water and 0.04 percent in the grinding water imparted an off-flavor to soymilk.

Soymilk prepared from cracked beans contained the lowest amount of protein and lowest viscosity as compared to soymilks prepared by other methods. Soymilk prepared from soy flour developed a cooked-cereal flavor which resulted in lower acceptability. Soymilk prepared from whole soybeans contained a high percentage of protein and was very good in acceptability. Home preparation of soymilk from whole soybeans is easily accomplished, less time consuming and requires the least amount of equipment. Considering all the factors involved in the various methods of soymilk preparation, the following simple procedure as represented by Method 2 is recommended for preparing soymilk from whole soybeans:

Recommended procedure for preparation of soymilk:

1. Dry clean the whole soybeans, drop them directly into five times their weight of boiling water containing 0.05 percent sodium bicarbonate, and boil for five minutes.

2. Discard this blanch water and drop the partly blanched beans into ten times the raw bean weight of boiling water containing 0.04 percent sodium bicarbonate.

3. Boil the beans for an additional five minutes and grind, with the second blanch water, in a Waring blender for one minute at highest speed. (Hand grinder which will produce a finely ground material, can be used in place of the Waring blender.)

4. Stir the slurry well and filter with six-fold finely woven, moist cheesecloth. Squeeze out as much extract as possible.

5. Cook the filtrate at the simmering point for twenty minutes.

6. Flavor with 0.2 g salt, 4 g sugar and 17.6 microliter artificial cream flavor per 100 ml of soymilk.

7. Stir well to dissolve all the ingredients, pour hot into bottle and cool. Store in refigerator and use as fresh milk.

8. Follow directions carefully. Boiling times longer than recommended for whole beans will reduce the amount of protein in the final product.

Table 3. Organoleptic evaluation of soymilk prepared from three different forms of soybean and formulated with three percent sugar

	Mean Organoleptic Scores for						
Treatment	Color	Flavor	Off-flavor	Chalkiness	Bitterness	Mouth drying	Viscosity
Whole beans	6.2	7.4	7.1	7.8	8.3	8.0	7.2
Cracked beans	6.2	6.9	6.7	7.7	8.0	7.6	6.6
Full-fat soy flour	7.1	7.0	6.4	7.5	8.0	7.6	7.0

It must be emphasized that care be exercised in measuring ingredients and especially in controlling cooking times according to specifications. The residue which remains after filtering contains about 50 percent of the protein and fat of the raw beans. Thus, this residue is nutritionally valuable and should be used in preparing a number of high protein foods in the home.

Soymilk recipe using standard household measures rather than metric units.

Ingredients:

2/3 cup whole raw soybeans = 100 grams

2 cups of water containing (0.05 percent) 1/8 tsp $NaHCO_3$ for blanching = 500 ml

4 cups of water containing 1/4 tsp $NaHCO_3$ for grinding = 1000 ml

Flavoring for 1 cup soymilk:

2 1/4 tsp sugar
1/8 tsp salt
1 drop cream flavor

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(1) Part of a dissertation submitted by S. Kanthamani to the University of Illinois as partial fulfillment of the requirements for the M.S. degree in Food Science.

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SOYBEAN BREAKFAST AND PATTY FOODS: TIME AND ENERGY SAVING FOR HOME PREPARATION

by

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Introduction

Whole soybeans contain about 40 percent protein. Concentration of the individual essential amino acids in soy protein ranges from 60 to 105 percent that of egg protein. Therefore, the whole soybean is one of the best vegetable sources of protein for human food in both quantity and quality. With soybeans selling for $8.00 per bushel and lean hamburger (20.7% protein) selling for $1.29 per pound, the soy protein costs $0.33 per pound as compared to $6.23 for hamburger protein. Soy protein cost has been about 5% that of hamburger protein for the last eight years. In addition to this protein of highly favorable quantity, quality and price, the whole soybean contains about 20% oil which is important for its caloric value. Also, this oil is 85% unsaturated and therefore highly desirable from a health standpoint.

In the Western world, whole soybeans are not well accepted as a direct food source which is mainly due to development of "beany" or "painty" flavors and odors which are generated by action of lipoxygenase enzyme on certain lipid components in the soybean. Both the enzyme and lipid are present in the mature raw soybean, but as long as the tissue is not disturbed or disrupted, no off-flavor or odor develops. Tissue disruption alone does not produce off-flavor or odor, however, addition of moisture to broken tissue effects instant off-flavor and off-odor development. Broken or crushed dry, raw beans can be dropped directly into boiling water to achieve hydration and enzyme inactivation before off-flavor reactions take place.

Nelson _et al._, 1971, described methods for enzyme inactivation and preparation of bland pre-cooked soybean foods. According to their methods, the whole dry beans were inspected and defective beans and foreign material were removed and the beans washed. Hydration and enzyme inactivation could then be done in sequence or simultaneously. As an example of the former, the cleaned beans were soaked in tap water for about six hours to obtain a 100% weight gain, the soak water was drained and the beans were added to boiling water for at least ten minutes. As an example of the latter, the dry, cleaned soybeans were dropped directly into boiling tap water for 20 minutes.

These procedures resulted in soybeans of very bland flavor, but very firm texture. Thus, for most food uses the soybeans must be tenderized. This can be accomplished by much longer cooking times or by adding up to 0.5% sodium bicarbonate to the soak and blanch waters; addition of sodium bicarbonate to the blanch water tends to reduce cooking time required to obtain a given tissue tenderness by about 50%. A popular soybean cookbook (Van Duyne, 1950) suggests soaking the beans overnight and boiling them for one hour. Rice (1973) suggests that soybeans should be soaked overnight in cold water and then boiled for three hours. Mueller _et al._ (1974) suggest soaking in three cups of water to one cup of beans overnight in the refrigerator. For cooking, they recommend removing the loose hulls from the soaked beans and boiling at a simmer for one to three hours.

Anti-nutritional factors are also present in raw soybeans. Perhaps the most important is the trypsin inhibitor which has the characteristic of inhibiting the activity of the proteolytic digestive enzyme, trypsin. Thus, the protein nutritional value of a soy product is decreased by about 50% if the trypsin inhibitor is not destroyed. However, the cooking times used in preparing soybeans by the process of Nelson _et al._ (1971) are quite adequate for destruction of the anti-growth factors as well as prevention of off-flavors and off-odors.

In many developing countries, long cooking times are not acceptable because of the need for fuel conservation. Soaking soybeans is also not practical in many parts of the world because of sanitation problems. Certainly in all parts of the world fuel conservation is rapidly becoming very important and long cooking times should be avoided where possible. Therefore, the purpose of this work was to devise a procedure for soybean preparation that does not require soaking or prolonged cooking. The experimental methods employed variations in cooking solution, wholeness of bean and addition of other foods such as cereals, vegetables or fruits. Under this concept, rapidly prepared weaning or breakfast foods and fried patties were developed which contained about 50% whole soybeans.

