PROCESSING CONDITIONS, NUTRITIONAL AND BAKING PROPERTIES OF QUICK-COOKING SOYBEANS

by

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INTRODUCTION

Shortage of protein in the diet is a serious problem for people in many of the developing countries.

Soybeans have great potential for use as human foods because of their high levels of protein and oil, ready availability and low cost (2). One of the most promising uses of soybeans is for fortification of cereal-based products, such as baked goods, because the profile of essential amino acids in soybeans is complementary to that in most cereals (3). Fortification with soy flour is known to be technically, nutritionally and economically sound (4).

In less developed countries, it is essential to produce an adequate diet at low cost. There is a great need for straightforward, small-scale methods of processing soybeans into human foods. Equipment and materials should be manufactured locally (5)

Numerous methods for preparing full-fat soy flours have been reported (2). Bastiaens (6) reported that in typical commercial methods used in the U.S.A., antinutritional factors may be inactivated by steam or dry heat; but in both methods control over protein solubility was found limited. Badenhop and Hackler (7) reported that dry roasting to reduce off-flavor characteristics of raw soybeans resulted in appreciable losses of tryptophan, lysine, cysteine and histidine, and a decrease in the PER (protein efficiency ratio). Harper and Lorenz (8) reported that high temperature, short time heating using a continuous salt bed roaster gave full-fat soy flours with PER's of 2.11 - 2.31 which could be used in bread. However, additional testing of functional properties was needed. The extrusion process developed by Mustakas et al. (9), and the drum-drying process developed by Nelson et al. (10), both yield bland soy flours, but the equipment costs are high (11).

The major objectives of the present investigation were:

1. To develop a simple and energy-saving method for producing full-fat soy products from soybeans.

2. To study the amino acid composition of these soy products.

3. To study the trypsin inhibitor activity of these soy products.

4. To determine the nutritive value of these soy products, in comparison with commercial full-fat soy flour and casein.

5. To study the baking properties of these soy products in bread, cakes and cookies.

LITERATURE REVIEW

Whole soybeans are an excellent source of protein; about 40% of dry matter in soybeans is protein. The amino acid distribution is close to that recommended by the FAO (Food Agricultural Organization), so the quality is very good. The whole soybean contains almost 20% fat, and this fat is desirable because it is largely unsaturated (10, 12). Most important of all, soybeans are low in cost (10, 12). The proximate compositions of soybeans and seed parts are shown in Table 1 (16).

Full-fat soy flours are commercially milled in the United States and England. Beans are cleaned, steamed, dried, cracked between corrugated rolls, dehulled by aspiration and screening, then ground and sieved (13). Alternatively, the beans may be cracked and dehulled prior to steaming. The steam treatment inactivates antinutritional factors and enzymes such as lipoxygenases that can catalyze oxidation of lipids to develop undesirable flavors (14).

An alternate process for preparing full-fat soy flours involves extrusion cooking. Beans are cleaned, cracked, dehulled, heated, raised to 18% moisture, extruded (121 - 143°C), then cooled and ground (15).

Full-fat soy flours prepared by either method have a composition (Table 2) closely resembling that of whole soybeans, because only the hulls (seedcoats) are removed during processing. Heat treatment during processing decreases solubility of the proteins as measured by the nitrogen solubility index and inactivates

Table 1. Proximate Compositions of Soybeans and Seed Parts.

Fraction	Protein (N x 6.25) (%)	Fat (%)	Carbohydrate (%)	Ash (%)
Whole bean (100%)	40	21	34	5
Seed coat (8%)	9	1	86	4
Cotyledon (90%)	43	23	29	5
Hypocotyl (2%)	41	11	44	4

Table 2. Proximate Analysis and Biochemical Parameters of Soy Flour.

	Full-Fat Flour[a]
Moisture, %	3.4
Protein (N x 6.25), %	41.0
Crude fat, %	22.5
Crude fiber, %	1.7
Ash, %	5.1
PER[b]	2.15
Inactivation of trypsin Inhibitors, %	89.0
Urease Activity, pH change	0.1
Nitrogen solubility index	16.0

[a]Experimental sample (Mustakas et al. 1970).

[b]Protein efficiency ration corrected to casein (2.50).

the bulk of the trypsin inhibitors. The protein efficiency ratio is about 90% of the value for the casein standard (16).

Serious food shortages in many parts of the world are usually accompanied by deficiencies in fuels. Soybeans in their native state are not satisfactory as a food. Even after being soaked overnight, they must be cooked a long time (4-5 hours) to bring them to an edible state; this consumes an inordinate amount of fuel.

However, a process was developed for preparing quick-cooking soybeans by Rockland in 1972. It consists of: (a) blanching the beans by a brief contact with boiling water; (b) soaking in an aqueous solution containing sodium chloride, a chelating agent, and two alkaline agents; (c) rinsing; and (d) drying (17). No report has been available concerning the nutritional evaluation of such quick-cooked soybeans.

Blanching - raw soybeans are first contacted with boiling water for two minutes. This treatment has the critical effect of modifying or conditioning the beans so that they will properly take up the hydrating medium used in the second step. In the absence of this treatment with boiling water, the beans will not imbibe the medium to any useful extent even after soaking in the medium for a long period of time. On the other hand, if the contact with boiling water is to be continued substantially longer than the specified time, the skin will slough off and the kernels will split, exposing the cotelydons and embryos to oxidative and other deleterious actions.

Soaking - the conditioned soybeans are soaked for about 24 hours, at room temperature and at atmospheric pressure, in a special hydration medium. A solution is prepared with the following composition: sodium chloride 2.5%, sodium tripolyphosphate 0.5%, sodium bicarbonate 0.75%, and sodium carbonate 0.25%. The solution is thereafter referred to as Rockland's solution.

The sodium chloride has the principal effect of tenderizing the skins, and is also believed to assist in tenderizing protein components of the cotelydons.

A chelating agent, such as sodium tripolyphosphate or EDTA (Ethylene Diamine Tetraacetic Acid) exerts a variety of useful effects, including the following: a) It softens the pellicle or skin; b) It aids in the solubilization of proteins and starchy components; c) It acts as a buffer to maintain pH; d) It facilitates uniform penetration of the hydrating medium into the centers of the beans, so that the final products have a uniformly smooth texture; and e) It tends to lighten the color of the product.

The sodium carbonate or sodium bicarbonate not only acts as an alkaline agent and buffer but also acts as a protein-dissociating, solubilizing, or tenderizing agent.

Rinsing - after the beans are hydrated, they are rinsed with water to remove the hydrating medium from their surfaces. This rinsing is conveniently carried out by placing the hydrated beans on a screen and spraying them with water.

Drying - the beans are dried isothermally under a low velocity air stream at temperatures not exceeding 60°C for 24 hours, or higher temperatures up to 77°C for 8 hours or less (17, 18).

The cooking characteristics of soybeans can be tested with an experimental bean cooker. In 1946, Mattson (20) developed a cooker for studying the cooking rate of dry beans. A frame holds 100 saddles in each of which is placed a presoaked bean. A vertical plunger, weighing 82 grams and terminating at its lower end in a 1/16 inch diameter stainless steel rod, rests on each bean. Each saddle is perforated vertically, and when a bean becomes sufficiently tender, the rod penetrates the bean and drops a short distance through the hole in the saddle (20).

During an experimental run, the lower portion of the cooker holding the beans is lowered into water maintained at 98°C. At the end of each minute, the operator records the number of beans which have been penetrated by their plungers. When these data are plotted, they form an S-shaped curve and the cooking time for a sample is taken as the required time for 50% of the beans to be penetrated.

The plungers are hollow and are weighed with lead shot. With the weight of a plunger adjusted to 82 grams, it will penetrate a bean at about the time required to cook the bean to the same tenderness as judged by a human taster. The cooking times measured with this apparatus are median cooking times for the 100 beans in a sample. With the median cooking time only half the beans are cooked "done"; a substantially longer time should be required to cook the sample adequate for serving (19, 20, 21, 22).

Factors which will affect the cooking characteristics are: (a) soaking solution; (b) soaking time; and (c) soaking temperature (18, 23, 24, 25, 26).

Soaking solution. Generally, fresh green beans and peas cook more rapidly than their more mature field-dried counterparts. Older, less viable beans require longer cooking. Presumably legume proteins influence texture and cooking characteristics of cotyledons (18, 19, 20). Consistent differences are observed on polyacrylamide gel electrophoretograms of proteins extracted from immature green, field-dried mature and mature, dry-aged beans. On the basis of these observations, hydration media are designed to disperse or solubilize proteinaceous material (18).

Effects of temperature and time on bean hydration. The hydration and soaking time decreased with increasing temperature of the hydration medium up to temperatures of about 52°C (18).

It is wellknown that most legume foods, if not all, contain antinutritional factors in varying concentrations which must be eliminated before they are consumed or before evaluating their nutritive quality in experimental animals (27). Soybeans have high trypsin inhibitor activity values, about 4×10^{-4} units/gram (27). Controlled heating improved the nutritive quality of soybeans by destroying antinutritional factors (27). Overheating of soybeans reduces its protein quality either by decreasing the availability of cystine and methionine or rendering the meal more resistant to proteolytic enzymes (27).

Rackis (1974) stated that 80% destruction of soybean trypsin inhibitor activity resulted in the maximum Protein Efficiency Ration (PER) in rats (28). The higher the PER values in rats, the higher the nutritional value of the soy protein products.

In 1970, Mustakas et al. (15) reported that PER values improved with Trypsin Inhibitor inactivation. The highest PER value found, 2.15 (casein = 2.5), was reached with 89% inactivation. Although the differences between PER values for 89% and 98% trypsin Inhibitor inactivation were not significant at the 95% confidence level, a t-test showed PER values for 62% and 89% inactivation differed to a significant degree from that for 12% inactivation (Table 3).

In 1971, Badenhop and Hackler (7) evaluated the protein quality of raw soybeans by amino acid composition and protein efficiency ratio. A depressed PER value of 0.6 was obtained for the raw soybeans because of antinutritional factors in the raw soybeans. The total amino acid analysis of raw soybeans is given in Table 4.

