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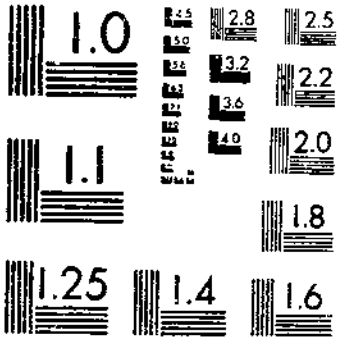
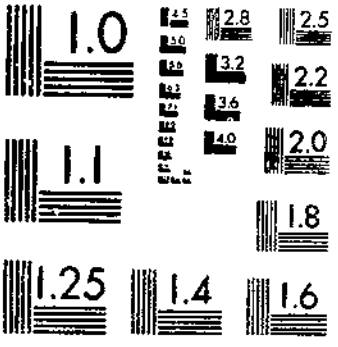


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
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Development of Rapid Methods of Soaking and Cooking Dry Beans[1]

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GENERAL SUMMARY

This study was undertaken primarily to develop more rapid basic methods of cooking dry beans than those commonly used by homemakers. Varieties of beans studied were pea, great northern, large lima, pinto, and red kidney.

The effect of different soaking and cooking conditions on rate of rehydration, cooking time, and palatability was investigated for all five varieties of beans. For pea beans, a study was made of the effect of storage at 40° and 75° F. for 1 year. Nutritive-value determinations also were made for pea beans, including thiamine, ash, and total solids contents of the beans after soaking and cooking in different ways.

The findings show that a short method of soaking in which the beans are added to boiling water, boiled 2 minutes, removed from the heat, and allowed to soak for 1 hour in the hot water gives satisfactory results. When soaked by this method and cooked in the liquid used for soaking, all the varieties of beans studied were comparable or superior in palatability to those prepared by the conventional procedure of soaking overnight.

In a study made with pea beans, palatability scores were higher when the soaking liquid was retained for cooking after the short soak than when it was discarded; with the long soaking method there was very little difference between drained and undrained samples.

Large lima and red kidney beans required the same cooking time, whether prepared by the short or long soaking method. Great northerns and pintos soaked for 1 hour in hot water required 15 and 30 minutes longer cooking time, respectively, to reach the same degree of tenderness as comparable bean samples soaked for 18 hours in cold water.

When prepared by the short-soak method, pea beans stored for 1 year at 75° F. required a longer cooking time than those stored at 40°.

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[2] The authors wish to express their appreciation to Ann F. Doyle for her assistance in preparation of samples and to Elsie F. Dochterman and Albert B. Parks for statistical analysis of the data.

For pea beans soaked 1 hour in hot water after boiling 2 minutes, nutritive value in terms of thiamine and ash content was higher when the soaking liquid was retained for cooking than when it was discarded. Discarding or retaining the soaking liquid made little difference in the amounts of thiamine and minerals found in the cooked beans that had been soaked overnight in cold water. The nutritive value of these beans was similar to that of the short-soaked beans cooked in the soaking liquid.

In general, when the soaking liquid was retained for cooking, the addition of approximately ⅛ teaspoon of sodium bicarbonate (baking soda) to 1 cup of dry beans and 2½ cups of tap water resulted in a good quality product for all five varieties of beans studied, although the palatability scores were not quite as high as for beans without sodium bicarbonate. The presence of this small amount of sodium bicarbonate permitted up to 42-percent reduction in cooking time for some varieties of dry beans, and did not affect thiamine or ash content of pea beans.

Exclusive of heating up and cooling down time, cooking in a 4-quart pressure saucepan at 250° F. (15 pounds steam pressure) resulted in the following reductions in time from that required for cooking in boiling water in a covered glass saucepan: For great northern beans, from 90 to 3 minutes; for large limas, from 60 to 3 minutes; for red kidney beans, from 105 to 3 minutes; for pea beans stored at 40°, from 90 to 5 minutes; for pea beans stored at 75°, from 120 to 10 minutes; and for pinto beans, from 120 to 10 minutes. In addition to the cooking times at 250°, 25 minutes were required on the average for the beans to heat up to 250° and cool down to 212°. Palatability scores were very similar for beans cooked in a covered glass saucepan and in a pressure saucepan.

PURPOSE AND SCOPE OF WORK

Boiling is the method most commonly used in the United States for cooking dry beans and peas. A typical procedure includes soaking overnight at room temperature in several volumes of tap water and cooking until tender in the soaking water or in fresh water with salt and sometimes fat or meat. Baking after soaking, usually with the addition of tomato, molasses or brown sugar, and fat in some form, is common in certain parts of the country. Either process is time-consuming and with some varieties of beans and some kinds of water the cooking is so long that it may deter homemakers from cooking beans.

As a step toward wider and improved use of an economical, nutritious food, the study reported here was undertaken. The principal objective was to develop basic methods of preparing dry beans that would save time and also conserve nutritive values and yield products of high acceptability.

The effect of method, temperature, and time of soaking, the use of soft and hard water, and the addition of sodium bicarbonate (baking soda) on the rehydration capacity, cooking time in a covered saucepan, palatability, and nutritive value of pea beans stored at 40° and at 75° F. was investigated. In the nutritive-value study, total ash, insoluble ash, moisture, and thiamine contents of raw beans, soaked beans, soaking solution, and cooked beans were determined.

Studies on great northern, large lima, pinto, and red kidney beans were limited to the methods of soaking and cooking that had proved most effective with pea beans.

Other studies were concerned with cooking the five varieties of beans in a pressure saucepan, primarily to determine the optimum cooking time.

REVIEW OF LITERATURE

The problem of hardshell in beans has been studied by a number of investigators (*5, 6, 7, 12, 14*).[3] Various treatments, such as treatment of seeds by concentrated sulfuric acid to increase the percentage of germination (*5, 12*) and scarification of the seed coat to increase the rate of water imbibition, have been recommended (*12, 14*). Snyder (*14*) reports that with beans which cooked relatively well the cooking time was reduced 40 percent by scarification but the appearance was less desirable. The scarification treatment has not been used extensively by bean processors, however, as it would be difficult, if not impossible, to prevent breaks in the seed coats of the processed beans so treated (*12*).

Several authors report the use of some kind of heat treatment prior to soaking as a very effective, practical, and convenient means of preparing hardshell beans that are to be processed for food (*3, 5, 12, 14*). Among the heat treatments suggested are steaming (*5*), a 1-minute dip in boiling water (*12*), a 1-minute dip in hot water at 170° F. or 2 or 3 minutes at 150° (*3*), and soaking at 50° C. (122° F.) (*14*). The application of heat during soaking appeared to have possibilities for home use.

Morris, Olson, and Bean (*12*) report that a secondary effect of an initial 1-minute boil before soaking is the reduction of micro-organisms. Signs of fermentation and off-flavors in beans soaked overnight at room temperature, particularly in hot weather, have been reported. Some directions for preparing dry beans suggest draining the beans after soaking and adding fresh water for cooking as a means of reducing off-flavors in the cooked product. The question arises, "Are valuable nutrients and flavor lost in the drained liquid?" If a practical method for a quick, hot soak for home use could be developed, the need for draining the beans after soaking might be eliminated.

Mattson (*11*) found that the most important factor in the cookability of peas was the high content of phytin, which is a calcium and magnesium precipitant. He states that the precipitating power of phytin is greatly increased at boiling temperatures. At the pH of peas, that is, pH of about 6, phytin can function as a magnesium precipitant only at boiling temperature.

Greenwood (*7*) and Snyder (*14*) found the use of baking soda (sodium bicarbonate) in either the soaking or cooking water to be an effective means of softening the seed coats of pinto, great northern, or navy beans. Reeve (*13*), as a result of a study on possible tenderization treatments for peas in which sodium hexametaphosphate, sulfites of both potassium and sodium, oxalic acid, ammonium oxalate, and hydrochloric acid were used in gradations of 0.1 percent aqueous dilutions of 1:100 to 1:1,000, concluded that the tenderization effects

[3] Italic numbers in parentheses refer to Literature Cited, p. 53.

involve only changes that reduce the toughening effects of calcium and magnesium on the seed coats.

Investigators differ as to the effect of the use of sodium bicarbonate in the soaking or cooking water on the thiamine content of cooked beans. This variation may be due to the differences in method of preparation and degree of alkalinity of solutions used. Lantz (*9*), in her study of pinto beans, reported that soaking in a 0.5-percent solution of baking soda for 16 hours before cooking in fresh distilled water for 2¾ hours caused a greater loss of thiamine than soaking in distilled water. She also reported that the destruction of thiamine was increased by long cooking. Therefore, it would appear that if the cooking time of dry beans could be reduced sufficiently by the use of sodium bicarbonate, the saving effected in the cooking time might compensate for the loss of thiamine due to the higher alkalinity of the solution used in soaking or cooking.

In a study of navy beans, Aughey and Daniel (*2*) reported that navy beans cooked in tap water with or without sodium bicarbonate retained all of their original thiamine value. Their method of cooking was as follows: 1 cup beans was soaked in 2 cups water for 16 hours, the water drained off, and the beans dropped into boiling salted water (3 cups water to 1 cup beans) and boiled gently until soft. When sodium bicarbonate was used, 0.4 gm. was added per cup of dry beans.

Johnston and others (*8*), in a study of the effect of the addition of sodium bicarbonate in the proportion of 0.22 gm. to 180 ml. of water for cooking 85 gm. of fresh and frozen peas, found that there was only slightly greater destruction of thiamine when sodium bicarbonate was added and this was due to the greater destruction of that leached out of the peas; however, the amount remaining in the peas at the conclusion was the same by both methods of cooking.

Masters (*10*) found that among the methods which greatly reduced the cooking time and decreased the solids in the soaking water were soaking overnight or for 4 hours in tap water containing sodium bicarbonate, draining, and adding fresh water for cooking. When a concentration of 0.1 percent sodium bicarbonate was used in the cooking water for unsoaked beans, the cooking time was reduced and the loss of solids was only slightly greater than when the beans were cooked in tap or distilled water. When 2 percent sodium bicarbonate was used in soaking, the cooking time was the same as for 1 percent, but the loss in solid matter was greater. The nature of these solids was not studied.

COOKING DRY BEANS IN A COVERED SAUCEPAN

General Procedures

Source of Beans and Storage Conditions.—Dry beans for the study were obtained at the end of the growing season from wholesale distributors in various sections of the United States where the different varieties were produced. Two hundred pounds of pea beans were obtained from Michigan, 50 pounds of large lima beans from California, 25 pounds each of great northern and pinto beans from Idaho, and 50 pounds of red kidney beans from New York.

Beans of each variety were well mixed and sampled for storage in sealed glass jars at 38° to 40° F. until used. For the study of the effect

of storage temperature, 50 pounds of the pea beans were stored for 1 year at 70° to 77° in the burlap bag in which they were shipped to simulate storage conditions common in the trade. The relative humidity in the storage room ranged from 67 to 95 percent, varying with local weather conditions.

TYPES OF WATER USED.—For soaking and cooking pea beans, water of three types was used: (1) Distilled water, (2) synthetic hard water—distilled water containing calcium sulfate in amounts calculated as 250 p. p. m. calcium carbonate, and (3) synthetic hard water with the addition of 0.5 gm. of sodium bicarbonate to 623 ml. of water (0.08 percent solution). Hardness of 250 p. p. m. was selected because 90 percent of the population in the United States uses water of this hardness or less (*4*). Although natural hard waters contain other ions, the calcium and sulfate ions of this specially prepared hard water represent the type of permanent hardness found in most hard waters of this country.

For the cooking studies on great northern, pinto, red kidney, and large lima beans, tap water was used. This water had the following description:

Turbidity	5 to 8 p. p. m.	Hardness	0 to 5
Total solids	46 to 50 p. p. m.	Alkalinity	21 to 22 p. p. m.
pH	8.6	Iron	0.10 p. p. m.

Beans of these varieties were soaked and cooked also in a solution of 0.5 gm. sodium bicarbonate in 628 to 658 ml. tap water.