Raw Bean Treatments

Initial work on the studies reported in this paper showed that breaking or crushing the raw beans resulted in a greatly reduced cooking time to obtain a given tenderness. Each raw, dry bean was broken with a hammer into approximately 20 pieces. Later work showed that the dry beans could be satisfactorily broken or crushed in a hand operated mill (Fig. 4) or in a power-driven mill, such as a Buhr mill.

The soybeans used throughout this work were of the Wayne variety. However, any fully mature, dry field or vegetable variety should be suitable. The beans were mechanically dry cleaned and hand-sorted to remove foreign material and moldy, crushed or seriously discolored soybeans.

Hydration

Treatments in this first study differed in the use of whole or crushed beans, in addition of sodium bicarbonate to the cooking medium, and in time of cooking. In preparation, the beans were dropped directly into boiling water. For all cooking times greater than 30 minutes, 100 ml of cooking medium were added for each additional 30 minutes to assure the presence of an adequate amount of cooking liquid.

The results in Figure 1 clearly showed that two important factors are involved in water absorption by soybeans; they are the length of cooking time and whether the soybeans are crushed or whole. Soybeans absorb more of the cooking medium if they are cooked longer; this was generally true for all treatments. Crushed beans always absorbed more of the cooking medium than the whole. The average for all cooking times showed that 100 grams crushed beans absorbed 83.3 grams more of the cooking medium than the whole beans. This increased absorption of the cooking medium by the crushed beans may be due to three factors. First, the intact hull is known to reduce hydration of the whole bean (Spata et al., 1974); in crushed beans the hull is no longer intact. Second, the crushed beans have an increased surface area per unit weight so that more surface area is available for water penetration. Third, the crushing action enhances the water permeability of the bean meats during cooking and tends to increase heat penetration into the bean tissue. This increased rate of hydration and heat transfer should lead to more rapid inactivation of enzymes and inhibitors. Albrecht et al. (1966) verified these suggestions.

Tenderization

A study was also made to determine whether crushed beans were more tender than whole beans after cooking. Toughness was measured with a Lee-Kramer shear press as described by Nelson et al. (1976). As shown in Figure 2, cooking time, composition of cooking medium and whether the soybeans are crushed or whole are important factors in tenderization. Toughness decreased when cooking time was lengthened, when the beans were crushed and when either 0.05% or 0.5% sodium bicarbonate was added to the cooking solution. The use of 0.5% sodium bicarbonate was more effective for tenderizing than 0.05% sodium bicarbonate solution. Crushed soybeans cooked in tap water were less tender than whole soybeans cooked in 0.5% sodium bicarbonate. As shown in Figure 2 the use of sodium bicarbonate appears to be of greater importance in tenderizing the bean tissue than is crushing of the beans. However, the combination of sodium bicarbonate and crushing was by far the most effective treatment for rapid tenderization of the tissues.