Bread and other wheat-based products are nutritionally inferior because they are generally deficient in lysine. One simple way to remedy the lysine deficiency is to fortify wheat flour with high quality protein - rich additives such as soy flour and soy products (29).

Fortifying wheat flour with full-fat soy flour for making bread can raise protein content, balance essential amino acids, and increase the bread's caloric value (4). Such fortification, however, can adversely affect both rheological properties and baking quality of wheat flour. All breads with 12 to 28% soy flour exhibited a small loaf volume and poor grain score. Sodium stearoyl-2 lactylate (SSL) was found to increase the stability of dough containing 12 to 28% soy flour and to improve the baking performance of soy-fortified flours. The effect was enhanced with increased additions of SSL (0.25 to 2.0%) (4, 30). Baking quality of wheat flour with defatted soy flour was inferior to that of wheat flour with full-fat soy flour, even compared on an equivalent protein basis (4).

Specific loaf volume is an important parameter of bread's marketability. Specific loaf volume (cubic centimeters per gram) is calculated from the average loaf weight and volume.

Soy fortified flour can also be used to make cakes and cookies. For cake making, volume and internal texture of the cakes are used to evaluate the baking quality of cake flour. For cookie making, spread ratio is used to evaluate the baking quality of cookie flour (31, 32).

Table 3. Correlation of Protein Efficiency Ratio (PER) with Trypsin Inhibitor (TI) Inactivation.

TI Inactivation (%)	PER[a]
12	1.82 A
43	1.96 AB
62	2.03 BC
89	2.15 C
98	1.98 ABC

[a]Adjusted to casein = 2.5. Least significant difference at 95% level between two PER values is 0.18. PERs having no letter in common differ significantly at 95% level.

Table 4. Amino Acid Composition g/16g N and Essential Amino Acid Index of Raw Soybeans.

Aspartic acid	11.5
Threonine	4.66
Serine	4.99
Glutamic acid	18.40
Proline	5.44
Glycine	4.26
Alanine	4.23
Valine	4.30
Cystine	1.52
Methionine	1.04
Isoleucine	3.94
Leucine	7.80
Tyrosine	3.02
Phenylalanine	4.64
Lysine	6.19
Histidine	2.50
Arginine	7.47
Tryptophan	1.51
Available lysine	4.11
Essential Amino Acid Index	73.80

MATERIALS AND METHODS

MATERIALS

William soybeans (1978 crop) from Kansas Crop Improvement Association at Kansas State University were used in this study.

Hard, red winter wheat flour, used for breadmaking, was milled from a composite of wheats (1978 crop) in the pilot mill of the Department of Grain Science and Industry, Kansas State University. It had a moisture content of 15.2%, a protein content of 12.1%, an ash content of 0.43%, and a fat content of 1.5%.

The flour used for cakemaking was a typical baker's cake flour, named Lite Maid flour, obtained from International Multifoods, with a moisture content of 12.1%, a protein content of 9.4%, an ash content of 0.39%, and a fat content of 0.70%.

The cookie flour, which was obtained from Mennel Milling Company, was used for cookiemaking. Its moisture, protein, ash and fat contents were 12%, 9.7%, 0.5%, and 1.2%, respectively.

The commercial full-fat soy flour named Nutrisoy flour was obtained from ADM Milling Company. The proximate composition of the soy flour was: moisture 4.1%, protein 40.4%, ash 5.0%, and fat 22.4%

All chemicals used were reagent grade or equivalent. Distilled water was used for physical and chemical analyses, conditioning and soaking soybeans, and baking tests.

Preparation of Quick-cooking Soybeans

The quick-cooking method, which was developed by Rockland at the U.S.D.A. Western Regional Research Center in 1972

(17), was modified to prepare bean paste as outlined in Figure 1. The important steps included: (a) blanching; (b) soaking; (c) draining; (d) rinsing; and (e) cooking.

Bean Cooker

The bean cooker used to test the softness of soybeans in this experiment was modified from the experimental bean cooker devised by Burr et al. (1968) (22). The cooker's frame holds 25 vertical plungers, each resting on an individual bean (Figures 2 and 3). The lower part, holding the beans, is lowered into boiling water. When a bean reaches a certain stage of tenderness, it is penetrated by the plunger, which then drops about 1 centimeter. The operator counts the number of plungers that have dropped at the end of each minute, and when the cumulative number is plotted against time, an S-shaped curve is obtained (Figure 4). The total weight of each plunger is adjusted to 82 grams. It will penetrate a bean at about the time required to cook the bean to the same degree of tenderness as judged by a human taster.

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Figure 1. Flow Sheet for Soybean Paste Preparation.

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FLOW SHEET

dry soybeans

↓

blanch in boiling water for two minutes

↓

soak in salt soaking solution
for 18 hrs at 25°C
(bean) 1 : 3 (solution)

↓

drain

↓

rinse with water two times

↓

cook in boiling water
(bean) 1 : 3 (H_2O)

↓

add water and homogenize
(bean) 1 : 2 (H_2O)

Figure 2. A Draft of the Frame of the Bean Cooker Which Yields a Continuous Cookability Curve.

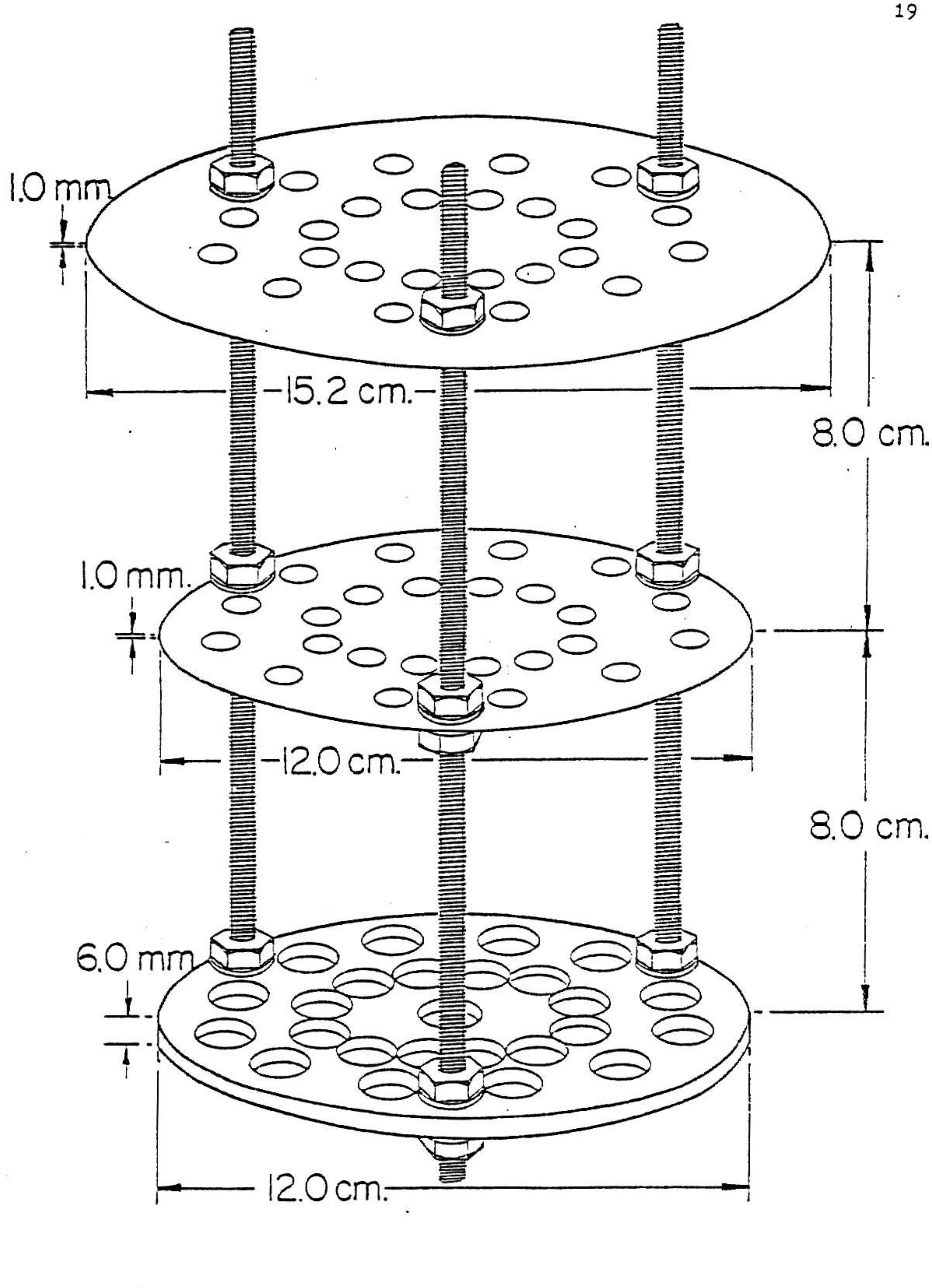
1.0 mm.
15.2 cm.
8.0 cm.
1.0 mm.
12.0 cm.
8.0 cm.
6.0 mm
12.0 cm.

Figure 3. A Draft of a Plunger of the Bean Cooker Which Yields a Continuous Cookability Curve.