PROPORTION OF WATER TO BEANS.—The amount of water needed varied with the cooking time. Preliminary cooking tests, in which the proportions by volume of water to beans were 2 to 1, 2½ to 1, 3 to 1, and 4 to 1, showed that a 2½-to-1 proportion was most satisfactory for pea beans cooked for 1½ hours. With a 2-to-1 proportion, beans were not uniformly cooked because the top layer was above the surface of the water for at least a part of the cooking time. For beans requiring a 2-hour cooking time, a 3-to-1 proportion of water to beans was needed. Both flavor and texture of the beans were impaired when more water than needed was used. The proportions of water used for great northern, large lima, pinto, and red kidney beans are given in table 1.

PREPARATION AND SOAKING PROCEDURES.—Damaged beans or beans with noticeable breaks or blemishes in the seed coats were sorted out and discarded. Two-hundred-gram samples of dry beans were washed twice—in distilled water for the pea bean study, in tap water for the other studies—and drained before soaking.

Two methods of soaking were used with all varieties: (1) The beans were soaked for 18 hours (overnight) in cold water at room temperature; (2) the beans were added to boiling water, boiled 2 minutes, removed from the heat, and soaked in the hot water for 1 hour. The temperatures during soaking are given in table 1.

After soaking, the beans were drained for 1 minute, then weighed on a torsion balance and measured in a beaker graduated in ounces. The soaking solution was measured in a 500-ml. graduate cylinder.

In the pea bean study, two preparation procedures were compared: (1) The soaking liquid was discarded and an equal amount of fresh water or solution of the same kind as that used for soaking was added

TABLE 1.—*Standard procedures for soaking and cooking dry beans in 2-quart covered saucepans* [1]

Bean	Type of water and method of soaking	Weight of dry sample	Volume of water	Proportion of water to beans by volume [2]	Temperature during soaking				Cooking time
					Initial		Final		
					Range	Average	Range	Average	
		Grams	*Milliliters*		° *C.*	° *C.*	° *C.*	° *C.*	*Minutes*
Pea [3]	Distilled water:								
	1-hour soak (hot)	200	623	2½ to 1	----	100	52–65	58	90
	18-hour soak (cold) [4]	200	623	2½ to 1	24–28	25	22–26	24	90
	Hard water:								
	1-hour soak (hot)	200	623	2½ to 1	----	100	55–63	59	90
	18-hour soak (cold)	200	623	2½ to 1	23–30	26	22–24	24	90
	Hard water with 0.5 gm. sodium bicarbonate:								
	1-hour soak (hot)	200	623	2½ to 1	----	100	61–68	64	60
	18-hour soak (cold)	200	623	2½ to 1	26–29	26	23–24	23	60
Great northern	Tap water:								
	1-hour soak (hot)	200	754	3 to 1	----	100	----	63	90
	18-hour soak (cold) [4]	200	628	2½ to 1	24–29	27	24–25	25	75
	Tap water with 0.5 gm. sodium bicarbonate:								
	1-hour soak (hot)	200	628	2½ to 1	----	100	63	63	60
	18-hour soak (cold)	200	628	2½ to 1	25–29	27	24–25	25	45
Large lima	Tap water:								
	1-hour soak (hot)	200	645	2½ to 1	----	100	61–66	63	60
	18-hour soak (cold) [4]	200	645	2½ to 1	25–29	27	24	24	60
	Tap water with 0.5 gm. sodium bicarbonate:								
	1-hour soak (hot)	200	645	2½ to 1	----	100	64	64	60
	18-hour soak (cold)	200	645	2½ to 1	25–28	27	24–25	24	30

Pinto	Tap water:								
	1-hour soak (hot)	200	789	3 to 1		100	66	66	120
	18-hour soak (cold) [4]	200	658	2½ to 1	24–29	26	24–26	25	90
	Tap water with 0.5 gm. sodium bicarbonate:								
	1-hour soak (hot)	200	658	2½ to 1		100	61–64	62	90
	18-hour soak (cold)	200	658	2½ to 1	22–28	26	24–25	24	60
Red kidney	Tap water:								
	1-hour soak (hot)	200	774	3 to 1		100			105
	18-hour soak (cold) [4]	200	774	3 to 1	24–27	26	23–24	24	105
	Tap water with 0.5 gm. sodium bicarbonate:								
	1-hour soak (hot)	200	645	2½ to 1		100			60
	18-hour soak (cold)	200	645	2½ to 1	21–26	25	23–24	24	60

[1] All samples were cooked in the water in which they were soaked, except pea beans. For pea beans, the same procedures were used when soaking liquid was discarded as when soaking liquid was retained for cooking.

[2] These proportions were calculated on the basis of the following weights, in grams, for 1 cup of dry beans: Pea, 190; great northern, 188; large lima, 184; pinto, 181; and red kidney, 184. The weight of 1 cup of water used was 237 gm.

[3] Same procedures used for beans stored at 40° and 75° F.

[4] This procedure was also used for the reference sample.

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to the beans for cooking; (2) the soaking liquid was retained for cooking the beans. In the studies on all other varieties, the soaking liquid was retained for cooking.

COOKING PROCEDURE.—The beans were cooked in 2-quart covered glass saucepans. Four 6-inch, 5-speed units of two electric ranges were used for cooking the beans. Input of electricity at different heat settings was as follows: High, 1,250 watts; medium, 675 watts; low, 575 watts; very low, 170 watts; simmer, 78 watts.

The heat was turned on "high" until the boiling point was reached, at which time the heat was turned to "low," and cooking time was counted from this point. The saucepan cover was adjusted to permit steam to escape for the first 5 minutes of cooking to prevent foaming over. The cover was replaced and the beans continued to cook on "low" to maintain a gentle boil. The cooked beans were drained, weighed, and measured as described for soaked beans. The cooking liquid was measured in a graduate cylinder and returned to the saucepan with the beans. The saucepan cover was replaced and the saucepan placed on the warm unit with electricity turned off until the beans were served to the judging panel.

In this study, the cooking time for pea beans prepared by both the long and short soaking methods in distilled and synthetic hard water was held constant (1½ hours). The beans soaked and cooked in hard water with added sodium bicarbonate were cooked for 1 hour.

The cooking times for great northern, large lima, pinto, and red kidney beans, as established in preliminary experiments, are given in table 1.

SELECTION AND TRAINING OF JUDGING PANEL.—A questionnaire was circulated to prospective panel members, asking such questions as "Do you like beans?" and "Do you prefer beans very well done or very slightly done?" Only those who liked beans were considered for inclusion on the panel. Consideration was given also to the number of other panels on which the person served in order to have a sufficient time interval between tasting sessions. Eight preliminary judging sessions were held immediately before the palatability tests on pea beans for the purpose of training the judges, setting up a recognized standard or reference sample, and determining the palatability scores for that sample. For each of the other varieties of beans studied, four training sessions were held.

For the pea bean study the training was divided into two parts: (1) On texture or doneness; (2) on intensity of natural flavor. Training for each quality characteristic required 4 days.

On the first day, three samples of pea beans were cooked to different degrees of doneness—underdone, well-done, and overcooked—with sufficient variation in the samples to make the differences easy to detect (1½, 2, and 2½ hours for this lot of beans). The samples identified by cooking time were presented to the judges. Judges were instructed to examine the samples carefully and compare the appearance and texture. Open discussion followed. No scores were assigned to the samples, but the score sheet to be used in the study was examined critically by each member of the panel. Panel members were asked to offer suggestions for improvement.

On the second day, the samples were prepared as for the first, except that the margin of difference in cooking time for the samples

was reduced to 15 minutes. The samples were cooked 1¾, 2, and 2¼ hours. Again, the samples were identified by cooking time and the open discussion technique was used.

On the third day, the samples were replicates of the series prepared for the first day of training. A duplicate of one of the samples was introduced as a check on the judge's ability to reproduce his scores. The reference sample, representing as nearly optimum quality as possible, was labeled "control"; other samples were identified by code letter only. Judges were asked to score the samples. Discussion and comparison of individual scores followed.

Similarly, on the fourth day samples were replicates of those prepared for the second day of training, plus a duplicate of one sample. They were presented to the judges, scored, and compared as on the previous day. From these ratings the scores for the reference sample were established.

For training on intensity of natural flavor, the samples were prepared in progressively decreasing volumes of water to increase the strength of flavor of the cooked beans. All samples were cooked 2 hours.

On the first day, three samples were prepared with the following proportions of water to beans: 3 to 1, 3½ to 1, and 4 to 1. On the second day, the margin of difference between the samples was decreased; the proportions used were 3 to 1, 3¼ to 1, and 3½ to 1. In this series, samples were labeled with the proportion of water to beans and, as in the training sessions for texture, they were not scored on the first 2 days. The sessions on the third and fourth days were repetitions of the first and second days, except that the samples were labeled with code letters.

Training of judges for testing other varieties of beans was limited to one quality factor, texture—the most important factor in evaluating the relative success of a method or treatment.

The training sessions served a twofold purpose in the study of different varieties of beans: First, as training for the panel members; second, as an exploratory study to form a basis for the selection of the reference sample and the variables to be included in a later study.

On the first 2 days of training the procedure was the same as that used for pea beans; the cooking times and proportions of water to beans varied with the variety of bean.

For the third and fourth days of training, the procedure followed in the preparation and cooking of the samples was determined by the results of the preceding days' tests. The samples, labeled only by code letter, were presented to the judges, scored, and compared.

The selected panel consisted of seven food and household-equipment specialists who were most able to reproduce their scores on duplicate samples. Five were used as regular judges and two with the same training as the regulars were used as replacements in cases of absenteeism or resignation.

Serving of Samples.—Approximately 2 tablespoons of the sample were served to each panel member on a warmed, white plate labeled only with a code letter. A reference sample of predetermined score, labeled "control," was served first. Then three experimental samples and a duplicate of the reference sample as an unknown control were served to each judge in randomized order, one after the other in

quick succession, so that the judge had all five samples before him at once for purposes of comparison.

RATING OF SAMPLES.—The quality of the experimentally cooked beans was evaluated by a panel of five trained judges. A score sheet using numerical values to express differences in quality was set up for analytical judging. Descriptive terms accompanied each rating on the scale to insure uniform interpretation of the numerical values.

The quality characteristics evaluated by the panel were appearance, texture of skin, texture of cotyledon, intensity of natural flavor, and absence of off-flavor. For appearance, the scale of values ranged from 5, whole, to 1, mushy; for texture, both of skin and cotyledon, the scale ranged from 5, tender, to 1, completely disintegrated or mushy, and from 5 to 9, increasing toughness or hardness. For natural flavor, the scale ranged from 5, natural, full bodied, to 1, lacking. For off-flavor, the scale was from 5, none, to 1, very pronounced. Thus, for each characteristic, 5 was the optimum score.

A separate score sheet was used for rating general acceptability on a 5-point scale: 5 represented very good; 4, good; 3, fair; 2, poor; and 1, very poor.

CALCULATION OF REHYDRATION RATIOS.—The rehydration ratio for the soaked beans was obtained by dividing the weight of the soaked beans by the weight of the dry beans. The rehydration ratio for cooked beans was obtained similarly by dividing the weight of the cooked beans by the weight of the dry beans.

PH DETERMINATIONS.—pH of the soaking solution and of the liquid from the cooked beans was determined with a pH meter, using calomel-saturated potassium chloride, and glass electrodes.

DETERMINATION OF THIAMINE, ASH, AND MOISTURE.—Samples of 100 gm. of the dry beans, taken from the large batch obtained for the study, were ground in a Wiley mill through a 20-mesh sieve. Subsamples were taken from the ground beans for analyses. Samples were weighed quantitatively for thiamine, moisture, ash, and insoluble ash determinations. Of the 200 gm. of dry beans, soaked or cooked, subsamples were taken for moisture, ash, and insoluble ash determinations (*1*).