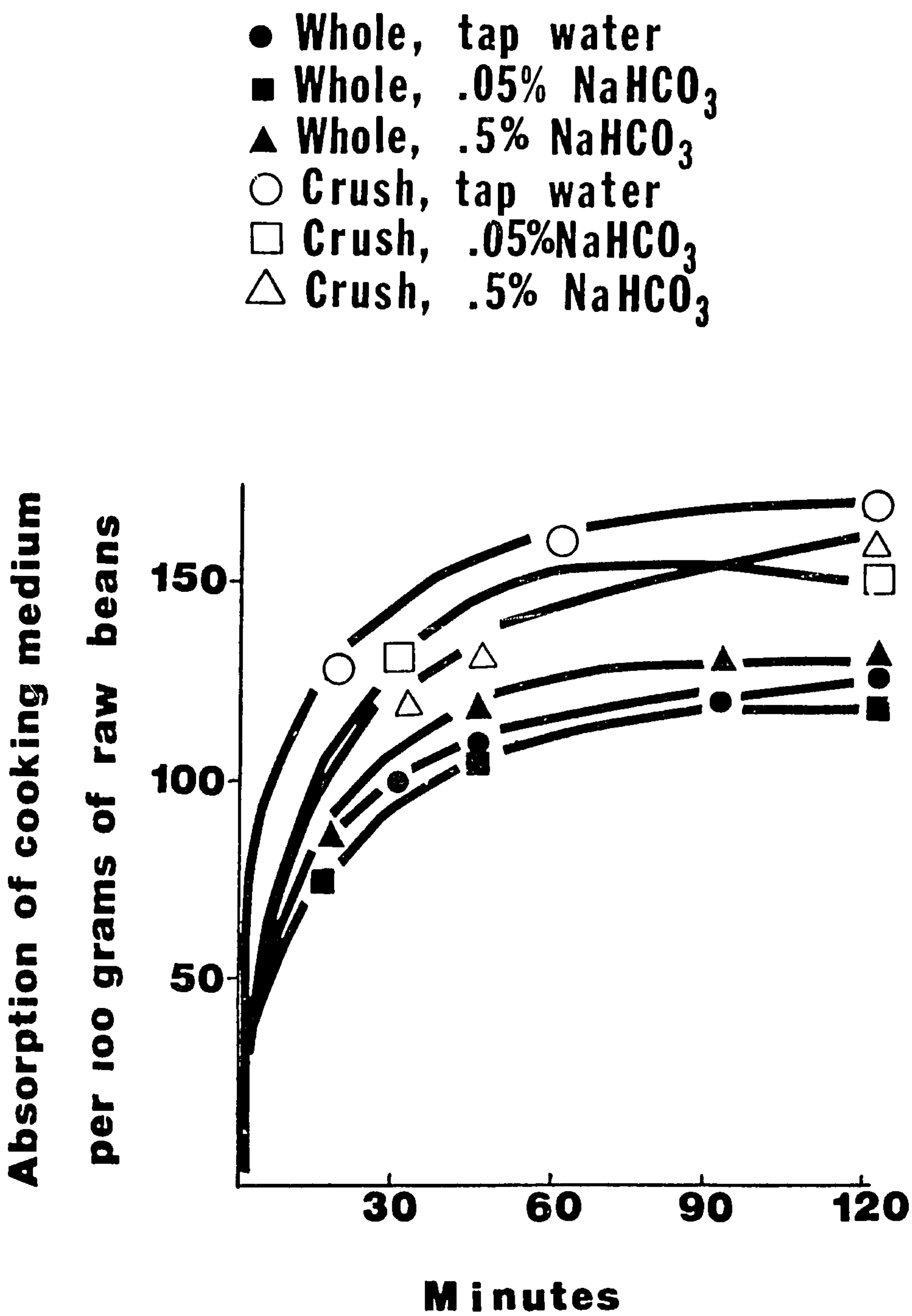


Figure 1. Soybean absorption of cooking medium after various treatments

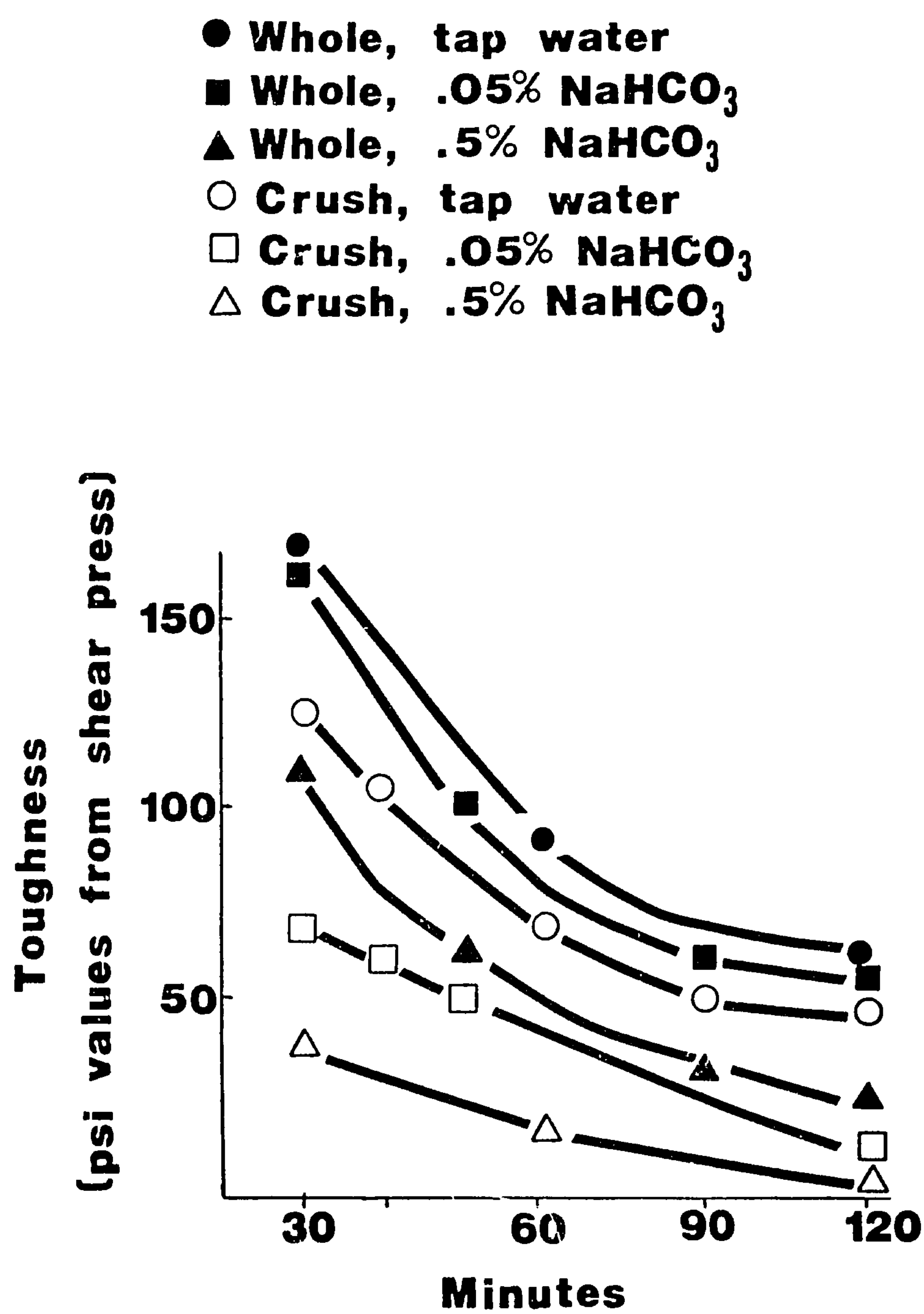


Figure 2. Tenderness of beans determined after various cooking treatments

The Lee-Kramer shear press readings for the study just described were made on a constant weight of the cooked product, and no adjustment was made for samples which contained greater amounts of absorbed water. Therefore, another tenderness study was made in which a constant amount of cooked bean tissue solids, 50 grams, was used as the sample in each evaluation. The data obtained from this study were plotted in Figure 3. The curves representing the various treatments were in the same order as in Figure 2. However, the difference between maximum and minimum tenderness values for each cooking time were reduced.

Inhibitor Inactivation

Two replications were made using four samples to determine the time required for the trypsin inhibitor inactivation. In one replication the initial ten minutes cooking time eliminated all of the trypsin inhibitor, while in the second, 94% of the trypsin inhibitor was destroyed. However, when the soybeans and other products were cooked for an additional 15 minutes, for a total cooking time of 25 minutes, 100% of the trypsin inhibitor was eliminated in all of the samples. Thus, it is clearly evident that the cooking times used for the preparation of these products are more than adequate to completely eliminate the trypsin inhibitor.

Concepts for Soybean Food Products

The previous cooking tests for crushed beans showed that thirty minutes total cooking time in water containing sodium bicarbonate thoroughly tenderized the tissue. This was clearly shown by shear press readings, as well as by organoleptic evaluations. Thus, it appeared that a concept might be developed for preparation of soy foods using crushed soybeans in combination with short total cooking time. Two product types were considered, a weaning or breakfast food and a fried patty that might be classified as a meat substitute. Mixtures of approximately 50:50 soybeans:cereals or vegetables on a solids basis were arbitrarily selected for product development. The 0.05% bicarbonate concentration adequately tenderized the tissue so it was used in all subsequent development studies.

Development of the final formulations and procedures required considerable time and effort. Only the most desirable will be presented here. Data covering many product evaluations for weaning or breakfast foods were analyzed statistically and it was determined that a ten minute cooking of the crushed beans, plus 15 additional minutes of cooking with other ingredients, yielded the highest average score for appearance, flavor and texture.

No statistical study was carried out on cooking times for fried products. However, it was found that cooking crushed beans for ten minutes in boiling 0.05% sodium bicarbonate solution, plus about 15 minutes of additional cooking with the other ingredients was adequate for the fried products. Grinding of the soybeans and cereal or vegetable mixture after the final cooking is a most essential step in preparation of these products. The usual food chopper or grinder is not recommended. Figure 4 shows the type of plate grinder that is most desirable (Molino Corona, Landers, Mora and CIA Ltd., Colombia). This grinder is available in most developing countries; in the United States, it is generally available in health food stores. The food being ground passes between the two round serrated plates (Fig. 4) which can be placed under considerable tension to increase the grinding action.

Weaning or Breakfast Foods

Final formulations and preparation procedures were as follows:

(1) Soy-whole wheat

Crush 100 grams of dry, whole soybeans and drop into 750 ml of boiling 0.05% sodium bicarbonate solution. Simmer for ten minutes. Add 1/4 tsp. salt, 2 tbsp. of molasses (Brer Rabbit Molasses), 100 grams of ground whole wheat (Olde Mill, Stone Ground whole wheat) and 25 grams of brown sugar (Godchaux dark brown cane sugar) and continue cooking all ingredients for 15 minutes with stirring. Pass through hand grinder adjusted for high tension between the plates. Heat the finished product to the boiling point and serve.