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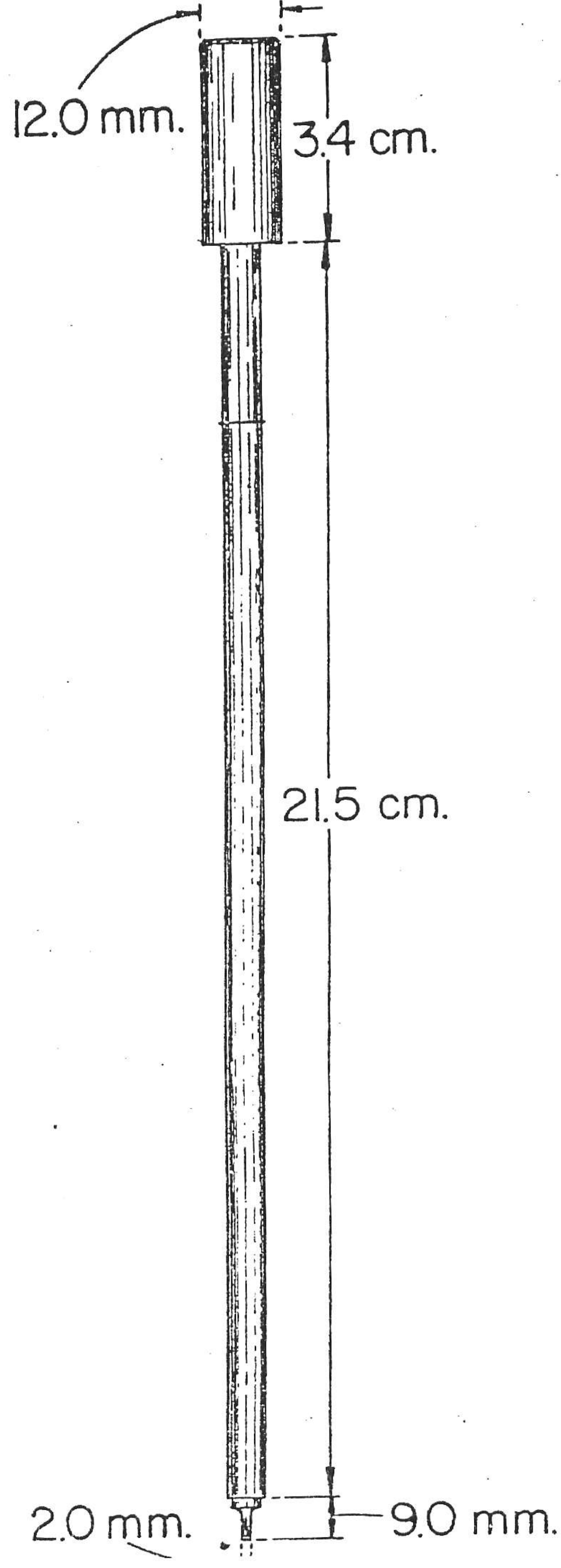
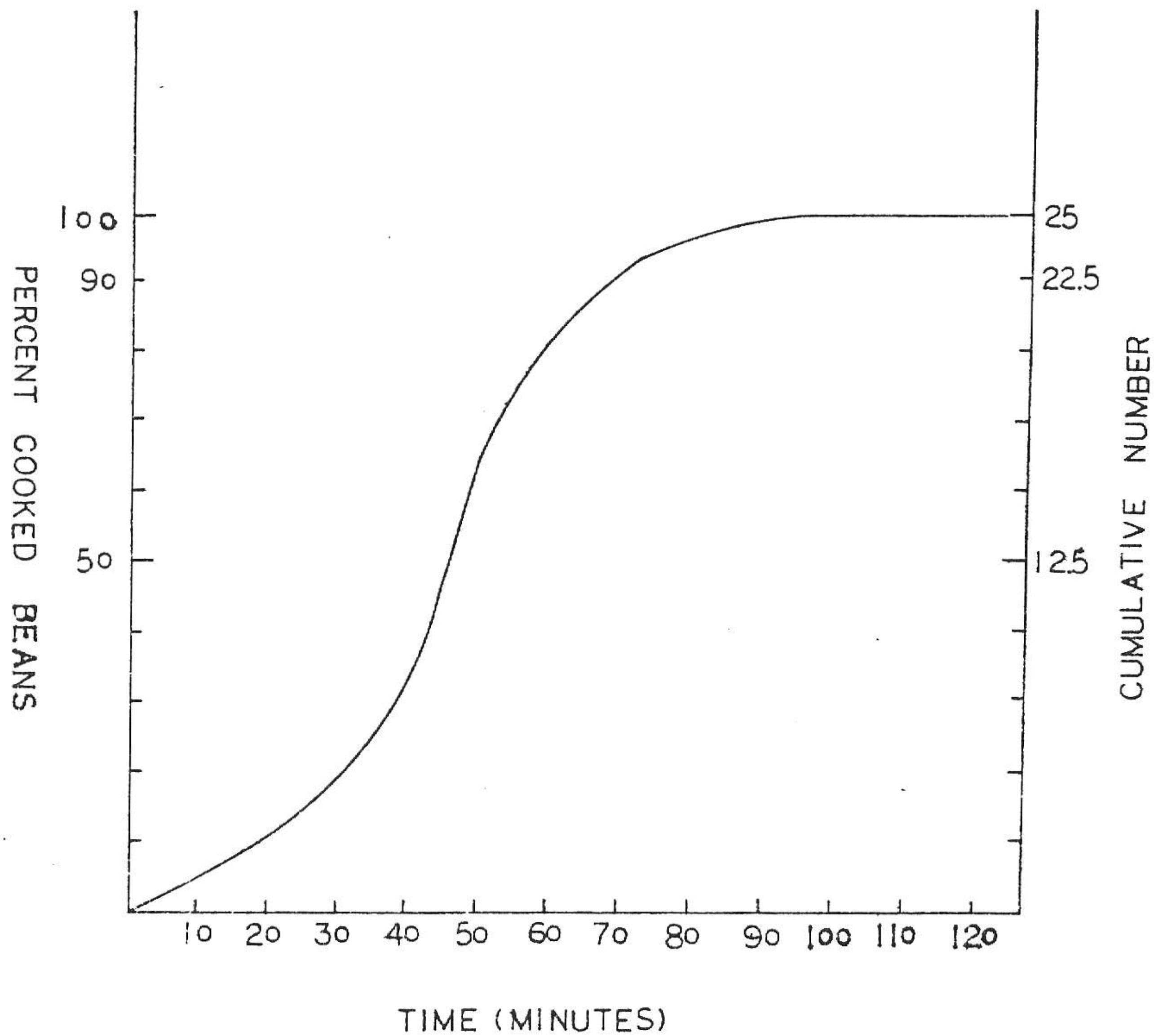

12.0 mm.
3.4 cm.
21.5 cm.
2.0 mm.
9.0 mm.

Figure 4. Cookability Curve of Soybeans (% Cooked and Cumulative Number vs. Time).
The 90% Point of the Curve Is Taken as the Soybean Cooking Time.


100
90
50
PERCENT COOKED BEANS
25
22.5
12.5
CUMULATIVE NUMBER
10 20 30 40 50 60 70 80 90 100 110 120
TIME (MINUTES)

Determination of Soaking Solution

Part I: Seven kinds of soaking solution were used to soak soybeans: (a) 1% sodium chloride; (b) 1% sodium tripolyphosphate; (c) 1% sodium bicarbonate; (d) 1% sodium carbonate; (e) 1% EDTA; (f) Rockland's solution: 2.5% sodium chloride, 0.5% sodium tripolyphosphate, 0.75% sodium bicarbonate, 0.25% sodium carbonate; and (g) distilled water. The procedure shown in Figure 1 was used to prepare quick-cooking beans. The soaking temperature was set at 25°C; soaking time was 18 hours. The soybeans were cooked in boiling distilled water with a bean cooker.

Part II: Rockland's solution and various concentration levels, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0%, of sodium carbonate solutions were used to soak soybeans. The soaking temperature was done at 25°C for 18 hours. The soybeans were cooked in boiling distilled water with a bean cooker.

Determination of Soaking Temperature

The beans were soaked at temperature of 10, 20, 30, 40, and 50°C, 1% sodium carbonate and Rockland's solutions were used to soak the soybeans; the soaking time was 18 hours. The soybeans were cooked in distilled water with a bean cooker.

Determination of Soaking Time

Various soaking times (5, 10, 15, 18, 24, and 36 hrs) were used to soak the soybeans. 1% sodium carbonate and Rockland's solutions were used to soak beans. The soaking temperature was set at 25°C. The soaked soybeans were cooked in distilled water with a bean cooker.

Determination of the Color of Cooked Soybeans

Seven kinds of soaking solution were used to soak soybeans: (a) 1% sodium chloride; (b) 1% sodium tripolyphosphate; (c) 1% sodium bicarbonate; (d) 1% sodium carbonate; (e) 1% EDTA; (f) Rockland's solution; and (g) distilled water. The procedure listed in Figure 1 was used to prepare quick-cooking beans. 90% cooking time was used to cook each group of soybeans. The soaked soybeans were cooked in distilled water with a bean cooker.

For color measurements, 90% cooked soybeans were used. The water on the surface of the soybeans was dried by a paper towel. An Agtron multichromatic abridged reflectance spectrophotometer Model M-300A was used to evaluate the colors of soybeans, with monochromatic spectral line: green (546 nm).

Soy Flour Preparation for Trypsin Inhibitor Activity Analysis, Amino Acids Contents Analysis, Feeding Tests and Baking Test

Four kinds of soaking solutions were used to soak soybeans: (a) distilled water; (b) 1% sodium bicarbonate; (c) 0.8% sodium carbonate; and (d) Rockland's solution. The procedure listed in Figure 1 was used to prepare soy paste. A steam cooker instead of a bean cooker was used to cook 1500 g beans in boiling distilled water for a period to reach 90% cooking time. Subsequently the soy paste was dried by a freeze drier and ground into flour.

Full-fat soy flours, prepared according to the procedure (Fig. 1) from beans soaked in distilled water, 1% sodium bicarbonate, 0.8% sodium carbonate and Rockland's solution were referred to as soy flours A, B, C, and D, respectively.

Trypsin Inhibitor Activity Analysis

Initially, raw soybeans were ground, then dried for 24 hours under 29 mg Hg vacuum at 40°C. Commercial full-fat soy flour, full-fat soy flours A, B, C, and D were dried for 24 hours under 29 mg Hg vacuum at 40°C (5). Then the six kinds of soy flour were defatted by AOAC method Aa 4-38 (1971) with petroleum ether as the extracting solvent (30). The defatted samples were desolventized at 40°C for 2-3 hours in a vacuum oven. Trypsin Inhibitor Activity (TIA) was determined by AACC method 71-10 (1976) using benzoyl-DL-arginine-p-nitroanillide (BAPA) hydrochloride as a substrate (33).