Thiamine was determined on the soaked or cooked beans by blending equal weights of beans and 0.2 normal hydrochloric acid in a Waring blendor. The slurry was placed in wide-mouth, brown glass bottles, and chloroform added as a preservative. The bottles were stoppered and stored in a refrigerator until analyzed. The soaking liquid was acidified by adding 1 ml. of reagent hydrochloric acid to every 100 ml. of liquid.

At the time the analyses were carried out, 1-gm. samples of the ground dry beans, 4-gm. samples of the soaked bean-acid mixture, 10-gm. samples of the cooked bean-acid mixture, or 25 ml. of acidified soaking liquid were weighed into 100-ml. volumetric flasks. The pH was adjusted to 2.0 with 2.5 normal sodium acetate, 5 ml. of 10 percent pepsin solution added, and the mixture incubated at 37° C. for 2 hours. The pH was then adjusted to 4.5 with 2.5 normal sodium acetate, 5 ml. of 10 percent takadiastase solution added, and the samples incubated at 37° overnight. In the morning the mixture was made up to 100 ml. and the thiochrome determination carried out on a filtered aliquot (*1*).

Rehydration Under Different Soaking Conditions

An exploratory study was carried out to determine the amount of water absorbed by dry pea beans during soaking in distilled water under various conditions.

Beans for this experiment were bought in retail markets in Washington, D. C. They were held at room temperature during the course of the study.

Two-hundred-gram samples of dry beans were soaked in distilled water, using a 3-to-1 proportion by volume of water to beans. Temperatures of soaking included (a) room temperature, 23° to 25° C. (72°–75° F.), (b) 50° C. (122° F.) initial temperature decreasing to room temperature, (c) 50° C. (122° F.) constant temperature, (d) 100° C. (212° F.) initial temperature decreasing to room temperature, and (e) 100° C. (212° F.) for 2 minutes decreasing to room temperature.

Beans were drained and weighed after soaking for ½, 1, 2, 4, 6, and 16 hours to determine the water uptake under the different soaking conditions. Figure 1 shows the comparative rate of rehydration of pea beans in distilled water as affected by temperature and time of soaking.

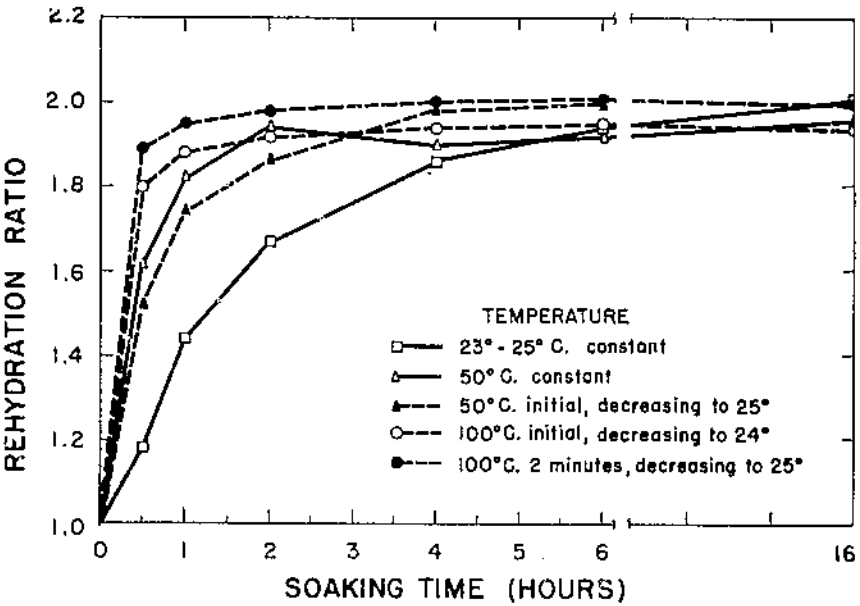

Figure 1.—Rehydration of pea beans as affected by temperature and time of soaking in distilled water.

The time required for rehydration to a constant ratio depended on the temperature of the soaking water. The rehydration ratio of the soaked beans (weight of soaked beans divided by weight of dry beans) reached an average of 1.94 to 1.95 in 1 hour when the beans were boiled 2 minutes and allowed to cool at room temperature, in 4 hours by starting but not holding at 100° C., in 2 hours by holding at 50°,

in about 3½ hours by starting at 50° and cooling at room temperature, and in 6 hours by holding at room temperature (23°–25°). The amount of water absorbed by the beans after 16 hours of soaking was approximately the same as after 6 hours when soaking was started at 100°.

As far as water absorption is concerned, long soaking periods were unnecessary when an initial temperature of 100° C. was used. Furthermore, when the beans were soaked for 16 hours at 50° definite signs of spoilage were observed. Soaking for 1 hour after a 2-minute initial boil was the most efficient of the methods studied.

Addition of Sodium Bicarbonate or Sodium Hexametaphosphate

In preliminary studies designed to show the effect of soaking and cooking in alkaline solutions on rehydration and palatability of pea beans, sodium bicarbonate or sodium hexametaphosphate was added in amounts varying from 0.3 to 2 gm. in 623 ml. distilled water.

The optimum amount of sodium bicarbonate—the amount which shortened the cooking time appreciably and had only a slight effect on flavor—was found to be 0.5 gm. in 623 ml. water. Cooking time was reduced approximately one-third by the addition of this amount of sodium bicarbonate to the soaking and cooking water. Pea beans that required 1½ hours to cook in distilled water were done in 1 hour in sodium bicarbonate solution. When 1 gm. or more was added, the cooking time was shortened even more, but the cooked beans had a disagreeable odor and flavor and a mushy appearance.

A solution made of 0.5 gm. sodium hexametaphosphate and 623 ml. distilled water proved less effective than sodium bicarbonate solution in reducing the cooking time; pea beans cooked in this solution required 1¼ hours to become tender. Solutions containing larger amounts of sodium hexametaphosphate were unsatisfactory because of the undesirable flavor imparted to the beans.

Pea Beans

The rehydration capacity, cooking time in a covered saucepan, palatability, and nutritive value of pea beans as affected by temperature and time of soaking, discarding or retaining the soaking solution, the use of soft or hard water, and the addition of sodium bicarbonate were investigated. The beans were stored at 40° and at 75° F. for 1 year prior to the soaking and cooking studies.

The experiment was planned as a randomized factorial design. Individual differences between means were subsequently analyzed. A total of 24 experimental combinations, replicated 3 times, were randomized over 24 days of testing. Three experimental samples and one control were cooked and analyzed each day.

The mean scores and analysis of variance of these scores for natural flavor, off-flavor, texture of skin, texture of cotyledon, appearance, and acceptability of pea beans prepared under different conditions of soaking and cooking are presented in tables 2 to 8.

Table 2 shows the combined values for method of preparation, soaking and cooking solution, and storage temperature. In tables 3 to 8, the results for each palatability factor and each storage temperature are shown in three parts: (1) Mean scores for each method of

TABLE 2.—*Mean scores and mean squares for all palatability factors for pea beans stored at 40° and 75° F. for 1 year*

Palatability factor	Mean score [1]		Mean square (1 degree of freedom)
	40° F.	75° F.	
Natural flavor	4.0	4.2	5.878**
Off-flavor	4.8	4.8	.002
Texture of skin	4.4	5.3	83.136**
Texture of cotyledon	4.2	5.3	112.225**
Appearance	3.6	3.8	2.958**
Acceptability	3.8	3.9	.100

**Significant at 1-percent level.

[1] Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough and hard, and 1 was completely disintegrated and mushy.

preparation and solution used; (2) mean squares from the analysis of variance of methods within solution; (3) mean squares from the analysis of variance of solutions within method of preparation. In the first part of each table, the effects of draining and duration of soaking on pea beans soaked and cooked in various solutions are presented. The second part gives the significance of differences among methods using the same solution, while the third part gives similar information for comparisons among solutions for the same method. The mean squares are included to assist in the interpretation of the mean scores.

PALATABILITY

NATURAL FLAVOR.—In general, pea beans stored at 75° F. were scored slightly but not significantly higher on intensity of natural flavor than those stored at 40° (table 2). The mean natural-flavor score for all beans stored at 75° was 4.2, against 4.0 for those stored at 40°.

For beans stored at 40° F., soaking 1 hour or 18 hours made no real difference in the natural-flavor scores when distilled water or hard water plus sodium bicarbonate was used as the cooking medium (table 3). Undrained beans soaked by either method and cooked in the soaking solution were scored higher on natural flavor than drained samples cooked in fresh solution. When hard water without sodium bicarbonate was used, the short-soaked, undrained samples received significantly higher scores than those prepared by other methods.

After 75° F. storage, differences in flavor scores of beans soaked 1 hour or 18 hours, drained or not drained before cooking, were not statistically significant, regardless of the type of water used.

OFF-FLAVOR.—Mean scores for off-flavor indicate that few off-flavors were present in any of the samples of beans (table 4). The lowest mean score of 4.3 for beans prepared in hard water by the

18-hour overnight soak and not drained before cooking indicates that perceptible off-flavors were present only in this sample. Differences between scores with respect to temperature of storage, methods employing the same solution, or solutions used for the same method were not significant.

TEXTURE OF SKIN.—Temperature of storage had a highly significant effect on texture of skin (table 2); the skins of pea beans cooked after storage at 75° F. for 1 year were tougher than those cooked after storage at 40°.

The skins were slightly too tender when the beans stored at 40° F. were given a 1-hour hot soak and drained before cooking in fresh distilled water (table 5). When the beans were cooked in the soaking solution, the skins were close to optimum in tenderness. On the other hand, after the 18-hour cold soak in distilled water the skins of the undrained beans cooked in the soaking solution were more tender than those of the drained beans. Differences in skin texture due to method of preparation were in the same direction for beans stored at 75°. That is, with the 1-hour soak the drained beans had more tender skins than the undrained, and with the 18-hour soak, the undrained beans had more tender skins than the drained.

When the beans stored at one temperature were soaked and cooked in hard water, flavor scores were very similar, whether the soaking time was 1 hour or 18 hours and whether the beans were drained or undrained. However, as pointed out previously, the beans stored at 40° F. were in general more tender than those stored at 75°.

The skins were too tender when beans stored at 40° F. were drained after soaking either 1 hour or 18 hours in sodium bicarbonate solution and cooked in fresh sodium bicarbonate solution. Tenderness of skins was closer to optimum when the beans were not drained and were cooked in the soaking solution. Likewise, beans stored at 75° had more tender skins when drained after a 1-hour hot soak and cooked in fresh sodium bicarbonate solution than when cooked in the soaking solution. After the 18-hour cold soak, draining made little difference in the tenderness of the skins of beans stored at 75°; both drained and undrained beans had tender skins after soaking and cooking in hard water with sodium bicarbonate added.

TEXTURE OF COTYLEDON.—Mean values for texture of cotyledon of beans stored at 75° F. were significantly different from the values for those held at 40° (table 2). In most cases the beans stored at 40° were rated slightly too soft and those stored at 75° were scored slightly too hard.

Of the beans stored at 40° F. those prepared by the short soak without draining were scored closer to 5.0 (tender) than those prepared by other methods, whatever the type of water used (table 6). The other methods gave lower scores (softer texture), in most cases significantly lower.

For beans stored at 75° F. the long soaking procedure, with or without draining, gave in general the most satisfactory scores with distilled water and hard water plus sodium bicarbonate. When hard water was used, there was little difference in texture scores due to method of soaking or draining. The short soak without draining resulted in slightly too hard beans, regardless of the type of water;

the short soak with draining resulted in slightly too soft beans when hard water plus sodium bicarbonate was used.

Comparing the effect of different solutions within the same method for beans stored at 40° F., the only methods in which significant differences in scores occurred were those that included draining. With those methods, hard water plus sodium bicarbonate produced scores in the too-soft range. The different solutions had no significant effect on texture scores for beans stored at 75°.

APPEARANCE.—Pea beans stored at 75° F. had higher scores for appearance and were less broken than those stored at 40° (table 2).

Of beans stored at 40° F. (table 7) those soaked and cooked in hard water with sodium bicarbonate showed the influence of draining; those prepared without draining, whether soaked for a short or long time, had significantly better appearance scores than those drained. There were no significant differences in appearance due to method of soaking or draining for any of the other kinds of water.