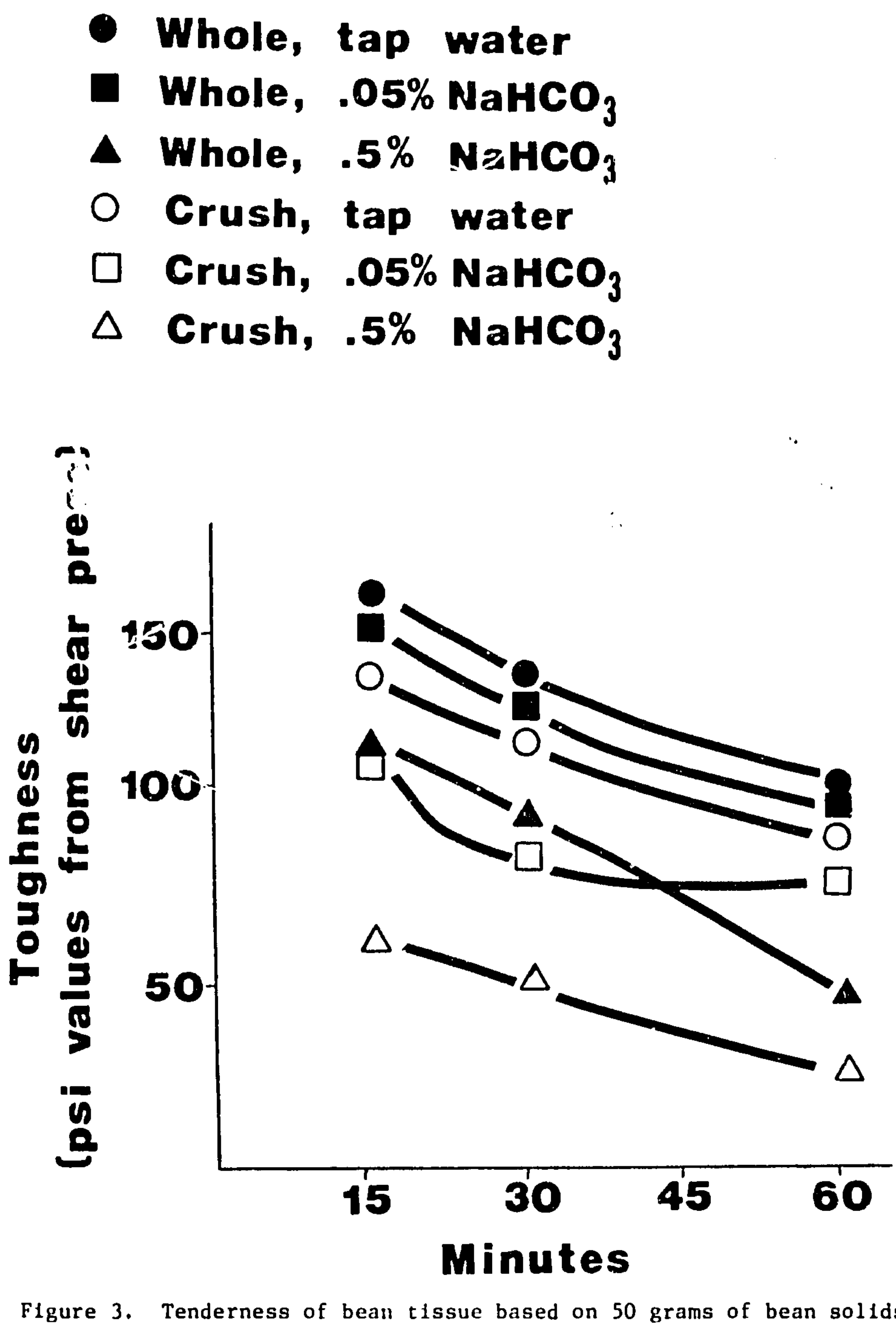
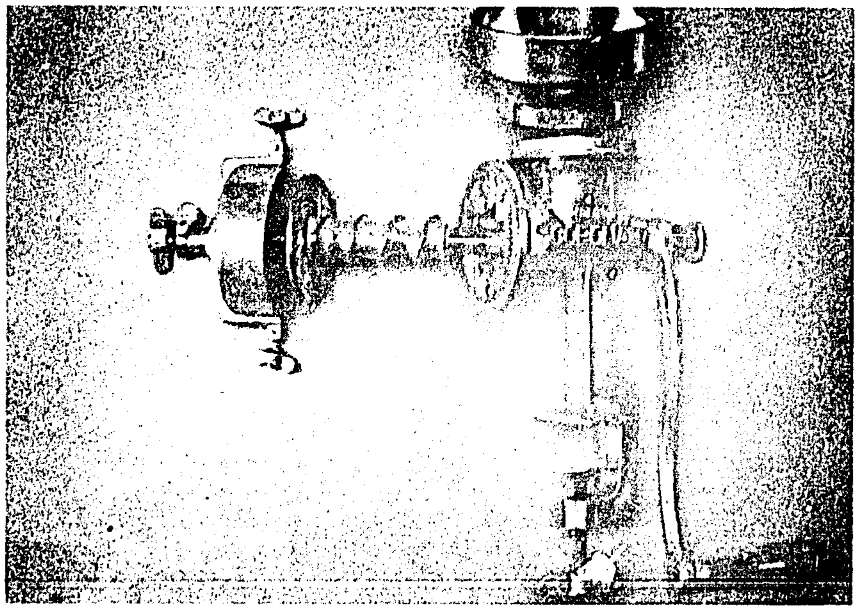


Figure 3. Tenderness of bean tissue based on 50 grams of bean solids after various treatments



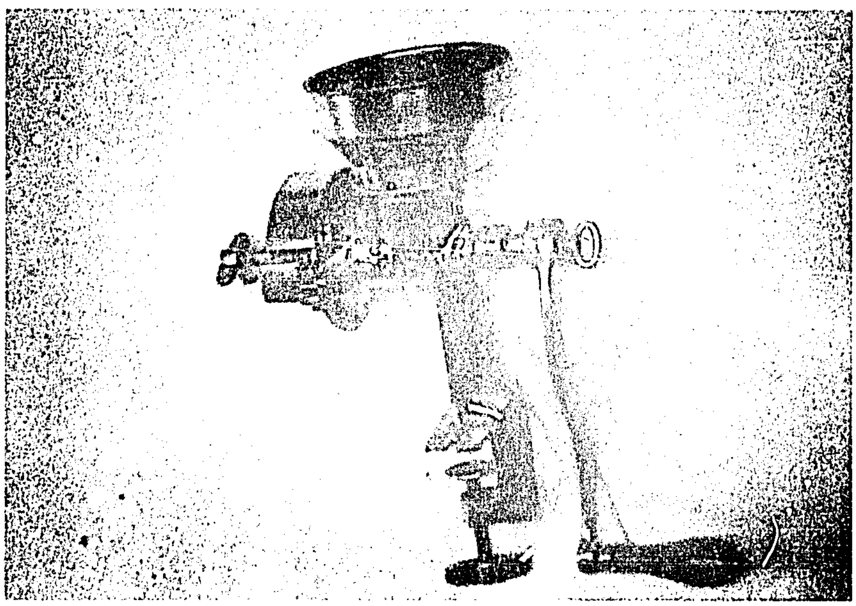


Figure 4. Plate Grinder

(b) Soy-corn

Crush 100 grams of dry, whole soybeans and drop into 750 ml of boiling 0.05 percent sodium bicarbonate solution. Simmer for ten minutes. Add 1/4 tsp. salt, 2 tbsp. of molasses, 100 grams corn meal, and 25 grams brown sugar and continue cooking all ingredients for 15 minutes with stirring. Pass through hand grinder adjusted for high tension. Heat the finished product to the boiling point and serve.