Amino Acid Composition

Gas-liquid chromatography was used to determine amino acid composition of various soy flours (34, 35).

Nutritional Studies of Soy Flours

The nutritive value of soy flours was determined by rat feeding studies. Casein, wheat flour, commercial soy flour, soy flours A, B, C, and D were used as the source of protein. The moisture, protein, ash, fat and fiber (AACC, 1976; AOCS, 1971 methods) of the soy flours were determined so that equivalent experimental diets could be formulated. The proximate composition of the wheat flour used was: moisture 15.2%, protein (N x 5.7) 12.1%, ash 0.43%, fat 1.5%. The protein content of casein was 87.0%.

Vitamin and mineral premixes were prepared according to NRC formulas (1972) to support optimum rat growth (36). Four percent vegetable oil was added to each diet to improve texture and decrease dustiness. Compositions of vitamin and mineral premixes are shown in Tables 6 and 7, respectively. Table 8 shows the composition of diets.

Design of Animal Feeding Experiments

A randomized complete block design was used. Four-week-old male weanling rats (Charles River CD) were fed experimental diets that contained 10% protein supplied by casein, wheat flour or soy flours for 35 days. The rats, whose initial weights varied from 50-60 grams, were randomly divided into groups of six per treatment. Each rat was housed in a screen bottom cage in an environmentally controlled laboratory and given a test diet and water *ad libitum*. Fresh water was supplied every second day; feed cups were checked daily and filled as needed. Feed consumption and weight gain were recorded weekly for each rat. Feces were collected daily in the 4th and 5th weeks. Records were kept to determine (a) weight gain; (b) protein efficiency ratio (PER); and (c) feed conversion ratio (FCR) = gm feed consumed/gm body weight gained; and (d) % digestibility of protein.

Table 5. Proximate Composition of Soy Flours.

Soy Flour	Moisture %	Protein (N x 6.25) %	Ash %	Fat %
Soy flour A	2.0	45.9	4.0	21.1
Soy flour B	1.7	47.5	3.9	22.0
Soy flour C	1.5	46.8	4.4	21.7
Soy flour D	1.9	45.1	6.2	21.8

Table 6. Composition of Vitamin Premix for Experimental Diets.

Ingredient	Mg used/Kg diet
Vitamin A (10,000 IU/gm)	229.00
Vitamin D (15,000 IU/gm)	74.00
Vitamin E (25% alpha-tocopherol)	156.00
Vitamin K (equivalent)	0.06
Choline chloride	833.00
Niacin	16.70
Riboflavin	2.80
Calcium Pantothenate	8.90
Thiamine Hydrochloride	1.39
Vitamin B6	7.80
Vitamin B12	0.0056
Corn Starch	8,670.00

Table 7. Composition of Mineral Premix for Experimental Diets.

	g/kg of the diet						
Ingredients	Diet 1[b]	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
$CaPO_4$	23.18	19.45	15.91	16.81	17.03	16.92	16.66
$CaCO_3$	---	2.10	3.60	3.12	3.00	3.06	3.24
NaCl	7.36	1.80	1.84	1.84	1.84	1.84	1.84
K_2CO_3	16.96	2.74	---	---	---	---	---
$MgSO_4$	9.60	2.40	2.40	2.40	2.40	2.40	2.40
Trace[a]	12.00	3.00	3.00	3.00	3.00	3.00	3.00

[a]Trace mineral mix contained (%) Mn 10, Fe 10, Ca 14, Cu 1, Zn 5, I 0.3, and Co 1.

[b]The protein source in the diets:
Diet 1. Casein
Diet 2. Wheat flour
Diet 3. Commercial full-fat soy flour
Diet 4. Soy flour A
Diet 5. Soy flour B
Diet 6. Soy flour C
Diet 7. Soy flour D

Table 8. Composition of Diets for Rat Study.

	% of the diet						
Ingredients	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7
Casein	11.49	---	---	---	---	---	---
Wheat Flour	---	75.19	---	---	---	---	---
Soy Flour	---	---	24.75	21.79	21.05	21.37	22.17
Oil	4	4	4	4	4	4	4
Vitamin	1	1	1	1	1	1	1
Mineral	3.47	3.15	2.68	2.72	2.73	2.72	2.71
Fiber	2	---	---	---	----	---	---
Starch	58.53	12.49	50.68	52.87	53.42	53.18	52.59
Sugar	19.51	4.17	16.89	17.62	17.80	17.73	17.53

Effect of Soy Flour on the Physical Dough Properties and Bread, Cake, Cookie Qualities

Farinographs

The farinograph measures and records the resistance of a dough to mixing. It is used to evaluate the absorption of water by flour and to determine stability and other characteristics of dough during mixing. Two basically different methods are in common use: the constant dough weight procedure and constant flour weight procedure. The two procedures may not yield identical results (13).

The constant flour weight method was used in this study. Water absorption was adjusted to obtain a dough having a maximum consistency of 500 Brabender Units (B.U.). Wheat flour and soy flour were mixed for five minutes before titration with water. The addition of water was completed within 25 seconds after opening the buret stopcock. Four kinds of soy flour were used in this study: (a) commercial full-fat soy flour; (b) soy flour B; (c) soy flour C; and (d) soy flour D.

Baking Test

Bread. The K-State (Kansas State University) process for making high-protein bread was used (37): 88% wheat flour, 12% soy flour, 3% yeast, 5% sugar, 2% salt, variable water, 40 ppm potassium bromate and 0.5% surfactant (% based on total flour). First, the flours were mixed together, and then transferred to the water -jacketed Hobart mixer bowl. Surfactant (SSL) was suspended in 100 ml of 54°C distilled water. The salt and sugar were dissolved in 24°C distilled water. The yeast was also dissolved in 24°C distilled water. All ingredients were emptied into a Hobart A200 mixer equipped with a McDuffee type bowl maintained at a constant temperature (31°C). The ingredients were mixed at low speed (No.1) for one minute and mixed at medium speed (No.2) until optimum dough development was attained. Dough was then scaled to 500 g, rounded and rested for 40 minutes at 30°C and 85% relative humidity. The fermented dough was punched to release gas and then molded, panned, and proofed to 1.5 cm above the pan at 36°C and 92% relative humidity and finally baked at 218°C for 23 minutes. Loaf weight and volume averaged from duplicates were measured within 10 minutes after bread was removed from the oven. Specific loaf volume was then calculated from the average loaf weight and volume. Specific volume is important in bread marketability. Generally in the U.S.A., a one pound loaf should have a specific volume of at least 6.00 cc/g or have a volume of 2722 cc, with acceptable crumb, texture, and grain. Breads were scored 18 hours after baking. Finished bread that scored below 5 was regarded as unsatisfactory.

Different kinds of soy flour were used in this study. The amount of soy flour added to wheat flour for baking tests was based on the same amount of protein content. Breads were fortified with the following soy flours: (a) commercial full-fat soy flour; (b) soy flour B; (c) soy flour C; and (d) soy flour D. White flour breads were also baked for comparison purposes.

<u>Cake</u>. The AACC standard method for making cake was modified to

make soy-fortified cake: 88% wheat flour, 12% soy flour, 14% sugar, 50% shortening, 12% nonfat dry milk, 9% dried egg whites, 3% salt, 5.25% baking powder, and variable water. All ingredients (except shortening) were combined, then sifted well. These ingredients were then transferred to the mixing bowl of a Hobart C-100 mixer; the shortening and 60% of the water were then added to the mixer. The ingredients were mixed at low speed (No. 1) for 0.5 minute, scraped down, then mixed at medium speed (No. 2) for 4 minutes. One-half of the remaining water was added, mixed at low speed for 0.5 minute, scraped down, and mixed at medium speed (No. 2) for 2 minutes. The remaining water was added, mixed at low speed (No. 1) for 0.5 minute, scraped down, and mixed at medium speed (No. 2) for 2 minutes. The pans were greased lightly with commercial pan grease, then lined with parchment paper. Using a scale, 425 g of batter was poured into each of two pans, then baked at 191°C for 25 minutes.

After baking the cakes remained in the pans for about 30 minutes, they were removed from the pans and allowed to cool for another 30 minutes. The cakes were dusted lightly with flour before cake weight and volume were measured. Calculated specific cake volume from the average cake weight and volume. Cakes should be graded for texture on the same day they are baked.

Different kinds of soy flour were used in this study. The amount of soy flour added to wheat flour for baking tests was based on the same amount of protein content. Cakes were fortified with the following soy flours: (a) commercial full-fat soy flour; (b) soy flour B; (c) soy flour C; and (d) soy flour D. White flour cakes were also baked for comparison purposes.

Cookies. The AACC standard method 10-50D (1976) for making cookies was modified to make soy-fortified cookies. The formula for making white flour cookies is shown on Table 9. The formula for making soy-fortified cookies is shown on Table 10. Shortening, sugar, salt and soda were combined in the mixing bowl of a Hobart C-100 mixer at low speed (No. 1) for 3 minutes (scraped down after each minute). Dextrose solution and distilled water were then added, mixed 1 minute at low speed (No. 1), then scraped. The batter was then mixed at medium speed (No. 2) for 1 minute. All of the flour was added and mixed 2 minutes at low speed (scraped down every ½ minute). Six portions of dough were placed at well spaced points on a cookie sheet. The dough mounds were flattened lightly with the palm of a hand and the dough was then rolled to proper thickness with a rolling pin on guage stripes. The cookies were cut on the sheet by lifting scrap dough up from around the cutter and discarding. The cookies were baked for 10 minutes at 204°C, removed from the oven, then lifted from the sheet with a wide spatula and placed on absorbent paper.

After the cookies were allowed to set on absorbent paper for 30 minutes, they were lain edge to edge and their width was measured. They were then rotated 90° and remeasured, yielding an average width (W) of 6 cookies (in mm). The cookies were stacked on top of one another to measure thickness. They were then restacked in different order to provide a second measure of average thickness (T) of 6 cookies (in mm). Readings were to the nearest ½ mm. Width (W) divided by thickness (T) is the W/T ratio (spread ratio).