When the influence of type of water on appearance scores of beans stored at 40° F. was analyzed, it was found that differences were significant only in the short-soak-and-drain method. In this method, beans soaked and cooked in distilled water or hard water scored higher than those in hard water with sodium bicarbonate.

Appearance scores of pea beans stored at 75° F. were not affected by method of preparation or type of water used.

ACCEPTABILITY.—Temperature of storage had no significant effect on the scores for acceptability (table 2). When the same type of water was used in all methods, beans held at 40° F. and prepared by the short-soak method without draining received scores that were significantly higher than the scores for beans prepared by other methods (table 8). When the beans were stored at 75°, differences in these scores attributable to method of preparation were not significant.

When beans stored at 40° F. were soaked by the short method and cooked without draining, those prepared in hard water with sodium bicarbonate were scored significantly lower for acceptability than those in distilled or hard water. Beans in hard water plus sodium bicarbonate were scored slightly lower also when other methods of soaking and cooking were used, but the differences were not significant.

REHYDRATION

In general, after 40° F. storage, pea beans soaked overnight at room temperature and cooked 1½ hours in distilled or hard water, or 1 hour in hard water plus sodium bicarbonate, imbibed slightly more water than beans prepared by the short soak in hot water (table 9). The beans soaked overnight in cold water had rehydrated more than was necessary for optimum tenderness, as shown by texture scores in table 6. The texture of cooked beans, drained or not drained after the long-soak process, was softer than the texture of the undrained short-soaked beans.

When pea beans stored at 40° F. were prepared by the 1-hour hot soak and cooked in the soaking solution, the rehydration ratios were slightly lower than when the soaking liquid was discarded and fresh solution added for cooking. However, the scores for texture were significantly higher and closer to optimum for the former, suggesting

TABLE 3.—NATURAL FLAVOR OF PEA BEANS: *Mean scores and analysis of variance for beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

MEAN SCORES FOR NATURAL FLAVOR [1]

Description of sample	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
1-hour soak (hot):						
Drained, cooked in fresh solution	3.9	3.9	3.2	4.1	4.1	3.9
Not drained, cooked in soaking solution	4.7	4.5	4.1	4.7	4.6	4.1
18-hour soak (cold):						
Drained, cooked in fresh solution	4.0	3.5	3.9	4.3	3.9	3.8
Not drained, cooked in soaking solution	4.3	3.9	3.7	4.5	4.5	4.3

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO SOLUTION USED

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
Method	3	1.928	2.639**	2.444	0.756	1.511	0.667
Drain	1	4.816*	3.750**	1.666	1.667*	4.266*	1.667*
Soak	1	.150	3.750**	.266	0	.266	.067
Drain×soak	1	.817	.417	5.401*	.600	.001	.266

Judge	4	1.441	1.692	2.600	1.642**	2.141	1.083*
Method×judge	12	.719*	.458	.833**	.464	.719*	.250
Error	40	.300	.467	.300	.400	.300	.367

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO METHOD OF PREPARATION

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked				Pea beans stored at 75° F., soaked, and cooked			
		1-hour soak (hot)		18-hour soak (cold)		1-hour soak (hot)		18-hour soak (cold)	
		Drained	Undrained	Drained	Undrained	Drained	Undrained	Drained	Undrained
Solution	2	2.222**	1.155	0.955	1.755	0.289	1.622**	1.155	0.200
Judge	4	1.300**	1.500	2.478	.867	2.133*	.667*	1.744**	1.589*
Solution×judge	8	.500	.767*	.928**	.617	.483	.233	.628	.172
Error	30	.289	.289	.244	.600	.267	.244	.422	.489

* Significant at 5-percent level.
** Significant at 1-percent level.

[1] Mean of 15 values (3 replicates scored by 5 judges) on following rating scale: 5, natural, full-bodied; 4, moderately full-bodied; 3, slightly weak; 2, weak; 1, lacking.

TABLE 4.—OFF-FLAVOR OF PEA BEANS: *Mean scores and analysis of variance for beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

MEAN SCORES FOR OFF-FLAVOR [1]

Description of sample	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
1-hour soak (hot):						
Drained, cooked in fresh solution	4.9	4.9	4.9	4.9	4.9	4.8
Not drained, cooked in soaking solution	5.0	5.0	4.8	4.8	5.0	4.7
18-hour soak (cold):						
Drained, cooked in fresh solution	4.9	4.8	4.5	4.9	4.9	4.7
Not drained, cooked in soaking solution	5.0	4.3	4.7	4.9	4.6	4.7

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO SOLUTION USED

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
Method	3	0.089	1.661	0.444	0.044	0.461	0.061
Drain	1	0	.817	0	.066	.150	.016
Soak	1	0	2.817*	1.066	0	.417	.150
Drain×soak	1	.266	1.349	.267	.067	.816	.017

Judge	4	.141	1.291	1.016	.441*	.225	.858*
Method×judge	12	.075	.536**	.138	.142	.058	.436
Error	40	.100	.116	.417	.133	.217	.233

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO METHOD OF PREPARATION

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked				Pea beans stored at 75° F., soaked, and cooked			
		1-hour soak (hot)		18-hour soak (cold)		1-hour soak (hot)		18-hour soak (cold)	
		Drained	Undrained	Drained	Undrained	Drained	Undrained	Drained	Undrained
Solution	2	0.022	0.200	0.466	2.022	0.066	0.289	0.289	0.289
Judge	4	.355*	.089	1.033	1.355	.133	.755**	.589	.644
Solution×judge	8	.022	.089	.217	.606*	.066	.205	.289*	.094
Error	30	.133	.111	.400	.200	.133	.155	.117	.378

* Significant at 5-percent level.
** Significant at 1-percent level.

[1] Mean of 15 values (3 replicates scored by 5 judges) on following rating scale: 5, none; 4, perceptible; 3, slightly pronounced; 2, moderately pronounced; 1, very pronounced.

TABLE 6.—TEXTURE OF COTYLEDON OF PEA BEANS: *Mean scores and analysis of variance for beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

MEAN SCORES FOR TEXTURE OF COTYLEDON [1]

Description of sample	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
1-hour soak (hot):						
Drained, cooked in fresh solution	3.9	4.3	3.3	4.9	5.4	4.3
Not drained, cooked in soaking solution	4.7	5.1	4.4	6.0	5.9	5.9
18-hour soak (cold):						
Drained, cooked in fresh solution	4.3	4.2	3.6	5.3	5.5	4.9
Not drained, cooked in soaking solution	4.1	4.2	4.1	5.0	5.3	5.1

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO SOLUTION USED

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
Method	3	1.733*	3.127*	3.755**	4.333*	1.083	5.972**
Drain	1	1.666	2.816	9.600**	3.267	.417	10.417**
Soak	1	.266	3.750*	0	1.667	.817	.150
Drain×soak	1	3.268*	2.817	1.666	8.066*	2.016	7.350

Judge	4	.391	1.817	1.500*	.650	.400	.692
Method×judge	12	.636	.794	.311	.694	.444	.680
Error	40	.383	.467	.483	1.217	.817	1.300

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO METHOD OF PREPARATION

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked				Pea beans stored at 75° F., soaked, and cooked			
		1-hour soak (hot)		18-hour soak (cold)		1-hour soak (hot)		18-hour soak (cold)	
		Drained	Undrained	Drained	Undrained	Drained	Undrained	Drained	Undrained
Solution	2	3.889*	2.022	2.022*	0.067	4.266	0.155	1.355	0.466
Judge	4	.589	1.522	1.522*	.855	.244	.811	.411	.744
Solution×judge	8	.555	.939	.439	.289	.211	.378	1.328	.577
Error	30	.266	.422	.511	.578	1.333	.644	.844	1.022

* Significant at 5-percent level.
** Significant at 1-percent level.
[1] Mean of 15 values (3 replicates scored by 5 judges) on the following rating scale: 9, very hard; 8, hard; 7, moderately hard; 6, slightly hard; 5, tender; 4, slightly too soft; 3, moderately too soft; 2, too soft; 1, mushy.

TABLE 7.—APPEARANCE OF PEA BEANS: *Mean scores and analysis of variance for beans stored at 40° and 75°F. for 1 year and prepared under different conditions of soaking and cooking*

MEAN SCORES FOR APPEARANCE [1]

Description of sample	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
1-hour soak (hot):						
Drained, cooked in fresh solution	3.5	3.7	3.2	3.6	3.6	3.7
Not drained, cooked in soaking solution	3.9	3.7	3.7	4.1	4.0	4.1
18-hour soak (cold):						
Drained, cooked in fresh solution	3.5	3.5	3.1	3.7	3.8	3.7
Not drained, cooked in soaking solution	3.7	3.6	3.6	3.7	3.8	3.7

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO SOLUTION USED

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
Method	3	0.372	0.111	1.305**	0.644	0.400	0.683
Drain	1	.817*	0	3.750**	1.600*	.600	.816
Soak	1	.150	.266	.150	.266	0	.816
Drain × soak	1	.150	.067	.016	.067	.600	.417

Judge	4	.642*	.191	.333	.725	1.275**	.141
Method × judge	12	.219	.292	.222	.158	.275	.086
Error	40	.183	.233	.267	.300	.150	.283

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO METHOD OF PREPARATION

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked				Pea beans stored at 75° F., soaked, and cooked			
		1-hour soak (hot)		18-hour soak (cold)		1-hour soak (hot)		18-hour soak (cold)	
		Drained	Undrained	Drained	Undrained	Drained	Undrained	Drained	Undrained
Solution	2	1.088*	0.155	0.800	0.022	0.089	0.066	0.089	0.022
Judge	4	.422	.189	.533	.255	.078	.367	.700*	.522*
Solution × judge	8	.256	.322	.217	.189	.394	.067	.367	.189
Error	30	.244	.156	.244	.267	.422	.222	.178	.156

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Mean of 15 values (3 replicates scored by 5 judges) on following rating scale: 5, whole; 4, slightly broken; 3, moderately broken; 2, broken; 1, mushy.

TABLE 8.—ACCEPTABILITY OF PEA BEANS: *Mean scores and analysis of variance for beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

MEAN SCORES FOR ACCEPTABILITY [1]

Description of sample	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
1-hour soak (hot):						
Drained, cooked in fresh solution	3.7	3.8	3.3	3.9	3.9	3.6
Not drained, cooked in soaking solution	4.5	4.4	3.9	3.7	4.1	3.9
18-hour soak (cold):						
Drained, cooked in fresh solution	3.7	3.7	3.5	3.8	3.9	3.7
Not drained, cooked in soaking solution	4.1	3.7	3.7	4.1	3.8	3.8

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO SOLUTION USED

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked in—			Pea beans stored at 75° F., soaked, and cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
Method	3	2.150*	1.838*	1.217*	0.467	0.311	0.194
Drain	1	4.816**	1.350	2.816**	.067	.066	.417
Soak	1	.816	2.816*	.016	.267	.600	.017
Drain × soak	1	.818	1.350	.818	1.066	.267	.149

Judge	4	.267	.858	1.083*	.642	.516	.750
Method × judge	12	.456	.214	.328	.230	.033	.250
Error	40	.275	.517	.317	.567	.358	.467

MEAN SQUARES FOR EACH STORAGE TEMPERATURE ACCORDING TO METHOD OF PREPARATION

Source of variation	Degrees of freedom	Pea beans stored at 40° F., soaked, and cooked				Pea beans stored at 75° F., soaked, and cooked			
		1-hour soak (hot)		18-hour soak (cold)		1-hour soak (hot)		18-hour soak (cold)	
		Drained	Undrained	Drained	Undrained	Drained	Undrained	Drained	Undrained
Solution	2	1.266	1.488*	0.289	0.800	0.555	0.622	0.066	0.555
Judge	4	.144	.478	.367	1.411*	.478	.355	.689	.578
Solution × judge	8	.544	.128	.483	.245	.361	.456	.122	.111
Error	30	.444	.311	.356	.400	.222	.378	.444	.711

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Mean of 15 values (3 replicates scored by 5 judges) on following rating scale: 5, very good; 4, good; 3, fair; 2, poor; 1, very poor.