(c) Soy-sweet potato

Crush 100 grams of dry, whole soybeans and drop into 750 ml of boiling 0.05 percent sodium bicarbonate solution. Simmer for ten minutes. Add 300 grams raw, peeled and diced sweet potatoes and continue cooking all the ingredients for an additional 15 minutes with occasional stirring. Pass through hand grinder adjusted for high tension. Heat the finished product to the boiling point and serve.

These formulations were evaluated by a nine member taste panel. This group included several foreign students and represented a broad contrast of food preferences. Individual ratings for appearance, texture and flavor ranged from good to excellent, with the average invariably in the very good range. Since this work was completed, these products have been prepared for a number of visitors and the reaction and comments have always been highly favorable.

Fried Patty-Meat Substitute

Final formulations and preparation procedures were as follows:

(a) Soy-potato

Crush 100 grams of dry whole soybeans and drop into 800 ml of boiling 0.05 percent sodium bicarbonate solution. Simmer for ten minutes. Add 450 grams of diced (3/8" or less) raw white potatoes along with 1/4 tsp. salt and continue cooking all ingredients for another 15 minutes with stirring. Pass through hand grinder adjusted for high tension. Add chopped green peppers and onions to taste. Make patties from the above mixture and fry until they are brown (approximately 20 minutes). Serve hot.

(b) Soy-rice

Crush 100 grams of dry whole soybeans and drop into 1,000 ml of boiling 0.05 percent sodium bicarbonate solution. Simmer for ten minutes. Add 100 grams of dry white long grain rice along with 1/4 tsp. salt and continue cooking all ingredients for another 15 minutes with continuous stirring. Pass through hand grinder adjusted for high tension. Add chopped green peppers and onions to taste. Make patties from the above mixture and fry until they are brown (approximately 20 minutes). Serve hot.

The soy-potato and soy-rice products were prepared for evaluation. Patties were also prepared from potatoes and from rice; these contained no soybeans but did have the prescribed amount of salt and same amounts of green pepper and onions. The four products were evaluated by a nine member taste panel using a scale of 1 to 9, with 9 as excellent. The average scores are shown in Table 1. The data were subjected to a statistical analysis of variance. The only characteristic showing a significant difference was appearance; soy-rice was superior to the 100 percent rice at the 5 percent level.

The soy-potato and soy-rice products showed an overall average score of 7.0, while the potato and rice patties averaged 6.7. Thus, the addition of soy actually improved organoleptic properties of the starchy foods when prepared as fried patties. Texture and flavor were roughly the same for products with and without soy.

Summary

Concepts for preparation of highly nutritious combinations of soybean with cereal or vegetable requiring short cooking times were developed. The recipes presented here should not be considered as final formulations. Flavorings can be altered to suit the local taste

and many other products such as porridges, soups, etc., can be considered. The amount of cooking medium will vary depending on intensity of boiling and whether a cover is used for the cooking pot. Thus, some slight adjustment may be required in the total amount of the cooking solution. It is suggested that these concepts may be applied to the development of many new products as well as adapted for use with some existing recipes.

Table 1. Organoleptic Evaluation of Fried Patty Meat Substitute

	Potato		Rice	
	With Soy	Without	With Soy	Without
Characteristic	Mean Scores			
Appearance	7.2	6.5	7.8	6.6
Texture	6.6	6.7	6.7	6.0
Flavor	6.7	6.3	7.0	7.0

Standard Household Measures Equivalent to Metric Units

2/3 c whole raw soybeans = 100 grams
3/4 c crushed soybeans = 100 grams
3/4 c whole wheat flour = 100 grams
3/4 c corn meal = 100 grams
1/2 c rice = 100 grams
1 3/4 c diced (about 3/8") sweet potato = 300 grams
2 1/2 c diced (about 3/8") potato = 450 grams
2 tbsp brown sugar = 25 grams
*1/4 tsp $NaHCO_3$ = 0.5 grams
3 cups water = 750 ml
3 1/3 cups water = 800 ml
4 cups water = 1000 ml

* This amount $NaHCO_3$ when added to 4 cups water corresponds to about 0.05 percent.

(1) Part of a dissertation submitted by D.S. Koch to the University of Illinois as partial fulfillment of the requirements for the M.S. degree in Food Science.

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FOOD PRODUCTS FROM WHOLE SOYBEANS

by

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The soybean offers the most practical and economical answer to the present shortage of protein for human food, both in the U.S. and developing countries. However, an objectionable flavor in whole soybeans has always discouraged their use as food in the U.S. Now, University of Illinois workers have developed simple methods to inactivate the lipoxidase enzyme which causes the off-flavor. The treated beans are bland in taste and have a pleasing, nutlike background flavor. It is believed these beans can be processed into an almost unlimited number of food products. About a dozen prototype food products made with whole soybeans have been developed to date.

Introduction

Whole soybeans are an excellent source of protein. About 40 percent of dry matter in soybeans is protein so the quantity is high. The amino acid distribution is close to FAO recommendations so the quality is very good. The whole soybean contains almost 20 percent fat for high energy and this fat is desirable because it is unsaturated.

Most important of all when considering malnourished and undernourished people, soybeans are low in cost.

In fact, soybeans in various forms have been used as a food staple by many millions of people for millennia in China and Japan.

However, whole soybeans are not regarded with favor for human use in the United States and many other countries because they always have an extremely objectionable flavor and odor characterized as "painty" or "beany." Until recently, this flavor has been considered to be an inherent constituent present in the original bean.

A vast amount of research has been performed and many patents have been granted and papers published on methods for control of this beany flavor. This work has been in progress for over 50 years.

Teeter et al. in 1955 summarized the state of these investigations as follows: "A large number of patents covering processes for 'debittering' soybeans are in existence. These processes are empirical, and there appears to be no available evidence that they are based on knowledge of the chemical nature of the beany or bitter principles."

In 1969, Mustakas et al. stated that: "The basic problems of upgrading the soybean to human food can be listed as follows: (a) inactiviating growth inhibitors, (b) producing a bland and palatable product, and (c) obtaining good storage stability."

Present thinking is that the flavor is not present in the original bean. When the cell tissue of soybean cotyledons is disrupted or damaged in any way in the presence of even a small amount of moisture, a highly objectionable "painty" or "beany" flavor develops.