Different kinds of soy flour were used in this study. The amount of soy flour added to wheat flour for baking tests was based on the same amount of protein content. Cookies were modified with the following soy flours: (a) commercial full-fat soy flour; (b) soy flour B; (c) soy flour C; and (d) soy flour D. White flour cookies were also baked for comparison purposes.

Table 9. Formula for White Flour Cookies.

Ingredient	Weight (g)
Shortening	64.0
Sugar	130.0
Salt, U.S.P.	2.1
Bicarbonate of soda, U.S.P.	2.5
Dextrose solution (8.9 g dextrose hydrous, U.S.P. in 150 ml H_2O)	33.0
Distilled water	33.0
Flour (14% m.b.)	225.0

Table 10. Formula of Soy-Fortified Cookies.

Ingredient	Weight (g)
Shortening	64.0
Sugar	130.0
Salt, U.S.P.	2.1
Bicarbonate of soda, U.S.P.	2.5
Dextrose solution (8.9 g dextrose hydrous, U.S.P. in 150 ml H_2O)	33.0
Distilled water	37.0
Wheat flour (14% m.b.)	198.0
Soy flour	27.0

RESULTS AND DISCUSSION

Determination of Soaking Solution

Part I: Table 11 shows the cooking times of soybeans which were soaked in various soaking solutions. The best soaking solution was 1% sodium carbonate, which gave the shortest cooking time, but there was no statistically significant differences between 1% sodium carbonate and Rockland's solution.

Part II: Table 12 shows the cooking times of soybeans which were soaked with Rockland's solution and various concentration levels of sodium carbonate solutions. There were no significant differences among 0.8% sodium carbonate, 1.0% sodium carbonate, and Rockland's solution; and also no significant differences among 1.4% sodium carbonate, 1.6% sodium carbonate, and 1.8% sodium carbonate solution. However, cooking time decreased gradually with the increasing sodium carbonate concentration level.

Determination of Soaking Temperature

Table 13 shows the cooking times of soybeans which were soaked at various soaking temperatures. For the soybeans soaked in 1% sodium carbonate solution or Rockland's solution. 25°C gave the shortest cooking time (Figure 5).

Determination of Soaking Time

Tables 14 and 15 show the cooking times of soybeans which were soaked for various periods. For the soybeans which were soaked in 1% sodium carbonate solution, 24 hours soaking gave the shortest cooking time, but there was no significant difference between 15 hours and 24 hours; for the soybeans which were soaked in Rockland's solution, 24 hours soaking gave the shortest cooking time.

Determination of the Color of Cooked Soybeans

Table 16 shows the Agtron reading of cooked soybeans which were soaked in different soaking solutions. The soybeans which were soaked in 1% EDTA gave the highest Agtron reading, which means that the soybeans had the lightest yellow color compared with other groups of soybeans; and the soybeans which were soaked in Rockland's solution gave the lowest Agtron reading, meaning that the soybeans had the darkest yellow color compared with the other groups of soybeans. There were no significant differences in the Agtron readings of 1% sodium carbonate soaked soybeans and Rockland's solution soaked soybeans. This means the color of 1% sodium carbonate soaked soybeans and the color of Rockland's solution soaked soybeans are very similar.

Trypsin Inhibitor Activity (TIA) Analysis

Table 17 shows the % Trypsin Inhibitor Activity destruction (% TIA destruction) of the soy flours which were soaked in various soaking solutions. The soy flour D gave the highest % TIA destruction; the soy flour B gave the lowest % TIA destruction. However, there were no significant differences in TIA destruction among soy flour D, soy flour A, soy flour C, and commercial full-fat soy flour.

Amino Acid Contents

The results of amino acid analyses are presented in Table 18. There were no marked differences in amino acid contents among soy flours A, B, C, and D.

Nutritional Study of Soy Flours

Weight Gain: The effects of seven diets on average net weight gain during the four weeks is shown in Table 19 and Figure 6. The casein control rats (Diet 1) had an average net weight gain of 112.4 g; rats on wheat flour (Diet 2) had an average net weight gain of 23.4 g. The average net weight gain for other diets ranged from 120.4 g for Diet 4 to 97.4 g for Diet 5.

Feed Consumption: Results are shown in Table 19. The casein control (Diet 1) had an average net feed consumption of 354.6 g. The wheat flour (Diet 2) had an average net feed consumption of 234.2 g. The average net feed consumption for other diets ranged from 435.3 g for Diet 4 to 408.4 g for Diet 5.

Feed Conversion Ration: Results are shown in Table 19. The casein control (Diet 1) had an average feed conversion ratio of 3.2. The wheat flour (Diet 2) had an average feed conversion ratio of 10.3. The average feed conversion ratio for other diets ranged from 4.2 for Diet 5 to 3.6 for Diet 4. There were no significant differences among the ratios for Diet 5, Diet 6, Diet 7, Diet 3, and Diet 4; and there were no significant differences among the ratios for Diet 7, Diet 3, Diet 4, and Diet 1. These results showed that the feed conversion ratios of soy flour D, commercial full-fat soy flour, soy flour A were comparable to that of the casein control.

Tale 11. Cooking Times of Soybeans Soaked in Various Soaking Solutions at 25°C for 18 Hours,

Soaking Solution	Cooking Time (mean[a]) min	
Distilled water	73.7	A
1% sodium chloride	54.3	B
1% EDTA	35.0	C
1% sodium tripolyphosphate	34.0	C
1% sodium bicarbonate	27.3	D
Rockland's solution	14.7	E
1% sodium carbonate	12.0	E

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Table 12. Cooking Times of Soybeans Soaked in Rockland's Solution and Various Concentration Levels of Sodium Carbonate Solutions at 25°C for 18 Hours.

Soaking Solution	Cooking Time (mean[a]) min
0.2% sodium carbonate	52.0 A
0.4% sodium carbonate	24.3 B
0.6% sodium carbonate	19.5 C
Rockland's solution	14.0 D
0.8 sodium carbonate	13.3 D
1.0% sodium carbonate	12.5 DE
1.2% sodium carbonate	10.0 E
1.4% sodium carbonate	8.5 FG
1.6% sodium carbonate	8.0 FG
1.8% sodium carbonate	7.5 GH
2.0% sodium carbonate	6.5 H

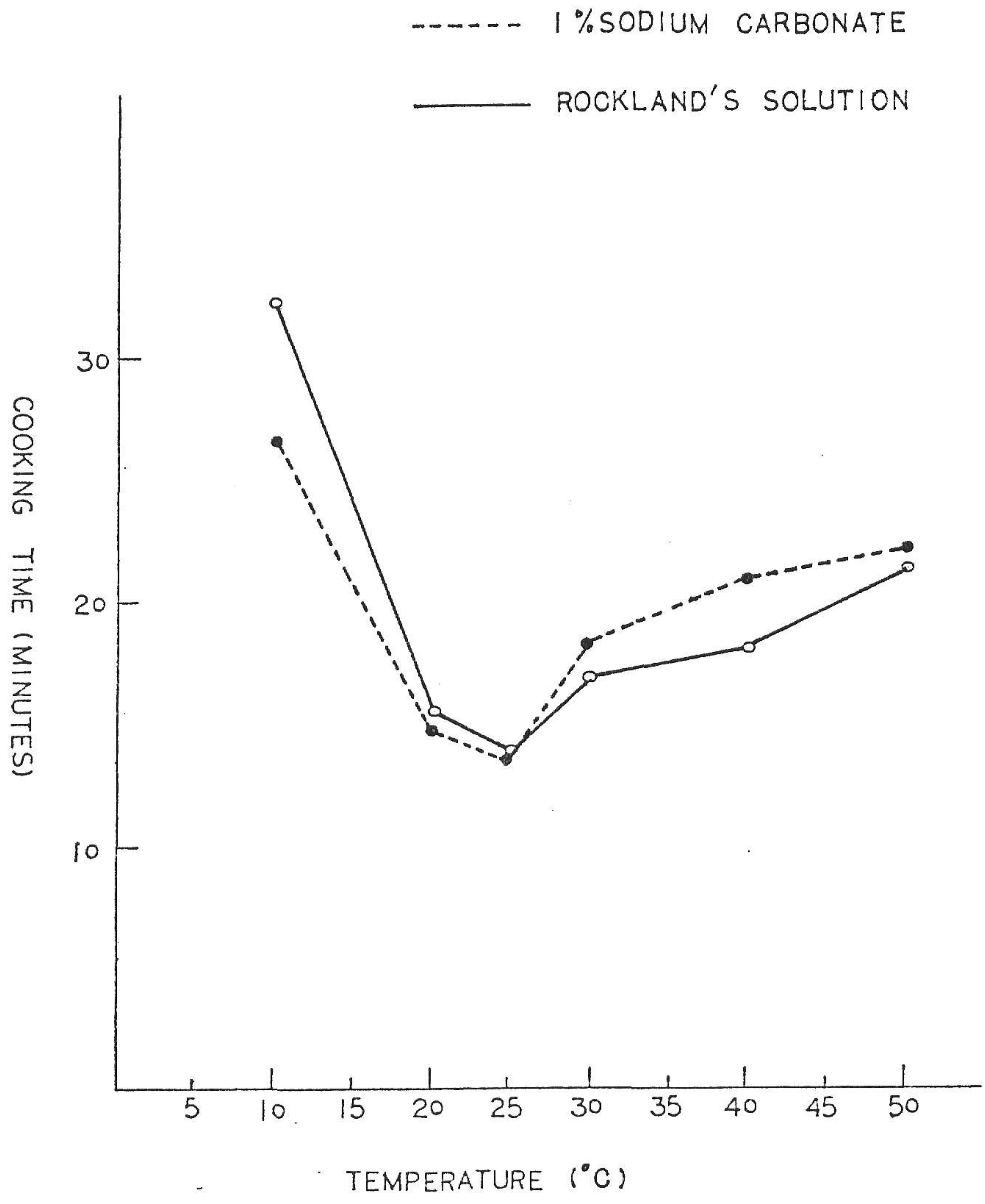
[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Table 13. Cooking Times[a] of Soybeans Soaked in 1% Sodium Carbonate Solution and Rockland's Solution at Various Temperatures for 18 Hours.