TABLE 9.—*Rehydration ratios [1] for pea beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

Storage temperature of dry beans	Description of sample	Rehydration ratio [2] for beans					
		Soaked in—			Cooked in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
40° F.	1-hour soak (hot):						
	Soaking liquid discarded	1.90	1.89	1.92	2.43	2.45	2.46
	Soaking liquid retained	1.91	1.90	1.92	2.40	2.38	2.37
	18-hour soak (cold):						
	Soaking liquid discarded	1.96	1.96	1.96	2.47	2.40	2.47
	Soaking liquid retained	1.98	1.98	1.95	2.46	2.42	2.44
75° F.	1-hour soak (hot):						
	Soaking liquid discarded	1.97	1.98	2.02	2.51	2.50	2.52
	Soaking liquid retained	1.99	1.97	2.02	2.42	2.42	2.41
	18-hour soak (cold):						
	Soaking liquid discarded	2.04	2.05	2.04	2.55	2.54	2.54
	Soaking liquid retained	2.05	2.05	2.04	2.57	2.53	2.50

[1] Calculated by dividing weight of soaked or cooked beans by weight of dry beans. [2] Mean of 3 replicates.

TABLE 10.—*Correlation of rehydration ratios*[1] *and texture scores for pea beans*

Factors correlated	Local market pea beans cooked by varied methods	Michigan pea beans cooked by selected methods
Rehydration ratio and texture of skin	−0. 944**	−0. 637**
Rehydration ratio and texture of cotyledon	−. 912**	−. 745**
Texture of skin and texture of cotyledon	+. 963**	+. 942**

**Significant at 1-percent level.

[1] Calculated by dividing weight of soaked or cooked beans by weight of dry beans.

that a rehydration ratio in the neighborhood of 2.37 to 2.40 is favorable to optimum tenderness of pea beans that have been stored at 40°.

When the cooking time for beans stored at either 40° or 75° F was adjusted as indicated to the kind of solution, and the short soaking procedure was followed, there was little difference in the rehydration ratios of the beans cooked in distilled water, synthetic hard water, or hard water plus sodium bicarbonate as long as the same draining procedure and storage temperature were used. With the long soaking procedure, however, these ratios, except for the beans stored at 75° and drained after soaking, were somewhat less consistent. There was apparently some fluctuating interrelationship between cooking time, storage temperature, draining procedure, and solution used for soaking and cooking in their effect on the rehydration ratio of the long-soaked cooked beans.

In general, beans prepared by the long cold soak had higher rehydration ratios than those prepared by the short hot soak, and beans drained and cooked in fresh solution had higher rehydration ratios than those cooked in the soaking solution. There were two exceptions: (1) Beans stored at 40° F. and soaked overnight in hard water had a lower rehydration ratio after cooking than corresponding samples prepared by the short hot soak; (2) beans stored at 75° and soaked overnight in distilled water had a higher rehydration ratio when cooked in the soaking solution than when cooked in fresh solution.

Rehydration ratios for pea beans stored at 75° F. for 1 year were higher, without exception, than for those stored at 40° and cooked by the same procedure, although the texture scores indicated that the beans stored at 75° were harder. In most instances they were too hard when cooked for 1½ hours, the time used in the standard method. Apparently some factor in addition to rehydration capacity plays a part in the relationship between cooking of stored dry beans and tenderness. Moisture content of the dry beans may have been a factor—those stored at 75° had 74 percent as high moisture content as those stored at 40°.

The usually close over-all relationship between rehydration ratios and texture scores observed in preliminary work was studied by means of correlation coefficients, with results as shown in table 10. These coefficients were obtained from data for both locally purchased pea

TABLE 11.—*Palatability scores and rehydration ratios of pea beans stored at 75° F. for 1 year and prepared by different methods*

Storage temperature of dry beans	Soaking conditions	Cooking time, in hours	Number of replications	Mean score [1]						Rehydration ratio [2]	
				Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability	Soaked beans	Cooked beans
						Skin	Cotyledon				
75° F.	1-hour soak (hot)	1¾	1	4.6	5	5.2	5.5	4.1	4.2	1.99	2.53
		2	3	4.8	4.9	5.0	5.2	4.2	4.6	1.99	2.57
		2¼	3	4.9	5.0	5.0	4.7	4.0	4.7	1.99	2.62
40° F. (control)	2-hour soak (hot)	1½	1	4.3	5.0	5.6	6.2	4.6	3.9	1.99	2.39
75° F.	18-hour soak (cold)	1½	4	4.8	4.9	5.0	4.6	3.9	4.6	1.98	2.48
		1½	3	4.5	4.9	4.9	5.0	3.7	4.1	2.05	2.57

[1] Scored by a panel of 5 judges. Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough or hard, and 1 was completely disintegrated or mushy.

[2] Calculated by dividing weight of soaked or cooked beans by weight of dry beans.

beans and Michigan beans of the type used in the palatability and nutritive value study but over a wider and more complete range of cooking times than those which were finally adopted.

The positive correlations significant at the 1-percent level, between scores for texture of skin and texture of cotyledon, suggest a high degree of relationship between these two palatability factors over a wide range of experimental conditions and the possibility of obtaining optimum results for both factors simultaneously by suitable choice of cooking methods.

The correlations for rehydration ratios and scores for either texture of skin or texture of cotyledon are necessarily negative, since the beans progressed from hard to soft as the rehydration ratio increased in value, but the texture scores could correspondingly decline from a maximum of 9 (very hard) through 5 (optimum) to a minimum of 1 (mushy).

The highly significant correlations obtained from the data on beans purchased locally indicate that over 80 percent of the variation in scores might be associated with changes in the rehydration ratio. Correlations for Michigan bean data are lower but still highly significant, suggesting over 40-percent common variation. A factor contributing to the smaller coefficients for the Michigan beans may be that over half of the cooking times available for analysis were 1 or 1½ hours which, as already shown, produced very similar results when the appropriate solution was used. The data for beans purchased locally, on the other hand, represented a wider range of concomitant variation and would be expected to reveal more accurately any correlation which existed between the two variables.

These results indicate that the rehydration ratio might be substituted for palatability panel tests in preliminary experiments to establish optimum cooking time when texture is the chief characteristic under consideration.

COOKING TIME REQUIRED FOR PEA BEANS STORED AT 75° F. FOR 1 YEAR

As was shown in the palatability study, pea beans stored at 75° F. for 1 year were not tender in the 1½-hour cooking time when the 1-hour hot soak was employed. To determine whether a longer cooking time would compensate for the short soaking time, beans were cooked for 1¾ hours, for 2 hours, and for 2¼ hours after a 1-hour hot soak. Other samples were soaked for 2 hours after the 2-minute initial boil. Beans stored at 40° for 1 year, soaked for 18 hours in cold water, and cooked for 1½ hours were used as a control and reference standard in the palatability panel tests.

Increasing the soaking time from 1 to 2 hours did not increase the rehydration ratio and had little, if any, effect on the texture of the cooked beans (table 11). Increasing the cooking time to 2 hours resulted in a product of very good quality. The rehydration ratio and texture scores for beans cooked 2 hours were comparable to those for similar beans prepared by the 18-hour cold soak and cooked for 1½ hours.

pH OF SOAKING AND COOKING LIQUID

The pH of the liquid as given in table 12 showed that the distilled water and the synthetic hard water were slightly acid before the beans were added. The hard water with sodium bicarbonate was slightly alkaline. After the beans were soaked in the different solutions for 1

TABLE 12.—*pH of pea beans stored at 40° and 75° F. for 1 year and prepared under different conditions of soaking and cooking*

Storage temperature of dry beans	Description of sample	pH of solution [1]								
		Before soaking of beans in—			After soaking of beans in—			After cooking of beans in—		
		Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate	Distilled water	Hard water	Hard water and sodium bicarbonate
40° F.	1-hour soak (hot):									
	Soaking liquid discarded	5.8	6.0	8.2	5.9	6.0	6.8	5.7	5.8	6.3
	Soaking liquid retained	5.9	6.1	7.7	6.0	6.0	6.8	5.7	5.7	6.0
	18-hour soak (cold):									
	Soaking liquid discarded	6.0	5.9	8.3	6.0	6.0	[2] 6.4	5.7	5.6	6.0
	Soaking liquid retained	6.2	6.4	8.2	6.0	6.0	6.1	5.7	5.7	6.0
75° F.	1-hour soak (hot):									
	Soaking liquid discarded	6.0	6.3	8.3	5.9	5.9	6.7	5.7	5.7	6.1
	Soaking liquid retained	6.0	5.8	8.2	6.0	5.9	6.7	5.7	5.7	6.0
	18-hour soak (cold):									
	Soaking liquid discarded	6.0	6.5	8.2	6.2	[2] 6.1	6.5	5.7	5.7	6.1
	Soaking liquid retained	6.5	6.0	8.4	6.3	6.1	6.5	5.8	5.8	6.2

[1] Mean of 3 replicates. [2] Mean of 2 replicates.

hour or 18 hours, the pH of the distilled water and synthetic hard water was unchanged; that of the hard water with added sodium bicarbonate was slightly acid after the 18-hour soak and near neutrality after the 1-hour soak.

After the beans were cooked, the liquid was more acid in all cases, although the pH of the hard water with sodium bicarbonate was higher than that of distilled water or synthetic hard water. There was no appreciable difference in the pH of liquid from the cooked beans, whether the 1-hour hot soak or the 18-hour cold soak was used, or whether the soaking liquid was discarded or retained for cooking.

THIAMINE AND ASH CONTENT

Dry beans stored at 75° F. for 1 year retained 81 percent as much thiamine as those stored at 40° (tables 13, 14). When the beans stored at 40° were cooked in the water in which they were soaked, the average thiamine retention was almost two-thirds of the original thiamine content, showing no great difference due to method of soaking, rehydration procedure, hardness of water, or use of the small amount of soda in the hard water. When the soaking water was discarded and fresh water used for cooking, the beans retained approximately two-thirds of the thiamine by the long soak in cold water and less than one-half by the short soak in hot water.

The liquid in which beans were soaked overnight contained very little thiamine, whereas the liquid from the 1-hour hot soak contained about one-fourth of the thiamine in the original dry beans. Consequently considerable thiamine would be lost if the soaking water were discarded in the short-soak method of preparation.

Less than 10 percent of the total ash and less than 5 percent of the insoluble ash were in the soaking liquid after the 18-hour soak and would be lost on discarding the soaking liquid. With the short method there was three times as much total ash and twice as much insoluble ash in the soaking liquid as there was with the long method. From the nutritive value standpoint, therefore, discarding the soaking liquid is not recommended in the 1-hour hot-soak method.

SUMMARY OF STUDIES ON PEA BEANS

A time-saving method of soaking, in which the beans are added to boiling water, boiled 2 minutes, removed from the heat, and allowed to soak for 1 hour in the hot water, gave very satisfactory results with pea beans. The tasting panel found that the new method provided cooked beans equal or superior in palatability to those prepared by the long soaking procedure in cold water for 18 hours.

When the short soaking procedure without draining was used, the addition of 0.5 gm. sodium bicarbonate to 200 gm. beans and 623 ml. synthetic hard water containing calcium sulfate reduced the cooking time from 90 to 60 minutes. Although scores for natural flavor and general acceptability were measurably lowered by the addition of sodium bicarbonate, the scores for all palatability factors were in the range of 3.7 to 4.8, indicating good quality whether the beans were prepared with or without sodium bicarbonate.

In general, with the short soaking method pea beans had higher palatability scores when the soaking liquid was retained for cooking than when it was discarded. With the long soaking method, palatability scores for the drained and undrained samples were very similar.