This off-flavor development is caused by an enzyme (lipoxidase) which is almost instantaneous in action. Once this off-flavor has developed, it is practically impossible to eliminate or mask it.

Reprinted from the January 1971, Soybean Digest, American Soybean Association, Hudson, Iowa 50643.

Mustakas et al. (1969) found that if lipoxidase was adequately inactivated in the soybean meats a bland and stable full-fat soy flour could be prepared from whole soybeans. Wilkins et al. (1967) reported that a highly acceptable soy milk could be prepared from whole soybeans.

The present work represents a twofold contribution. First is development of a simple and inexpensive treatment of the whole bean for inactivation of the lipoxidase enzyme before it can catalyze any off-flavor development. Second is the recognition that this bland whole bean can be used as the chief ingredient in a wide variety of processed food products.

Whole Bean Treatments

The dry beans are cleaned, inspected to remove defective beans and impurities, and washed. Rehydration and enzyme inactivation can then be done in sequence or simultaneously.

Thus, one treatment is to soak the beans in tap water for about 4 hours to obtain a 100 percent weight increase. Enzyme inactivation may then be accomplished by blanching, e.g., heating in tap water at about 210°F for about 10 minutes. The specific combination of time and temperature required for the inactivation should be determined for each case because it would depend on variety of soybean, use to be made of the blanched beans, etc.

Alternately soybeans can be hydrated and blanched in one operation by placing the dry beans directly in boiling tap water for about 20 minutes.

The resulting beans have a very firm texture. This is no disadvantage if they are to receive further heat processing such as in canning. For some food products a much more tender bean is required. This can be achieved by adding 0.5 percent sodium bicarbonate to the soak and blanch water. The blanching time after a tap water or bicarbonate soak would be as long as 30 minutes depending on the degree of tenderization desired.

If beans are soaked before blanching, care should be exercised to avoid damaging the beans after soaking and before blanching. If the bean tissue is disturbed after hydration and before blanching, instant off-flavor will be developed in the beans by the lipoxidase enzyme. However, if the hydration and blanching procedures are carried out as described, a highly palatable, high-protein raw material is available for processing into many food products.

New Food Products

To demonstrate the usefulness and acceptability of the treated whole soybean, about 10 formulated food products have been developed. Emphasis has been on canned products. Included are pork and beans, vegetarian soybeans of several types, soybeans with chicken, soybeans with lamb, soybeans with pork, soybean soup, and a soybean vegetable salad.

Two dry products, a weanling food for children which is made entirely from whole soybeans and bananas, and a ground meat extender have been developed.

Preparation of one product from each group will be described in some detail to show that the technology is simple.

Canned Soybean and Chicken

This product is prepared from whole soybeans, chicken meat, spices and flavorings.

Whole soybeans are dry-cleaned, inspected, and washed. They are hydrated and blanched in boiling 0.5 percent sodium bicarbonate solution for 20 minutes, drained, rinsed in tap water, and the loose skins removed by water flotation. Six ounces inspected beans are added per No. 1 can.

In preparation of the chicken meat, whole chickens are cooked in boiling water for 30 minutes or until the meat can be removed from the bones and diced. One ounce of diced chicken meat and skin is added per No. 1 can. The broth is saved for the sauce which contains water, chicken broth, tomato pulp, starch, salt, spice and flavorings. The sauce is brought to a boil and filled into cans containing the beans and chicken meat. The cans are closed and thermally processed at 250°F.

This and other canned products were enthusiastically received by several taste panels.

Dry Food for Weanlings

This product is prepared solely from whole soybeans and a fruit such as bananas.

Whole soybeans are prepared as above except that simultaneous hydration and blanching required 30 minutes. Ten parts water are added to one part blanched beans and finely ground in a comminuting mill. Fresh, ripe bananas are added at a ratio of one part banana solids to one part soybean solids and blended in the same mill. Sufficient sodium bisulfite is added to impart 100 ppm sulfur dioxide to improve color and storage stability. The slurry is dehydrated to 3 percent moisture with a double drum drier using 0.01-inch drum spacing and 40 psig steam pressure in the rolls. This soybean-banana product can be dehydrated more readily than either component alone.

The rehydrated powder is free of any off-flavor and has a pleasing banana flavor. Texture is grainy rather than pasty. Preliminary high-temperature-short-time storage tests indicate that the product will have very acceptable shelf life.

A similar product prepared with apple sauce in place of bananas was found to be excellent in flavor and other characteristics.

General Considerations

The number of other types of products that can be prepared from the treated whole soybeans appears to be unlimited. For example, recently much criticism was directed toward the breakfast cereal industry: their products were said to contain relatively small amounts of protein which could be of better quality. Techniques described here for producing a bland soybean may be utilized to improve protein quality of breakfast cereals.

The developing countries as well as a segment of our own population are in dire need of foods with improved protein and calorie content. Developments such as reported here indicate that the soybean could be an immediate answer for improving nutrition in these areas.

The economics of soybean utilization should not be overlooked. Soy protein costs 12¢/lb (5¢/lb beans, 42 percent protein) as compared to 268¢/lb for hamburger protein (59¢/lb hamburger, 22 percent protein).

Soybeans cost much less than the cheapest beans now used for food and have a higher protein content. The demand for soybean oil and meal is affected by the supply of other vegetable oils and meals. Another outlet utilizing whole soybeans should be most welcome to the soybean producers.

Much research remains to be done. The products developed to date are prototypes rather than the final formulations. Although organoleptic evaluations generally rate them as very good to excellent, storage studies with more extensive evaluations must be performed. For instance, rancidity development of the soybean oil in the whole bean might become a problem.

Also, many additional products made with whole soybeans should be developed. Finally, specific cost and nutritional data should be developed for the various products.

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DEVELOPING A SOYABEAN DAL FOR INDIA AND OTHER COUNTRIES

by

J. M. Spata, A. I. Nelson and S. Singh

In 1966 a comprehensive project* was undertaken to determine if soyabeans could be grown with satisfactory yields in India. This project was conducted at two Indian agricultural universities. Results of the experiment were extremely favourable. Previously yields of about 1,013 lb/acre had been considered satisfactory for high-protein crops in India. Soyabean yields in these experimental plots averaged about 2,947 lb/acre.
High yields alone are seemingly meaningless unless soyabeans can be used in the Indian diet. Thus food scientists began working on soyabeans to develop them into various foods. As a part of this research a stable soyabean dal was considered for development. Dal is a Hindi term, used for both dry dehulled split pulses and the gruel type of food made from the pulses. This general type of food is eaten in many countries around the world. The spices used and the method of preparation varies but basically the same pulses are consumed.
The objective of this research was to produce a soyabean dal similar in appearance and texture to the indigenous dals. Moreover, it must be competitive in price with the other dals. In either case the amount of protein in the diet would increase and the quality would be superior. Consequently, the nutritional value of a staple food would be improved.

Pulses occupy a very important place in the agricultural economy and diet of the people of India. The area under cultivation for pulses is 59 million acres,[4] representing 17 percent of the total cultivatable land area of India. From both the production and consumption point of view, chana, arhar, urd, moong, and masoor are important pulses in India. Pruthi compared the average yield of these pulses in India to that of soyabean (Table 1).