Soaking Temperature °C	Cooking Time (mean[a]) min		Rockland's	
10	26.8	A	32.0	A
50	21.2	B	20.3	BC
40	20.8	B	18.3	C
30	18.7	C	16.8	CD
20	14.8	D	15.8	D
25	12.0	E	14.7	D

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Figure 5. Effect of Soak-Temperature on the Cooking Time of Soybeans Soaked in 1% Sodium Carbonate and Rockland's Solution for 18 Hours.



1 %SODIUM CARBONATE
ROCKLAND'S SOLUTION
30
20
10
COOKING TIME (MINUTES)
5
10
15
20
25
30
35
40
45
50
TEMPERATURE (°C)

Table 14. Cooking Time of Soybeans Soaked in 1% Sodium Carbonate Solution for Various Periods at 25°C.

Soaking Time hr	Cooking Time (mean[a]) min
5	35.6 A
10	13.9 B
18	12.5 C
36	12.1 C
15	11.8 C
24	11.7 C

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Table 15. Cooking Time[a] of Soybeans Soaked in Rockland's Solution for Various Periods at 25°C.

Soaking Temperature hr	Cooking Time (mean[a]) min	
5	52.5	A
10	20.6	B
18	12.2	C
15	11.7	CD
36	10.8	D
24	8.7	E

[a]Duncan's Multiple Range Test (1975). Meas without a letter in common differ significantly ($P<0.05$).

Table 16. Agtron Readings[a] of Cooked Soybeans Soaked in Various Soaking Solutions at 25°C for 18 Hours.

Soaking Solution	Agtron Reading (mean[b])	
1% EDTA	66.3	A
1% sodium tripolyphosphate	59.5	B
1% sodium chloride	55.0	C
Distilled water	52.7	C
1% sodium bicarbonate	46.5	D
1% sodium carbonate	31.7	E
Rockland's solution	30.7	E

[a]Agtron reading was obtained with monochromatic spectral line: green (546 nm).

[b]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Table 17. The % Trypsin Inhibitor Activity Destruction (% TIA destruction) of the Soy Flours.

Soy Flours	TUI/mg soy flour	%TIA Destruction (mean[a])
Soy flour D	10.00	89.4 A
Soy flour A	11.25	88.0 A
Soy flour C	11.50	87.8 A
Commercial full-fat soy flour	11.75	87.4 A
Soy flour B	18.25	80.6 B

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly (P 0.05).

[b]Raw soybeans: 93.75 TUI/mg soy flour.

Table 18. Amino Acids[a] of Soy Flour.

Amino Acid	Commercial[b] Full-Fat Soy Flour	Soy Flour A	Soy Flour C	Soy Flour B	Soy Flour D
Aspartic acid	12.51	11.58	11.81	12.49	12.35
Threonine	4.13	3.77	3.88	4.03	4.03
Serine	5.97	5.53	5.65	5.86	5.84
Glutamic acid	12.13	19.23	18.67	18.91	17.60
Proline	7.22	6.09	6.24	6.40	6.65
Glycine	4.80	4.52	4.59	4.86	4.72
Alanine	6.38	5.89	5.89	5.28	6.09
Half cystine	1.48	1.25	1.13	1.10	1.37
Valine	3.53	3.32	3.40	3.44	3.23
Methionine	1.20	1.20	1.14	1.16	1.11
Isoleucine	3.22	3.23	3.02	3.01	2.99
Leucine	7.85	7.36	7.32	7.60	7.51
Tyrosine	3.71	3.15	3.28	3.19	3.45
Phenylalanine	5.75	4.49	5.55	4.32	5.54
Histidine	4.29	3.67	3.79	3.90	3.82
Lysine	5.98	5.42	5.49	5.78	5.90
Ammonia	1.30	1.33	1.24	1.52	1.48
Arginine	8.55	8.96	7.90	7.14	6.34

[a]Grams of amino acids per 100 g protein corrected to 100% recovery protein basis.

[b]Commercial soy flour (dehulled) is listed for reference only.

Table 19. Analysis Feed Conversion Ratio of Rats on Seven Diets for Four Weeks.

Diet Group	Weight Gained (g)	Feed Consumption (g)	Feed Conversion Ratio (mean [a])
Diet 2. Wheat flour	23.4	234.2	10.29 A
Diet 5. Soy flour B	97.4	408.4	4.23 B
Diet 6. Soy flour C	100.6	415.5	4.13 B
Diet 7. Soy flour D	113.7	431.1	3.86 BC
Diet 3. Commercial full-fat soy flour	110.0	413.6	3.80 BC
Diet 4. Soy flour A	120.4	435.3	3.63 BC
Diet 1. Casein	112.4	354.6	3.18 C

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Protein Efficiency Ration (PER): Protein efficiency ratios are given in Table 20. The casein control (Diet 1) had an adjusted protein efficiency ratio of 2.5. The wheat flour (Diet 2) gave the lowest PER (0.79 compared to casein at 2.50). The adjusted PER values for other diets ranged from 2.19 for diet 4 to 1.88 for Diet 5. There were no significant differences among the ratios for Diets 3, 4, and 7; and also among the ratios for Diets 3, 7, and 6 and between Diets 5 and 6. The results of this investigation show that both Rockland's solution and 0.8% sodium carbonate solution are good soaking agents for preparing soy flour with a high nutritive value. But 0.8% sodium carbonate solution is much simpler to prepare and less expensive than Rockland's solution to be used as a soaking agent (Figures 7 and 8).

Percentage Digestibility of Protein: The data for the 14 day-feeding test on percentage digestibility of protein are given in Table 21. The casein control (Diet 1) had a percentage digestibility of protein of 90.1. The percentage digestibility of protein values for the other diets ranged from 85.3 for Diet 5 to 81.0 for Diet 3. There were no significant differences in the percentage digestibility of protein among the soy flour diets.

Farinographs: The rheological data of wheat flour dough fortified with soy flours are shown in Table 22.

Water absorption of the wheat flour dough was 55%. The addition of 12% soy flour to the wheat flour increased water absorption considerably. The water absorption of 12% commercial full-fat soy fortified flour was 59.5%; 65% for 12% soy flour B fortified flour; 66% for 12% soy flour C fortified flour; and 67% for 12% soy flour D fortified flour. The relatively high increases in absorption arising from the addition of soy flour is attributed to its high protein content for water binding.

For the control wheat flour dough the arrival time was 1.5 minutes. The addition of soy flours to the control wheat flour at 12% level increased the arrival time. The arrival time for the soy-fortified doughs ranged from 2 minutes for commercial full-fat soy flour to 9 minutes for soy flour D. In dough rheology, the arrival time on the farinograph can be associated with the rate of hydration of the flour proteins, especially the gluten proteins. Although the addition of soy flour increased the water absorption, the rate of hydration of gluten proteins, as revealed by arrival time, was considerably delayed.

The farinograph peak time, which also indicates the time required for reaching optimum dough development, was 7.5 minutes for the control wheat flour. The addition of soy flour increased the peak time. The peak time for the soy-fortified doughs ranged from 9.5 minutes for commercial full-fat soy flour to 14 minutes for soy flour D and soy flour C.

In general, dough stability suggests the resistance of the dough to changes with mixing. A strong flour will produce a stable dough. The dough stability value for the control wheat flour was 19.5 minutes. Soy flour considerably reduced the dough stability to a range of 18 minutes to 12.5 minutes. Dough stability reflects the strength of gluten structure during mixing (38). Replacement of part of the wheat flour with oilseed flours has been cited to cause marked increases in water absorption, increased mixing requirements, and reductions in mixing tolerance (39, 40, 41).

Bread Quality: Specific volume of breads baked from wheat flour fortified with soy flours are presented in Table 23. The average specific volume of control bread was 6.96 cc/g. The supplementation of 12% soy flour to wheat flour yielded significantly smaller loaves. The average specific volume of soy fortified bread ranged from 6.29 for 12% commercial full fat soy flour to 5.62 for 12% soy flour C. Soy flour C fortified breads gave the lowest average specific volume. With 12% soy flour fortification, the grain structure had more holes and was more open than the control wheat flour breads.

Cake Quality: Specific volumes of cakes baked from wheat flour fortified with soy flours are presented in Table 24. The average specific volume of the control cake was 2.75 cc/g. Fortification of 12% soy flour to control wheat flour yielded smaller cakes. The average specific volume of soy fortified cakes ranged from 2.70 for 12% soy flour B fortified cake to 2.54 for 12% soy flour D fortified cake. With 12% soy flour fortification, the grain structure had more holes and was more open than the control cakes, and there were more blisters on the top surface of wheat-soy flour cakes.

Cookie Quality: The spread ratios of cookies baked from wheat flour fortified with soy flours are presented in Table 25. The average spread ratio of the control cookie was 8.85. The fortification of 12% soy flour to control wheat flour decreased the spread ratio. The average spread ratio of soy fortified cookies ranged from 7.94 for 12% commercial full-fat soy flour fortified cookies to 5.94 for 12% soy flour B fortified cookies.

From the results of this study, a conclusion can be made that a process has been developed in this study for preparing quick-cooking soybeans. It is a time, energy-saving process.

0.8% sodium carbonate solution and Rockland's solution were found to be the best solutions. The sodium carbonate not only acts as an alkaline agent and buffer but also acts as a protein-dissociating, solubilizing and tenderizing agent. The optimum soaking conditions for soybeans to be soaked at 25°C for 18 hrs.

The results of rat feeding studies showed that both 0.8% sodium carbonate solution and Rockland's solution are good soaking agents for preparing soy flour with a high nutritive value. But 0.8% sodium carbonate solution is much simpler to prepare and less expensive than Rockland's solution to be used as a soaking agent.