TABLE 13.—*Total ash, insoluble ash, and thiamine content of dry pea beans and pea beans prepared under different conditions of soaking and cooking* [1]

Type of water	Description of method and sample	Sample size		Moisture		Total ash		Insoluble ash		Thiamine	
		Volume of liquid	Weight of solid	Liquid	Solid	Liquid	Solid	Liquid	Solid	Liquid	Solid
		Milliliters	*Grams*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Milligrams per 100 grams*	*Milligrams per 100 grams*
	Dry Beans—										
	Stored at 40° F. 1 year	-------	-------	-------	11. 02	-------	3. 21	-------	1. 24	-------	0. 940
	Stored at 75° F. 1 year	-------	-------	-------	8. 18	-------	3. 32	-------	1. 36	-------	. 763
Distilled water	1-hour soak (hot):										
	Soaked beans	415	376	97. 37	56. 23	0. 39	1. 21	0. 48	. 71	0. 073	. 299
	Cooked beans:										
	Soaking liquid discarded.	-------	495. 5	-------	68. 60	-------	. 906	-------	. 45	-------	. 167
	Soaking liquid retained.	-------	496. 3	-------	67. 36	-------	1. 19	-------	. 41	-------	. 236
	18-hour soak (cold):										
	Soaked beans	437	386. 5	99. 45	56. 90	. 113	1. 50	. 035	. 64	. 0025	. 405
	Cooked beans:										
	Soaking liquid discarded.	-------	528	-------	70. 20	-------	1. 017	-------	. 47	-------	. 212
	Soaking liquid retained.	-------	501. 5	-------	67. 15	-------	1. 21	-------	. 51	-------	. 175

Hard water	1-hour soak (hot):										
	Soaked beans	400	370	97.18	54.79	.42	1.25	.093	.59	.095	.338
	Cooked beans:										
	Soaking liquid discarded.		476		66.90		.98		.42		.175
	Soaking liquid retained.		500.5		66.26		1.20		.55		.243
	18-hour soak (cold):										
	Soaked beans	435	386.5	99.40	56.84	.13	1.52	.025	.65	.0046	.510
	Cooked beans:										
	Soaking liquid discarded.		498.5		67.02		1.17		.50		.269
	Soaking liquid retained.		527.5		66.11		1.26		.52		.266
Hard water and sodium bicarbonate	1-hour soak (hot):										
	Soaked beans	462	372.5	97.54	56.28	.39	1.21	.055	.60	.087	.277
	Cooked beans:										
	Soaking liquid discarded.		599		72.63		.83		.40		.147
	Soaking liquid retained.		610		72.54		1.08		.43		.211
	18-hour soak (cold):										
	Soaked beans	463	385	99.41	56.94	.15	1.55	.017	.61	.004	.417
	Cooked beans:										
	Soaking liquid discarded.		615		72.53		1.04		.53		.222
	Soaking liquid retained.		628.5		73.61		1.04		.41		.209

[1] Pea beans used in soaking and cooking studies were stored at 40° F.

TABLE 14.—*Total ash, insoluble ash, and thiamine retention of dry pea beans and pea beans prepared under different conditions of soaking and cooking* [1]

Type of water	Description of method and sample	Retention			
		Thiamine		Total ash	Insoluble ash
		Solid	Liquid	Liquid	Liquid
		Percent	*Percent*	*Percent*	*Percent*
Distilled water	Dry beans: Stored at 75° F. 1 year	81. 17			
	1-hour soak (hot):				
	Soaked beans	75. 90	21. 23	26. 31	14. 18
	Cooked beans:				
	Soaking liquid discarded.	43. 99			
	Soaking liquid retained.	62. 29			
	18-hour soak (cold):				
	Soaked beans	83. 83	. 70	7. 85	5. 82
	Cooked beans:				
	Soaking liquid discarded.	59. 52			
	Soaking liquid retained.	46. 70			
Hard water	1-hour soak (hot):				
	Soaked beans	86. 76	23. 30	26. 64	14. 56
	Cooked beans:				
	Soaking liquid discarded.	44. 31			
	Soaking liquid retained.	64. 68			
	18-hour soak (cold):				
	Soaked beans	105. 90	1. 00	8. 79	4. 92
	Cooked beans:				
	Soaking liquid discarded.	71. 33			
	Soaking liquid retained.	74. 63			
Hard water and sodium bicarbonate	1-hour soak (hot):				
	Soaked beans	76. 28	28. 03	28. 56	9. 37
	Cooked beans:				
	Soaking liquid discarded.	46. 80			
	Soaking liquid retained.	68. 46			
	18-hour soak (cold):				
	Soaked beans	86. 54	1. 17	10. 41	3. 25
	Cooked beans:				
	Soaking liquid discarded.	72. 61			
	Soaking liquid retained.	69. 89			

[1] Pea beans used in soaking and cooking studies were stored at 40° F.

When pea beans were cooked in the water in which they were soaked, the average thiamine retention was almost two-thirds of the original thiamine content, showing no great differences due to method of soaking, rehydration procedure, hardness of water, or use of the small amount of soda in the hard water. When the soaking water was discarded and fresh water used for cooking, the beans retained approximately two-thirds of the thiamine by the long cold soak and less than one-half by the short hot soak. Discarding the soaking water is, therefore, not recommended in the short-soak method.

Great Northern, Large Lima, Pinto, and Red Kidney Beans

In the series of experiments on cooking great northern, large lima, pinto, and red kidney beans in a covered saucepan, investigations were made to determine the effect of the 1-hour hot soak in tap water versus the 18-hour cold soak in tap water, and the addition of a small amount of sodium bicarbonate, on the palatability and rehydration capacity of the dry beans.

The latin-square type of experimental design, in which the four methods of preparation were randomized on four electrical heating units, was used. Four replications were made, one complete replication on each of 4 days.

PALATABILITY

Great Northern Beans.—Palatability scores for great northern beans prepared by the 1-hour hot soak and the 18-hour cold soak, with and without sodium bicarbonate, are given in table 15. The 1-hour hot soak proved to be very satisfactory. In natural flavor there was no difference in the beans prepared by the short or long soaking procedure in tap water. When sodium bicarbonate was added, the beans prepared by the long soaking method received a significantly lower average score than those prepared by other methods. Short-soaked beans in sodium bicarbonate solution scored the same as the short- or long-soaked beans in plain tap water; all of them had a score of very good in natural flavor.

Very few off-flavors were reported in any of the samples and differences between methods were not significant.

Mean scores for texture of skin were 5.0 when rounded to one decimal. Scores for texture of cotyledon were very nearly optimum by all methods. Beans soaked for 1 hour in hot water and cooked for 90 minutes had a score of 5.1 or very slightly too hard and those soaked for 18 hours in cold water and cooked for 75 minutes had a score of 4.8 or very slightly too soft.

Appearance of great northern beans soaked for 1 hour in hot water was very good; for those soaked for 18 hours in cold water before cooking, appearance was rated good. However, the long soak with tap water was scored significantly lower than the other methods. The addition of sodium bicarbonate had very little effect on the appearance of the beans.

In general acceptability great northern beans prepared by the short-soak method received a slight but significantly higher average score than those soaked overnight. With sodium bicarbonate added, the long soak was less acceptable than the other methods and differences were statistically significant.

Summary of Palatability Studies on Great Northern Beans.—Great northern beans may be prepared by either the short or long soaking procedure with very good results. The cooking time after the 1-hour hot soak may be shortened ½ hour with no deleterious effects on flavor, texture, or appearance by adding 0.5 gm. sodium bicarbonate to 200 gm. beans and 628 ml. tap water.

LARGE LIMA BEANS.—The results of studies to compare the long and short soaking procedures and the effect of adding a small amount of sodium bicarbonate on the quality and cooking time of large lima beans are presented in table 16, with an analysis of variance of the panel scores for flavor, texture, appearance, and acceptability.

The effect of soaking was significant. The natural-flavor scores for lima beans soaked for 1 hour in hot water before cooking were higher than for those soaked 18 hours in cold water. The addition of sodium bicarbonate to the beans soaked by either method had little effect on the scores for natural flavor. The interaction effect of method of soaking and type of water was not significant. Individual methods were not statistically different from each other.

Scores indicate that there were practically no off-flavors in any of the samples of beans. Average scores for off-flavor were very similar for all methods of preparation. Apparently the amount of sodium bicarbonate used was too small to be perceptible. Differences among the four methods were nonsignificant statistically.

When the lima beans were soaked overnight in tap water containing sodium bicarbonate the skins were slightly tougher than when other methods of preparation were used. The difference between this method and the other three was statistically significant; mean scores for the overnight soak without sodium bicarbonate could not be differentiated statistically. However, the interaction of type of water and method of soaking was highly significant.

Lima beans prepared by the short-soak method had significantly higher scores for texture of cotyledon than those prepared by the long soak. The addition of sodium bicarbonate had no significant effect on scores for texture of cotyledon.

Inspection of the mean scores for texture of both skin and cotyledon of lima beans indicated that the short-soak method tended to produce a more uniformly cooked product than did the overnight soak. The scores indicated that the skins of beans prepared by the overnight soak were slightly tough, while the cotyledons were too soft; in the short soak, both texture of skin and texture of cotyledon were more nearly optimum.

Scores for appearance were significantly higher for lima beans prepared by the short-soak method than for those prepared by the long-soak method. The appearance score for beans soaked 18 hours and cooked in tap water was significantly lower than the scores for other methods. The addition of sodium bicarbonate had no significant effect on appearance.

Although the scores for general acceptability were slightly higher for lima beans prepared by the short soak, the differences were not statistically significant.

Summary of Palatability Studies on Large Lima Beans. In general, scores indicate that large lima beans prepared by the 1-hour soaking procedure were superior to those prepared by the long soaking procedure. The addition of 0.5 gm. of sodium bicarbonate to 200

gm. dry beans and 645 ml. tap water did not reduce the cooking time when the short soak was used, but produced more tender skins, resulting in a more uniformly cooked product in the same length of time. Lima beans prepared in tap water containing sodium bicarbonate were comparable to those prepared without sodium bicarbonate in all quality characteristics except texture of skin, whether the short or long soak was used. With the long soak, the skin was slightly tougher when sodium bicarbonate was used.

PINTO BEANS.—Results of soaking and cooking studies on pinto beans are given in table 17.

Natural-flavor scores for pinto beans prepared by the 18-hour cold soak in tap water were significantly higher than scores for those prepared by the 1-hour hot soak. When sodium bicarbonate was added, the beans soaked for 18 hours had lower scores than those soaked for 1 hour.

With the 1-hour soak the average score for natural flavor was slightly but not significantly higher when sodium bicarbonate was added than when tap water alone was used. With the 18-hour soak the reverse was true; that is, beans cooked in tap water rated higher than beans cooked in sodium bicarbonate solution.

Off-flavors were absent, as indicated by average scores of 5.0 for all methods.

Texture of skin of pinto beans was nearly optimum for all methods of preparation; method of soaking or kind of solution used had no statistically significant effect on the scores.

The scores for cotyledons of the pinto beans prepared by the 18-hour soak in cold water were significantly different from those for beans prepared by the short hot soak with or without the addition of sodium bicarbonate. The average texture score for cotyledons of beans soaked overnight in tap water was 4.8 or nearly optimum, whereas beans soaked for 1 hour had an average score of 5.3, indicating that the beans were slightly too hard. A slightly longer cooking time than was used after the short soak in tap water might achieve optimum tenderness.

The addition of sodium bicarbonate did not influence significantly the texture scores for beans prepared by the short soak. On the other hand, when sodium bicarbonate was added to beans prepared by the long cold soak, the average score for texture of cotyledon was significantly lower than for those without sodium bicarbonate, even though the beans were cooked a shorter time.

For appearance, the judging panel scored pinto beans prepared by the short soak significantly higher than those soaked overnight, regardless of the type of solution used. The addition of sodium bicarbonate had no significant effect on appearance.

The scores for general acceptability were similar whether pinto beans were prepared by the short or long soaking procedure in tap water. General acceptability of the beans given the short soak was not significantly affected by the presence or absence of sodium bicarbonate, but the acceptability scores for beans soaked overnight were impaired by the use of sodium bicarbonate.