It is apparent (Table 1) that soyabeans yield almost twice as much as chana and arhar and about three times that of urd and moong.

Table 1. The average yield of pulses of India compared to that of soyabean

Pulses	lb/acre	kg/ha
Chana	761	856
Arhar	740	835
Urd	408	465
Moong	387	435
Masoor	---	no information
Soyabean	1,200	1,345

Soyabeans are valuable for the quantity of protein (40%) and oil (20%) they contain. This fact alone would be enough to encourage soyabean use in the human diet. However, in addition, soyabean contains protein of high quality.[5] Thus, due to the high quality of protein, soyabean is of great importance to people who rely on plant materials for their protein.

* This research was supported by a grant from the Midwest Universities Consortium for International Activities.

Reprinted from World Crops, March/April 1974. Published by World Crops Publications Ltd., London WC2E7BD England.

Table 2 presents the cost of protein in selected food as compared with soya flour. This table shows how inexpensive soyabean protein is when compared to the protein cost from other sources.

Table 2. Approximate relative cost of protein from selected sources, India

Food	Price/kg* (Rs)	Protein content %	Cost of protein/kg (Rs)
Mutton	9.00	18	50.00
Eggs	5.00	13	38.40
Milk	1.00	3.3	30.00
Fish	5.25	30	26.25
Bengel gram (chana)	1.40	21	6.66
Soya flour	1.25	50	2.50

* One rupee = 13.3 U.S. cents

The LEE Kramer shear press is an instrument that is recognised as a standard for measuring tenderness of many food products.[2] This instrument was correlated with the simple shear press.[6] There was an overall coefficient of correlation of 0.9933 between instruments on cooked soyabean samples. This showed that the simple shear press could be used in place of the LEE Kramer instrument for determination of the tenderness of soyabeans or similar products. Shear press readings are directly related to the tenderness of soybeans. The higher the pressure required to shear the sample, the tougher the product.

The Northern Regional Laboratories in Peoria, Illinois,[3] studied alternate methods of processing soyabeans in developing countries. Their aim was to inactivate growth inhibitors, to produce a bland and palatable product and to obtain a flour with good storage stability. In order to accomplish this they investigated several basic and simple methods for cooking soyabeans. They studied atmospheric steaming, water-immersion cooking and various forms of dry heating or roasting. Their conclusion was that water immersion was the most desirable for rapid cooking and simple control.

Soyabean Dehulling

The soyabean dehuller was designed specifically for soyabeans of about 10 percent moisture content. This development was part of the soyabean processing programme at G.B. Pant University and was directed by Professor B.P.N. Singh. The dehuller consisted of a motor-driven knurled drum revolving at 325 rpm. Placed along side of the drum was a concave of 60 deg made of 3/16 inch steel with the same curvature as the drum. The distance between the concave and the drum could be adjusted by screw-type fittings. The soyabeans were fed between the revolving corrugated drum and the stationary concave. Soyabeans were generally too large to fit between the two surfaces. Thus the beans were distorted to such a degree that the hulls burst without breaking or crushing the cotyledons. The knurling on the drum's surface aided in separation of the hull from the cotyledon.

Survey of Indian Pulses

Table 3 presents data of a survey of Indian dals as compared to whole and raw dehulled soyabeans. All soyabeans used in this study were of the Bragg variety and were grown on the experimental farm of G.B. Pant University of Agriculture and Technology, Pant Nagar, Uttar Pradesh, India. The price survey was conducted to obtain relative costs of the dals for comparative purposes. All prices were obtained from the same market area (Taria region of northern India) in February 1972. Indications are that if soyabeans can be processed inexpensively into dal the product would be competitive with indigenous dals. The protein analysis of the dals and soyabean confirm the fact that soyabean contains a substantially greater amount of protein as compared to the indigenous dals. It should also be pointed out that soyabean protein is of higher quality. Simple shear press readings were taken on the dal and soyabean samples after 30 minutes of boiling in hard water (HW). By definition HW is water containing between 120 and 180ppm total hardness. Data (Table 3) indicated that soyabeans cooked for 30 minutes in HW, were in the same texture range as the indigenous dals. Further studies were made to relate cooking time of the various products with optimum tenderness. The dals and soyabeans were boiled in HW for various times and presented to a taste panel for tenderness evaluation. Boiling times to achieve optimum organoleptic tenderness for each product were determined by statistical analysis of the data. This study revealed that soyabean dal was preferred at a very soft texture, as were moong and urd. To cook soyabean dal to this desired texture it required about 138 minutes of boiling in HW. Thus it becomes apparent that a parboiling process is required in preparation of soyabean dal if the finished product is to be cooked in a time comparable with the tender dals. Thus the preliminary studies indicated that a parboiling tenderising treatment was desirable in the processing of soyabean dal. Albrecht et al[1] investigated several basic and simple methods of cooking soyabeans. He concluded that cooking in boiling water was the most feasible method that could be adapted for use in a developing country.

Table 3. Comparison of price, protein content and tenderness of dal and soyabeans

Hindi name	Arhar dal	Chana dal	Masoor dal	Moong dal	Urd dal	Soyabean	Soyabean
Botanical name	Cajanus cajan Milsp	Cicer arietinum L	Lena esculenia Moench	Phaseolus aurens Roxb	Phaseolus mungo	Glycine max	Glycine max
English name	Pigeon pea	Gram	Lentil	Green gram	Black gram	Dehulled soyabean	Whole Bragg soyabean
Approximate price per kg in rupees*	1.80	1.40	2.20	2.00	2.80	---	1.00+
Per cent protein, dry weight basis	26.10	25.35	28.33	29.04	27.95	41.89	36.25
Simple shear press reading after 30min of boiling in HW (psi)	738	722	633	57	88	538	863
Time of boiling (HW) to achieve preferred tenderness (minutes)	65	55	30	30	105	138	---
Simple shear press reading (psi)	355	572	633	57	Less than 30	77	---

* Rs1 = 13.3 U.S. cents
\+ Government support price and market price at Haldwani, UP, December 1972.

Soyabean Tenderisation

Studies were carried out to determine the most effective method for tenderising the soybeans. Experiments not presented here showed that soaking of raw beans reduced the boiling time required to tenderise the beans. The data showed that 5 hours of soaking in HW was optimum to develop tenderness with minimum boiling times. Table 4 presents texture data on the effect of water hardness, soaking and addition of 0.5 percent $NaHCO_3$ on whole and dehulled soyabeans boiled for 30 minutes. The addition of sodium bicarbonate to the cooking water for whole unsoaked soyabeans and raw dehulled soyabeans affected substantial tenderisation. Also the favorable effect on tenderness with soft water (SW) use (containing 0-60ppm of total hardness) was also apparent and an even more favorable effect was noted when SW plus sodium bicarbonate was used as the cooking medium. When whole soyabeans were soaked, the addition of sodium bicarbonate had slight, if any, effect on tenderness if the soyabeans were subsequently cooked in water containing 0.5 percent sodium bicarbonate. Soyabeans can be tenderised most effectively if they are dehulled prior to boiling in SW containing 0.5 percent sodium bicarbonate. Thus this information indicates that the most effective procedure for tenderising soyabeans is raw dehulling prior to boiling in SW containing 0.5 percent $NaHCO_3$.