Fortifying wheat flour with full-fat soy flour for making bread and other baking goods can raise protein content, balance essential amino acids, and increase the bread's caloric value. Data from baking tests from this study indicated that the fortification of wheat flour with 12% soy flour exerted some adverse effects on the quality of bread, cakes, and cookies.

Table 20. Analysis of Protein Efficiency Ratio (PER) of Rats on Seven Diets for Four Weeks.

Diet Group		Actual PER (mean[a])		Adjusted PER
Diet 1.	Casen	3.16	A	2.50
Diet 4.	Soy flour A	2.76	B	2.19
Diet 3.	Commercial full-fat soy flour	2.65	BC	2.10
Diet 6.	Soy flour C	2.42	CD	1.92
Diet 5.	Soy flour B	2.38	D	1.88
Diet 2.	Wheat flour	0.99	E	0.79

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

Table 21. Analysis of Ordered Means for Percentage Digestibility of Protein of Rats on Seven Diets for Five Weeks.

Diet Group	Protein Diet (%)	Protein Feces (%)	% Digestibility of Protein (mean[a])
Diet 1. Casein	87.0	17.0	90.1 A
Diet 5. Sodium bicarbonate soy flour	47.5	23.4	85.3 B
Diet 7. Mixture soy flour	45.1	24.1	85.0 B
Diet 6. Sodium carbonate soy flour	46.8	23.5	84.4 B
Diet 4. Distilled water soy flour	45.9	23.6	84.3 B
Diet 2. Wheat flour	12.1	23.5	83.8 B
Diet 3. Commercial full-fat soy flour	40.4	27.2	81.0 B

[a]Duncan's Multiple Range Test (1975). Means without a letter in common differ significantly ($P<0.05$).

[b]% digestibility of protein = 100 - weight of feces x 10 x protein content/weight of feed.

Figure 6. Cumulative Weight Gain of Rats Fed Experimental Diets.

Diet 1. Casein

Diet 2. Wheat flour

Diet 3. Commercial full-fat soy flour

Diet 4. Soy flour A

Diet 5. Soy flour B

Diet 6. Soy flour C

Diet 7. Soy flour D

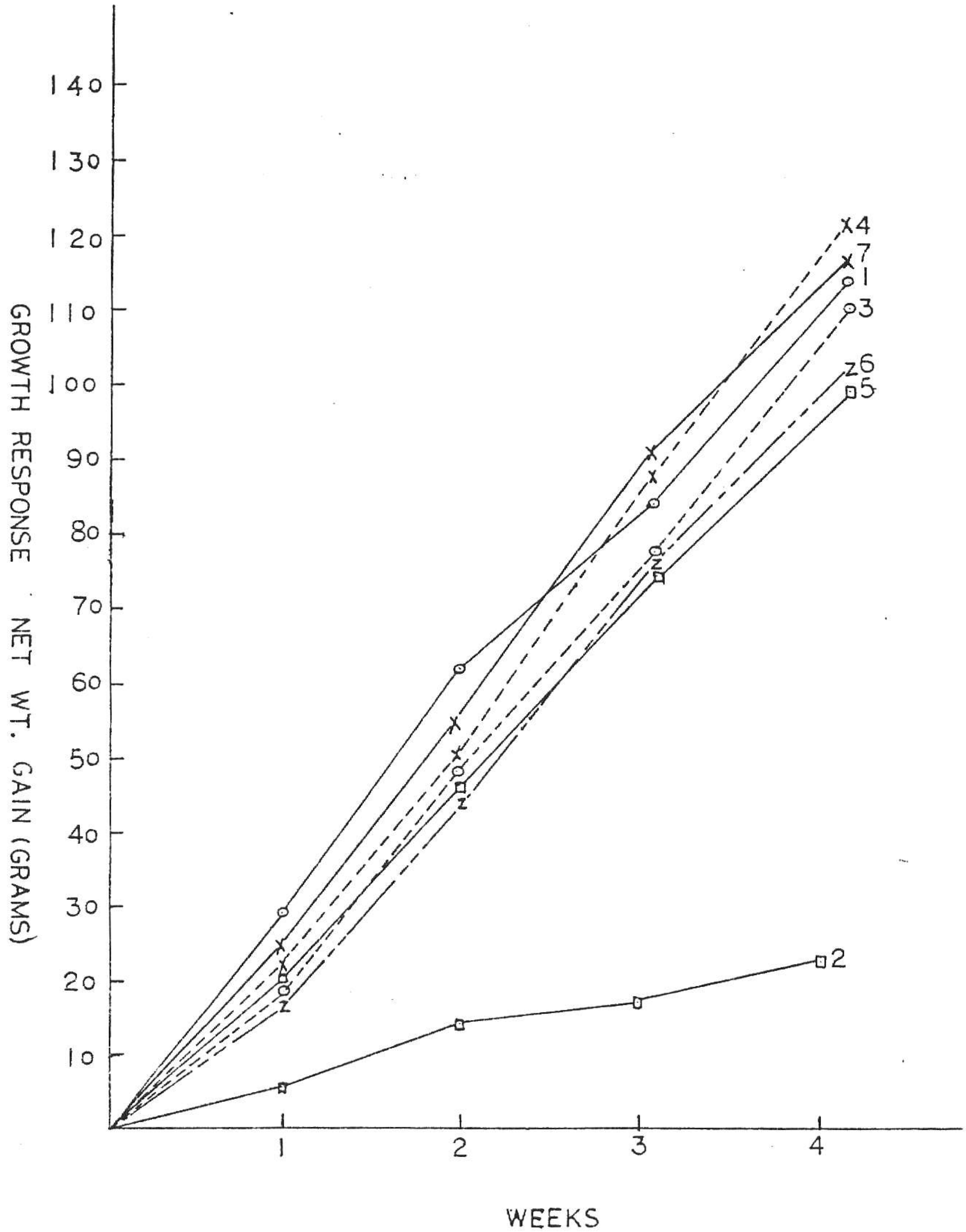

GROWTH RESPONSE NET WT. GAIN (GRAMS)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
1
2
3
4
WEEKS
4
7
1
3
6
5
2

Figure 7. Rats Fed Diets with Indicated Soy Flours, Wheat Flour, and Casein.

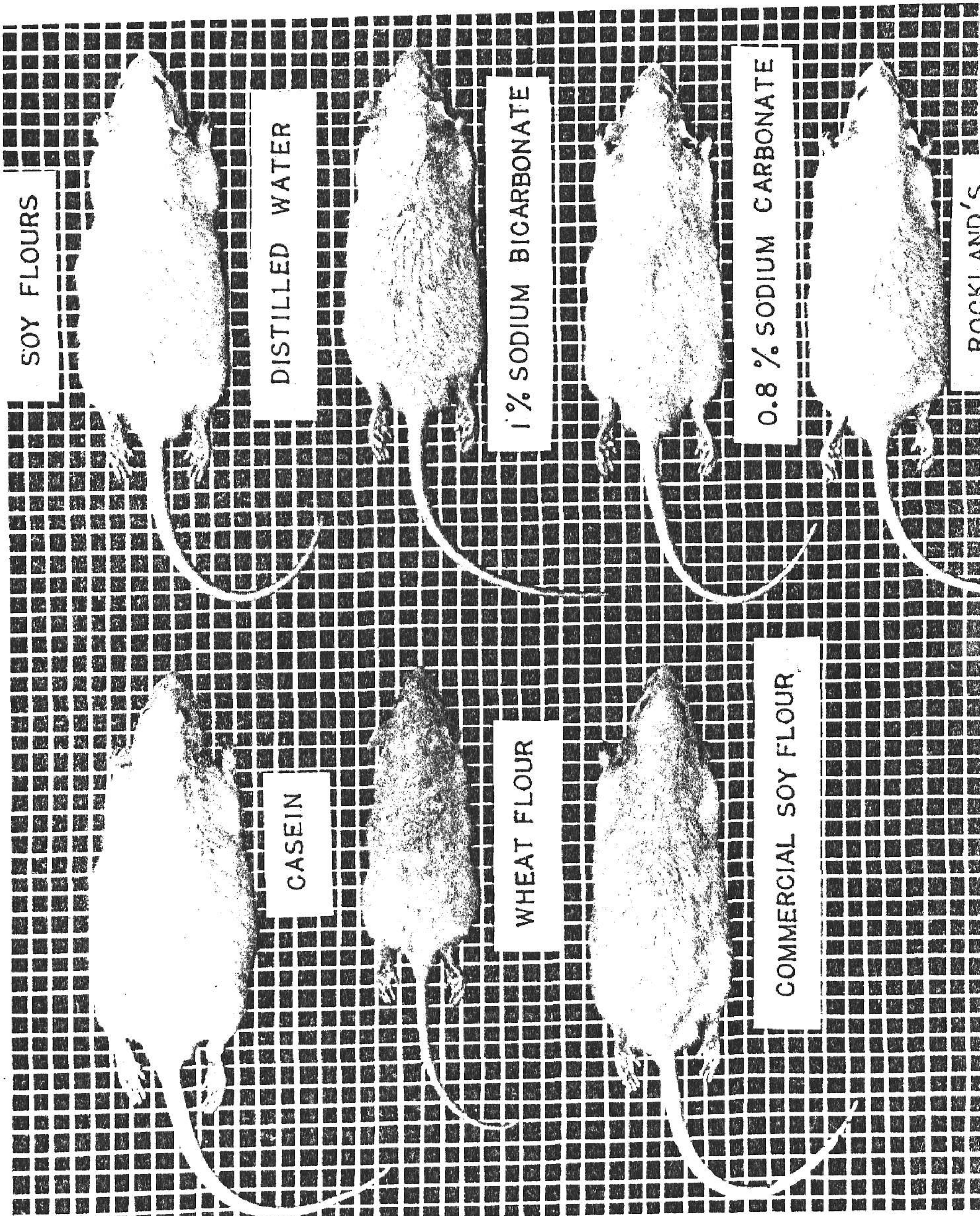

SOY FLOURS
DISTILLED WATER
1% SODIUM BICARBONATE
0.8 % SODIUM CARBONATE
ROCKLAND'S
CASEIN
WHEAT FLOUR
COMMERCIAL SOY FLOUR

Figure 8. Rats Fed Diets with Indicated Soy Flours.