Summary of Palatability Studies on Pinto Beans.—Considering all quality factors tested, scores indicate that pinto beans prepared by the hot, short soaking procedure in tap water were generally as good

TABLE 15.—GREAT NORTHERN BEANS: *Palatability scores and analysis of variance for beans prepared under different conditions of soaking and cooking*

MEAN PALATABILITY SCORES [1]

Description of sample	Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability
			Skin	Cotyledon		
Beans soaked and cooked in tap water:						
1-hour soak (hot)	4.6	4.9	5.0	5.1	4.6	4.5
18-hour soak (cold)	4.6	5.0	5.0	4.8	4.1	4.4
Beans soaked and cooked in tap water with sodium bicarbonate added:						
1-hour soak (hot)	4.6	5.0	5.0	5.2	4.8	4.5
18-hour soak (cold)	4.3	4.9	5.0	5.0	4.3	4.1

MEAN SQUARES FOR EACH PALATABILITY FACTOR

Source of variation	Degrees of freedom	Natural flavor	Off-flavor	Texture		Appearance	Acceptability
				Skin	Cotyledon		
Method	3	0.567*	0.17	0.17	0.912	2.121**	0.903**
Solution	1	.450	0	.050	.613	.800	.528
Soak	1	.800*	0	0	2.113*	5.512**	1.653**
Solution × soak	1	.450	.050	0	.012	.050	.528
Judge	4	.831**	.200*	.050	3.294**	.300**	.222
Day	3	.175	.083	.017	.579	.071	.036
Unit	3	.342	.017	.017	.146	.088	.103
Method × judge	12	358	.017	.017	.777	.329**	.278
Error	54	.195	.078	.026	.474	.072	.200

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Mean of 20 values (4 replicates scored by 5 judges). Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough or hard, and 1 was completely disintegrated or mushy.

TABLE 16.—LARGE LIMA BEANS: *Palatability scores and analysis of variance for beans prepared under different conditions of soaking and cooking*

MEAN PALATABILITY SCORES [1]

Description of sample	Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability
			Skin	Cotyledon		
Beans soaked and cooked in tap water:						
1-hour soak (hot)	4.5	5.0	5.4	5.0	4.6	4.2
18-hour soak (cold)	4.3	4.9	5.2	3.9	3.9	4.0
Beans soaked and cooked in tap water with sodium bicarbonate added:						
1-hour soak (hot)	4.6	4.9	5.1	5.0	4.5	4.2
18-hour soak (cold)	4.2	5.0	5.6	4.2	4.2	4.0

MEAN SQUARES FOR EACH PALATABILITY FACTOR

Source of variation	Degrees of freedom	Natural flavor	Off-flavor	Texture		Appearance	Acceptability
				Skin	Cotyledon		
Method	3	0.667*	0.075	0.836**	6.608**	1.745**	0.304
Solution	1		.012	.028	.200	.253	0
Soak	1	1.800**	.012	.528	19.012**	4.278**	.800
Solution × soak	1	.200	.200	1.953**	.612	.703	.112
Judge	4	2.281**	.044	.390*	2.316**	.222	.995*
Day	3	.025	.042	.003	.300	.186	.171
Unit	3	.108	.033	.186	.092	.095	.146
Method × judge	12	.386	.044	.253	.540*	.286*	.270*
Error	54	.215	.040	.150	.254	.136	.135

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Mean of 20 values (4 replicates scored by 5 judges). Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough or hard, and 1 was completely disintegrated or mushy.

TABLE 17.—PINTO BEANS: *Palatability scores and analysis of variance for beans prepared under different conditions of soaking and cooking*

MEAN PALATABILITY SCORES [1]

Description of sample	Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability
			Skin	Cotyledon		
Beans soaked and cooked in tap water:						
1-hour soak (hot)	4.6	5.0	5.1	5.3	4.8	4.6
18-hour soak (cold)	5.0	5.0	5.0	4.8	4.3	4.6
Beans soaked and cooked in tap water with sodium bicarbonate added:						
1-hour soak (hot)	4.8	5.0	4.9	5.2	4.9	4.7
18-hour soak (cold)	4.6	5.0	5.0	4.2	4.2	4.2

MEAN SQUARES FOR EACH PALATABILITY FACTOR

Source of variation	Degrees of freedom	Natural flavor	Off-flavor	Texture		Appearance	Acceptability
				Skin	Cotyledon		
Method	3	5.79**	0.017	0.146	4.767*	2.054**	1.046**
Solution	1	.113	0	.313	1.800*	0	.613
Soak	1	.113	0	.013	11.250**	6.050**	1.013*
Solution × soak	1	1.512**	.050	.112	1.250**	.112	1.512**
Judge	4	1.044**	.019	.106	.331	.102	1.019**
Day	3	.113	.050	.446*	.433	.104	.146
Unit	3	.246	.017	.113	.600	.038	.079
Method × judge	12	.194	.027	.156	.465*	.250**	.244
Error	54	.114	.024	.122	.239	.075	.205

*Significant at 5-percent level.
**Significant at 1-percent level.
[1] Mean of 20 values (4 replicates scored by 5 judges). Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough or hard, and 1 was completely disintegrated or mushy.

TABLE 18.—RED KIDNEY BEANS: *Palatability scores and analysis of variance for beans prepared under different conditions of soaking and cooking*

MEAN PALATABILITY SCORES [1]

Description of sample	Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability
			Skin	Cotyledon		
Beans soaked and cooked in tap water:						
1-hour soak (hot)	4.6	5.0	5.2	4.0	3.7	3.8
18-hour soak (cold)	4.5	5.0	6.2	5.2	4.0	3.8
Beans soaked and cooked in tap water with sodium bicarbonate added:						
1-hour soak (hot)	4.4	5.0	5.2	4.2	4.0	4.1
18-hour soak (cold)	4.5	4.9	5.9	4.6	3.6	3.8

MEAN SQUARES FOR EACH PALATABILITY FACTOR

Source of variation	Degrees of freedom	Natural flavor	Off-flavor	Texture		Appearance	Acceptability
				Skin	Cotyledon		
Method	3	0.033	0.050	6.113**	4.779**	0.883**	0.483
Solution	1	.050	.050	.613	1.013	0	.450
Soak	1	0	.050	17.113**	10.513**	.200	.800
Solution × soak	1	.050	.050	.612	2.812*	2.450**	.200
Judge	4	2.656**	.019	.419*	.950	.294	.500
Day	3	.500	.017	.113	.479	.083	.283
Unit	3	.233	.017	.046	.046	.083	.183
Method × judge	12	.148	.019	.394**	.717	.227	.400
Error	54	.320	.026	.144	.587	.194	.243

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Mean of 20 values (4 replicates scored by 5 judges). Intensity of natural flavor, absence of off-flavor, appearance, and acceptability were rated on a 5-point scale with 5 as the optimum score and 1 the poorest score. Texture of skin and of cotyledon were rated on a 9-point scale in which 5 was the optimum score, 9 was very tough or hard, and 1 was completely disintegrated or mushy.

as, and sometimes better than, beans prepared by the old-fashioned overnight soak in cold water. However, with the short soak, longer cooking was necessary—2 hours as compared with the 1½ hours required when the 18-hour soak was used.

When 0.5 gm. sodium bicarbonate was added to 200 gm. dry beans and 658 ml. tap water, a superior product was obtained by the short soaking procedure, and the cooking time was reduced from 2 hours to 1½ hours. Pinto beans soaked overnight with sodium bicarbonate added, although cooked only 1 hour, were too soft and scored lower on appearance and general acceptability than beans prepared by other methods.

RED KIDNEY BEANS.—Mean palatability scores for red kidney beans prepared in different ways and their statistical analysis are given in table 18.

Mean scores for intensity of natural flavor and for absence of off-flavors in beans prepared by short and long soaking procedures, with or without sodium bicarbonate, did not differ significantly one from another. Texture differences are interesting in that skins and cotyledons of red kidney beans prepared by the 1-hour hot soak were more tender than those of beans prepared by the 18-hour cold soak and cooked the same length of time.

The presence of sodium bicarbonate in the soaking and cooking water had no effect on texture when the beans were soaked 1 hour in hot water, but resulted in a slightly softer texture when the 18-hour soak in cold tap water was used. By either method, cooking time for the beans with sodium bicarbonate added was only 1 hour as compared with 1¾ hours for those without sodium bicarbonate. Although the interaction term, water × soak, was significant for appearance scores, the individual means were not statistically separable. Differences between scores for general acceptability were not significant.

Summary of Palatability Studies on Red Kidney Beans.—In general, the short hot soaking procedure and the long overnight soak in cold water gave equivalent results for red kidney beans. The addition of 0.5 gm. sodium bicarbonate to 200 gm. beans and 645 ml. tap water had no significant effect on the palatability scores but reduced the cooking time from 1¾ to 1 hour.

REHYDRATION RATIOS

The rate of rehydration during soaking varies with the variety of bean and the method of soaking (table 19).

GREAT NORTHERN BEANS.—Despite the fact that great northern beans prepared by the short-soak method took up more water during soaking than those prepared by the overnight soak, the former required 15 minutes additional cooking time to reach the same degree of rehydration as beans cooked in the same kind of solution after the overnight soak. Apparently some element in the structure or composition of the bean was responsible for the different reaction.

LARGE LIMA BEANS.—Although the rehydration ratio of large lima beans cooked after the short soak was somewhat lower than the rehydration ratio of those cooked after soaking overnight, the mean scores for texture indicate that the beans given the short soak were more uniformly cooked (table 16). Apparently in the long soak the cotyle-

don continues to take up more water and becomes too soft, while the skin remains somewhat tough.

For the short-soak beans, the addition of sodium bicarbonate to the soaking and cooking water resulted in slightly higher rehydration ratios and more tender skins. On the other hand, beans soaked overnight and cooked in sodium bicarbonate solution for 30 minutes had tough skins, as compared with beans soaked by any of the other methods and cooked 1 hour, but the cotyledons were too soft.

TABLE 19.—*Rehydration ratios* [1] *of soaked and cooked beans for great northern, large lima, pinto, and red kidney varieties*

Description of sample	Type of water and method of soaking	Rehydration ratio			
		Great northern	Large lima	Pinto	Red kidney
Soaked beans	Tap water:				
	1-hour soak (hot)	2.11	2.33	2.05	2.03
	18-hour soak (cold)	2.00	2.34	2.11	2.05
	Tap water and sodium bicarbonate:				
	1-hour soak (hot)	2.13	2.34	2.06	2.04
	18-hour soak (cold)	2.00	2.33	2.10	2.04
Cooked beans	Tap water:				
	1-hour soak (hot)	2.53	2.43	2.34	2.51
	18-hour soak (cold)	2.53	2.58	2.45	2.49
	Tap water and sodium bicarbonate:				
	1-hour soak (hot)	2.43	2.46	2.29	2.47
	18-hour soak (cold)	2.51	2.50	2.44	2.43

[1] Calculated by dividing weight of soaked or cooked beans by weight of dry beans.

PINTO BEANS.—In line with the scores for texture of cotyledon of pinto beans (table 17), the rehydration ratios for the beans soaked overnight in cold tap water with or without sodium bicarbonate were higher than the ratios for those given the short soak in hot water of either type. This was true in spite of the fact that the short-soaked samples were cooked 30 minutes longer than the samples soaked overnight in the same kind of water.

RED KIDNEY BEANS.—In the preparation of red kidney beans the short soak in hot water was very effective. The rehydration ratios of cooked beans prepared by the short-soak and by the long-soak methods were comparable. Beans soaked by the short method and cooked 60 minutes in tap water containing sodium bicarbonate reached nearly the same degree of rehydration as beans soaked overnight in tap water and cooked 105 minutes.

Summary of Rehydration Studies on Great Northern, Large Lima, Pinto, and Red Kidney Beans.—Great northern beans responded more favorably to the short, hot soak in either tap water or tap water containing sodium bicarbonate than did beans soaked overnight in cold water, as indicated by the higher rehydration ratios for the short-soaked beans (table 19). The reverse was true of pinto beans. The rehydration ratios for large lima and for red kidney beans were not affected by type of solution or method used for soaking.