Table 4. The effect of water hardness, soaking, and addition of 0.5 percent $NaHCO_3$ on whole and dehulled soyabeans boiled for 30 min.

Treatment	Simple shear press readings in psi	
	Hard water	Soft water
Whole soyabeans		
Unsoaked but cooked	863	692
Unsoaked but cooked in 0.5% $NaHCO_3$	557	413
Soaked 5hr and cooked in 0.5% $NaHCO_3$	308	285
Soaked 5hr in 0.5% $NaHCO_3$ and cooked in 0.5% $NaHCO_3$	290	223
Dehulled raw soyabeans		
Unsoaked but cooked	538	482
Unsoaked but cooked in 0.5% $NaHCO_3$	166	100

Lipoxidase, an enzyme present in raw soyabeans, causes the oxidation of unsaturated fatty acids. The results of this reaction is a rancid flavor that is difficult to eliminate or mask. When the soyabean tissue is damaged, the enzyme is released and is available for instant reaction if moisture is present. Thus it becomes important in the processing scheme to drop raw dehulled soyabean cotyledons directly into boiling water. This inactivates the lipoxidase enzyme before off-flavour develops.

Dehydration Studies

If a parboiling process is used, the soyabeans must then undergo some type of dehydration. Soyabean dehydration studies indicated that the beans dry more rapidly if hulls are removed before dehydration. The hull definitely inhibits moisture diffusion and apparently reduces thermal conductivity. In addition, the removal of the hull increases the surface area. Four hours of artificial dehydration at $140^{o}F$, $\pm 3^{o}F$ with a wet bulb of $85^{o}F$, a tray load of 0.65 lb/ft^2, and an air velocity of 585 linear ft/min was sufficient to reduce to the moisture content to 6.2% and water activity to 0.54. Sun drying to a similar moisture content was accomplished in about 8 hours with the same tray loads. The wind velocity was about 6 mph and temperatures ranged between 102 and $113^{o}F$.

Suggested Processing Schemes

Within the limits of the organoleptic evaluation it was found that soyabean dal was preferred at a very soft texture. To achieve the desired tenderness in soyabean dal with only 30 minutes of cooking by the housewife, the following processing procedure is suggested. Dehull the raw soyabeans, remove hulls, drop the cotyledons directly into boiling water for 45 minutes (soft water is preferable) containing 0.5 percent $NaHCO_3$ and dry to 6 percent moisture.

Results from the previous studies suggest processing schemes for soyabean dal at the plant and village level (Fig. 1). An alternative to the above scheme would be to merely raw dehull and sell the separated cotyledons to the consumer without further processing. This has the advantage of being inexpensive. However, it has disadvantages. If not held properly, the beans will pick up moisture and immediately develop off-flavour and off-odour in the product. Also, results indicate that it would take about 140 minutes to cook this product to a desired tenderness.

Figure 1. Recommended processing schemes for soyabean dal at the plant and village level

Processing Plant

Mechanical dry cleaning of beans to remove stones and other foreign material

↓

Hand picking of beans to eliminate moldy and other defects not removed by dry cleaning

↓

Dehull raw soyabeans at about 10% moisture

↓

Separate hulls from cotyledons (hulls and germ salvaged for cattle feed)

↓

Drop cotyledons into boiling H_2O (soft water desirable) containing 0.5% $NaHCO_3$ and parboil for 45min

↓

Drain beans

↓

Artificial dehydration at 140°F for 4hr

↓

Break and size cotyledons according to local preference

↓

Package

Village Level

Hand picking of beans to remove stones, moldy beans and other defects

↓

Dehull raw soyabeans at about 10% moisture

↓

Separate hulls and germ from cotyledons (hulls and germ salvaged for cattle feed)

↓

Drop cotyledons into boiling water containing 0.5% $NaHCO_3$ and parboil for 45min

↓

Drain beans

↓

Sun dry during the heat of the day (time depends upon weather conditions)

↓

Break and size cotyledons according to local preference (can be accomplished by hand with knives)

↓

Package and store similar to other dals

Estimate of Production Costs

It is beyond the scope of this research to develop exact cost figures for the production of soyabean dal. Table 5 suggests an estimate of the production costs of soyabean dal at the plant and village level. This estimate indicates that soyabean dal can be produced for about 2Rs/kg. Even if this estimate is low, it appears that soyabean dal would be competitive with the indigenous dals.

Storage Study

Parboiled dry soyabean dal was packaged in double-thick polyethylene bags and held for 10 weeks at 0, 70 and 120°F. Organoleptic evaluation was then performed on representative samples cooked with spices using the hedonic scale of 1 to 9. In this scale, 1 was considered very poor and 9 was excellent. A grade of 5 was borderline. The taste panel members were asked to judge the spiced soyabean samples as dal for overall acceptability. Acceptability included texture, flavour and appearance of the dal. The soyabean dal held at $0^{o}F$ received scores of 6.66, while samples that were held at 70 and $120^{o}F$ received scores of 6.71 and 5.57, respectively. A statistical analysis of the organoleptic results revealed no significant difference among samples at the 95% confidence level. Samples held at $120^{o}F$ were slightly lower in acceptability than those held at 70 and $0^{o}F$ for similar times. Thus it is indicated that soyabean dal is stable during storage if held at low moisture content. However, detailed storage experiments are required to fully clarify the effects of packaging, temperature, relative humidity, moisture content and storage time.

Table 5. Estimation of costs to produce soyabean dal at processing plant and the village level

Expenditures	Processing plant 1,000kg output daily Rate	Cost (Rs)*	Village level 100kg output daily Rate	Cost (Rs)*
Raw material				
Soybeans	Rs1/kg. 1,350kg required for 1,000kg output of dal	1,350	Rs1/kg. 135kg required for 100kg output of dal	135
$NaHCO_3$	Rs2.5/kg. 450g required for 1,000kg output of dal	11	Rs2.5/kg. 45g required for 100kg output of dal	1
Labour	10 people at about Rs10 each per day	100	Four people at about Rs5 each per day	20
Power	Electricity and steam per day	400	Wood per day	40
Packaging material	50kg burlap bags, Rs1 each	20	50kg burlap bags, Rs1 each	2
Equipment and building costs	Cost per day over five-year period	150	Cost per day over three-year period	2
Subtotal		2,031		200
Salvage from hulling loss (used for cattle feed)	Rs0.25/kg. About 11% loss in 1,350kg of soyabeans	-37	Rs0.25/kg. About 11% loss in 135kg of soyabeans	-4
Total		1,994		196
Cost/kg of processing soyabean dal		1.99		1.96

* Rs1 = 13.3 U.S. cents

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