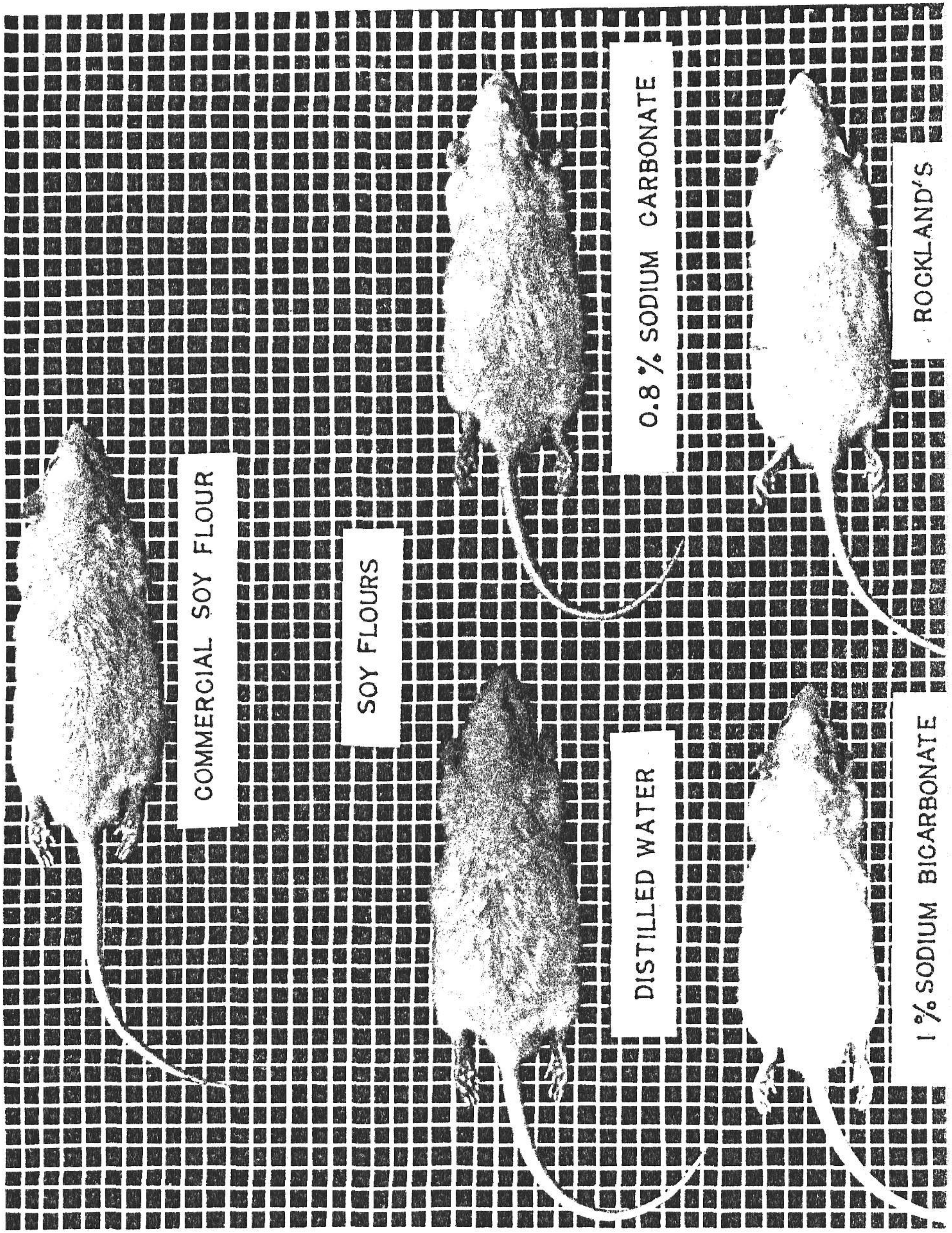

COMMERCIAL SOY FLOUR
SOY FLOURS
DISTILLED WATER
0.8 % SODIUM CARBONATE
1 % SODIUM BICARBONATE
ROCKLAND'S

Table 22. Farinographic Characteristics of Wheat Flour Fortified with Indicated 12% Soy Flours.

Flour Sample	Water absorption (%)	Arrival time (min)	Peak time (min)	Departure time (min)	Dough stability (min)
Wheat flour	55.0	1.5	7.5	21.0	19.5
Wheat-12% commercial full-fat soy flour	59.5	2.0	9.5	20.0	18.0
Wheat-12% soy flour B	65.0	4.0	12.0	21.0	17.0
Wheat-12% soy flour C	66.0	8.0	14.0	22.0	14.0
Wheat-12% soy flour D	67.0	9.0	14.0	21.5	12.5

Table 23. Mixing Conditions[a] and Specific Loaf Volumes of Bread from Wheat Flour Fortified with 12% Soybean Flours.

Bread Sample	Absorption (%)	Mixing Time	Specific Loaf Volume (cc/g)	Average Specific (cc/g)
Wheat flour bread	59	6	7.01	6.96
	59	6	6.90	
Wheat-12% commercial	63.5	5	6.43	6.29
full-fat soy flour	63.5	5	6.14	
Wheat-12% soy flour	69	5	6.25	6.05
B bread	69	5	5.84	
Wheat-12% soy flour	70	5	5.64	5.62
C bread	70	5	5.60	
Wheat-12% soy flour	71	5	5.78	5.71
C bread	71	5	5.64	

Table 24. Specific Cake Volumes of Cakes from Wheat Flour Fortified with 12% of Soybean Flour.

Cake Sample	Water Absorption (cc)	Specific Cake Volume (cc/g)	Average Specific Cake Volume (cc/g)
Wheat flour cake	270	2.78	2.75
	270	2.71	
Wheat-12% commercial	270	2.69	2.62
full-fat soy flour cake	270	2.54	
Wheat-12% soy flour B	270	2.71	2.69
cake	270	2.69	
Wheat-12% soy flour C	270	2.61	2.63
cake	270	2.65	
Wheat-12% soy flour D	270	2.52	2.54
cake	270	2.56	

Table 25. Spread Ratios of Cookies from Wheat Flour Fortified with 12% Soy Flour.

Cookie Sample	Water Absorption (cc)	Spread (cm)	Thickness (cm)	Spread Ratio
Wheat flour cookie	33	47.6	5.38	8.85
Wheat-12% commercial full-fat soy flour cookie	37	45.7	5.75	7.94
Wheat-12% soy flour B cookie	37	42.2	7.11	5.94
Wheat-12% soy flour C cookie	37	43.0	6.86	6.27
Wheat-12% soy flour D cookie	37	44.7	6.33	7.06

SUMMARY

Soybeans with approximately 40% protein & 20% oil (dry matter basis) are an excellent source of protein & oil for human consumption. However, they must be cooked for a long time to make them tender enough to be edible and to inactivate their trypsin inhibitor and other anti-nutritional factors. The cooking consumes an inordinate amount of fuel. A process for quick-cooking soybeans seems useful to fuel-deficient countries, particularly where diets low in protein & calories can be improved nutritionally by soy-fortification.

In this study, soaking conditions affecting the cooking characteristics of soybeans were examined. The nutritional & baking properties of soy flours prepared from quick-cooked soybeans were evaluated.

Of the seven solutions tested in this study, 0.8% sodium carbonate solution and Rockland's solution (2.5% sodium chloride, 0.5% sodium tripolyphosphate, 0.75% sodium bicarbonate, and 0.25% sodium carbonate) were found to be the best soaking solutions. The optimum soaking conditions for soybeans was found to be soaked at 25°C for 18 hours.

The nutritive value of soy flours prepared from quick-cooked beans was determined by rat feeding studies. The results showed that both 0.8% sodium carbonate solution and Rockland's solution were good soaking agents for preparing soy flour with a high nutritive value. But 0.8% sodium carbonate solution was much

simpler to prepare and less expensive than Rockland's solution to be used as a soaking agent.

Data from baking tests obtained from this study indicated that the fortification of wheat flour with 12% soy flour exerted some adverse effects on the quality of bread, cakes, and cookies. However, most soy fortified bakery products including bread, cakes and cookies prepared in this study were judged acceptable.

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PROCESSING CONDITIONS, NUTRITIONAL AND BAKING PROPERTIES OF QUICK-COOKING SOYBEANS

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ABSTRACT

Soybeans with approximately 40% protein & 20% oil (dry matter basis) are an excellent source of protein & oil for human consumption. However, they must be cooked for a long time to make them tender enough to be edible and to inactivate their trypsin inhibitor and other anti-nutritional factors. The cooking consumes an inordinate amount of fuel. A process for quick-cooking soybeans seems useful to fuel-deficient countries, particularly where diets low in protein & calories can be improved nutritionally by soy-fortification.

In this study, soaking conditions affecting the cooking characteristics of soybeans were examined. The nutritional & baking properties of soy flours prepared from quick-cooked soybeans were evaluated.

Of the seven solutions tested in this study, 0.8% sodium carbonate solution and Rockland's solution (2.5% sodium chloride, 0.5% sodium tripolyphosphate, 0.75% sodium bicarbonate, and 0.25% sodium carbonate) were found to be the best soaking solutions. The optimum soaking conditions for soybeans was found to be soaked at 25°C for 18 hours.

The nutritive value of soy flours prepared from quick-cooked beans was determined by rat feeding studies. The results showed that both 0.8% sodium carbonate solution and Rockland's solution were good soaking agents for preparing soy flour with a high nutritive value. But 0.8% sodium carbonate solution was much

simpler to prepare and less expensive than Rockland's solution to be used as a soaking agent.

Data from baking tests obtained from this study indicated that the fortification of wheat flour with 12% soy flour exerted some adverse effects on the quality of bread, cakes, and cookies. However, most soy fortified bakery products including bread, cakes and cookies prepared in this study were judged acceptable.