COOKING DRY BEANS IN A PRESSURE SAUCEPAN

The effect of cooking in a pressure saucepan on the rehydration, cooking time, and palatability of dry pea beans, pinto, great northern, large lima, and red kidney beans was investigated.

Preliminary Experiments

Preliminary experiments were conducted to standardize the procedure for cooking dry beans in a pressure saucepan. Directions issued by various manufacturers of pressure saucepans included such precautions as not to fill the cooker too full—not more than one-half full in some cases, two-thirds full in others. Some warned to start cooking on low heat to prevent foaming, to be sure the vent pipe is clear, and to reduce the pressure slowly.

Among the factors investigated was the addition of tomatoes or fat to the beans before cooking in an effort to reduce or eliminate foaming. This was of particular interest as some difficulty had been encountered when cooking dry beans under pressure because the vent tube became clogged by the foam. According to recommendations of some manufacturers of pressure saucepans, the foam may be kept to a minimum by starting the cooking on low heat. This, too, was investigated.

Other factors that received attention in the preliminary experiments included the effect of rate of heating, the effect of soaking conditions, and the effect of the quantity of beans in the cooker in relation to the capacity of the cooker.

The addition of ½ cup of canned tomatoes and juice to 2½ cups water for cooking 200 gm. beans had little, if any, effect on the foaming action. When 1 cup of tomatoes and juice was added to 2½ cups water, foaming action was practically eliminated. However, as might be expected, the skins of the beans were appreciably toughened by the use of as much as 1 cup of tomatoes.

The addition of 1 tablespoon of salt pork drippings proved to be a very effective means of reducing or almost completely eliminating foaming of pea, great northern, pinto, and red kidney beans. Lima beans, in contrast to other varieties of beans tested, foamed almost as much with as without the addition of the salt pork drippings. Unless some other means of reducing or eliminating the foam can be found, it may not be advisable in common practice to cook dry lima beans in a pressure saucepan. However, no difficulty was encountered in these experiments with lima beans because the quantity of beans cooked was small in relation to the capacity of the pressure saucepan.

In an effort to reduce foaming by regulating the rate of heating, beans were cooked in 4-quart pressure saucepans filled approximately one-fourth full, and started on "low" or on "medium" heat. It was not possible to determine whether the amount of foam was reduced by this procedure, but it proved to be impractical from the standpoint of time required to reach pressure. In a test in which the cooking was started on "low" the temperature inside the saucepan had not reached 250° F. (15 pounds steam pressure) in 30 minutes; therefore, the test was discontinued. When the cooking was started on "medium," from 29 to 35 minutes were required to reach 250°.

SOAKING CONDITIONS.—The effect of soaking conditions was studied by comparison of beans cooked in a pressure saucepan without soaking, after the 1-hour hot soak and after the 18-hour cold soak (see p. 5). Beans that were not soaked were unsatisfactory after cooking 45 minutes at 15 pounds steam pressure because of lack of uniformity in texture. Some beans were very hard and dark, while others were soft and light. Beans soaked by either the 1-hour or 18-hour procedure appeared to be equally satisfactory.

Further evidence of the superiority of the soaked beans may be found in the higher rehydration ratios of the soaked samples in contrast to those not soaked, as shown in table 20.

QUANTITY OF BEANS.—To determine the quantity of soaked beans and water that can be used in a 4-quart pressure saucepan, tests were made with the saucepans filled approximately one-fourth, one-third, and one-half full of pea beans and water. There were no visible indications that either of the two saucepans filled to one-fourth or one-third of their capacity was too full. When the air was exhausted from the saucepan that was approximately one-half full, a great deal of liquid spurted out through the vent along with the air. When the saucepan was opened there were particles of beans and globules of fat all the way to the top of the saucepan. In view of these results, it does not seem advisable to fill a pressure saucepan more than one-third full of soaked beans and water.

TABLE 20.—*Effect of soaking conditions on the rehydration ratio* [1] *of pea beans cooked in a pressure saucepan*

Soaking condition	Number of tests	Average rehydration ratio of cooked beans [2]
Unsoaked	1	2.37
1-hour soak (hot)	2	2.64
18-hour soak (cold)	2	2.65

[1] Calculated by dividing weight of soaked or cooked beans by weight of dry beans.

[2] Unsoaked beans cooked 45 minutes, soaked beans, 15 minutes at 15 pounds steam pressure.

GENERAL PROCEDURES

On the basis of the results of the preliminary work the following standard procedure was adopted for cooking dry beans in a pressure saucepan.

SOAKING AND COOKING PROCEDURE.—Two hundred grams of dry beans were soaked by the 1-hour hot-soak method in a glass saucepan (p. 5). A 2-to-1 proportion by volume of water and beans was adopted as most satisfactory for the pressure saucepan studies. After soaking, the necessary weights and measures were obtained and the beans and soaking liquid were transferred to a 4-quart pressure saucepan. One tablespoon of salt pork drippings was added. The cover was adjusted, and the heat was turned on "high" until the air was exhausted, as indicated by a steady flow of steam from the vent

for 1 minute. The pressure indicator was then placed on the saucepan. At this point, the heat was turned to "medium," where it remained until the temperature inside the pressure saucepan was approximately 10° F. below the desired temperature, at which time it was turned to "very low" or "simmer." The heat regulator was turned back and forth frequently to maintain a constant temperature of 250° F. ± 3°.

Temperatures were obtained by means of a thermocouple wire inserted in a rubber stopper. The stopper was placed upside-down in the opening normally used for the safety plug in the cover of each pressure saucepan. The thermocouples were attached to a recording potentiometer. Cooking time was counted from the time a temperature of 250° F. was reached. At the end of the cooking time, the pressure saucepan was removed from the heat and the temperature was allowed to drop gradually to 212°. First the pressure indicator, then the cover, was removed. The beans were drained, weighed, and returned to the pressure saucepan to keep warm for serving.

The control or reference sample for this series of tests was also prepared by the short-soak method and 1 tablespoon of salt pork drippings was added before cooking by the standard method in a 2-quart glass saucepan (table 1).

Cooking Time.—The cooking times recommended by 16 manufacturers of pressure saucepans varied from 15 minutes to 45 minutes for beans soaked several hours or overnight, from 30 minutes to 1 hour 40 minutes for those soaked 1 hour, and from 40 minutes to 2 hours for unsoaked beans. Some manufacturers suggest different cooking times for different varieties; others simply suggest one time with no mention of the kind of bean. Some recommend cooking dry beans at 10 pounds steam pressure; others recommend using 15 pounds.

A cooking time of 25 minutes at a temperature of 250° F. (15 pounds steam pressure) was selected as a starting point for the experiments with pea beans. Other cooking times investigated were 20, 15, 10, 8, and 5 minutes.

Based on the results of the experiments on pea beans, 5 minutes was selected as the initial cooking time for each other variety of bean tested. The palatability scores assigned to this sample were used as a guide in determining the cooking time for the second experimental sample. That is, if the beans cooked 5 minutes at 15 pounds steam pressure were scored too soft, the cooking time for the second experimental sample was reduced accordingly; if the beans were rated too hard or tough the cooking time was increased.

In addition to the cooking time at 15 pounds steam pressure the total cooking time included 7 minutes to reach a temperature of 212° F., 1 minute to exhaust the air from the pressure saucepan, 7 minutes to reach 250°, and 10 minutes to drop to 212°, or a total of 25 minutes to come up to pressure and go down again.

Palatability Determinations.—The same panel as that used for the other studies evaluated the quality of dry beans cooked in the pressure saucepan. At each judging session for pea beans, two or three experimental samples and two control samples, one known to judges and one unknown, were presented to each panel member. In

the pressure saucepan studies of great northern, large lima, pinto, and red kidney beans, two samples cooked different lengths of time, a duplicate of one of these samples, and two controls, one known and one unknown, were included in each session.

Pea Beans

Pea beans cooked 25 minutes at 15 pounds steam pressure were considerably overcooked, as shown by the palatability scores and rehydration ratios (table 21). Similar results were obtained for pea beans cooked either 15 or 20 minutes at 15 pounds steam pressure.

When the cooking time at 15 pounds steam pressure was reduced to 8 or 10 minutes, the palatability scores for the cooked beans were higher but still below optimum.

Pea beans cooked at a temperature of 240° F. (10 pounds steam pressure) required longer cooking time and there was no improvement in palatability. Therefore, all other varieties of beans were cooked only at 15 pounds steam pressure since the objective of the whole study was to reduce the cooking time of dry beans as much as possible and at the same time maintain a product high in quality and nutritive value.

Pea beans stored at 40° F. and prepared by the short-soak method were cooked satisfactorily in a pressure saucepan at 15 pounds steam pressure for 5 minutes. This is a tremendous saving in cooking time compared with the 1½ hours required in a covered saucepan. The mean rehydration ratios for the samples cooked 5 minutes at 15 pounds steam pressure were identical with those of the control sample cooked 1½ hours in a covered saucepan. However, the mean score for texture of cotyledons of those cooked under pressure was somewhat lower than that of the control, 4.3 for the former compared with 5.1 for the latter. Also, in beans cooked under pressure there was less uniformity than in the control. The skin was equally tender cooked by either method. For natural flavor and general acceptability the pressure-cooked beans were rated somewhat lower than the control. The scores for natural flavor were 4.3 and 4.8, respectively, and for general acceptability were 3.9 and 4.6, respectively, for beans cooked in a pressure saucepan and in a covered saucepan.

For the beans stored for 1 year at 75° F., 10 minutes at 15 pounds steam pressure was required for cooking to doneness.

Great Northern Beans

Great northern beans were cooked satisfactorily in 3 minutes in a pressure saucepan at 15 pounds steam pressure. The beans cooked in a pressure saucepan were rated as high in flavor and texture as those cooked by the standard method (table 22). Scores for appearance and acceptability were slightly lower for the pressure-cooked samples.

The rehydration ratio for beans cooked 3 minutes in the pressure saucepan was slightly lower than for those cooked in a covered saucepan for 1½ hours. With 5 minutes cooking, the beans had approximately the same rehydration ratio as those in the covered saucepan, but the cotyledons were too soft.

TABLE 21.—*Palatability scores and rehydration ratios for pea beans cooked in a pressure saucepan compared with pea beans cooked in a glass saucepan*

Description of sample	Method of cooking	Cooking time, in minutes	Mean palatability score[1]						Rehydration ratio[2]	
			Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability	Soaked beans	Cooked beans
					Skin	Cotyledon				
Pea beans stored at 40° F. for 1 year.	At 10 pounds steam pressure	30	3.7	4.4	4.2	2.5	2.5	3.0	1.90	2.57
		25	3.9	4.6	4.4	2.7	3.2	3.2	1.89	2.57
		20	3.7	4.1	4.3	3.3	3.0	2.9	1.90	2.56
		15	4.7	5.0	5.0	4.2	3.8	4.0	1.92	2.47
		10	4.8	5.0	5.0	4.2	3.3	3.8	1.91	2.50
	At 15 pounds steam pressure	25	3.8	4.4	4.2	3.0	3.0	3.2	1.89	2.56
		20	3.7	4.3	4.2	2.7	2.5	2.8	1.91	2.57
		15	3.8	4.5	4.3	2.8	3.0	3.2	1.90	2.55
		10	4.6	5.0	4.8	4.2	3.6	3.9	1.89	2.46
		8	4.3	4.9	4.9	4.0	3.5	3.8	1.89	2.45
		5	4.3	4.9	5.0	4.3	3.5	3.9	1.89	2.38
	In glass saucepan	90	4.8	5.0	5.1	5.1	4.2	4.6	1.89	2.38
Pea beans stored at 75° F. for 1 year.	At 15 pounds steam pressure	10	4.5	4.9	4.9	4.8	3.9	4.1	1.98	2.52
		5	4.6	4.8	5.0	5.3	4.0	4.0	1.98	2.43

[1] Mean of 15 values (3 replicates scored by 5 judges), except for beans cooked in a glass saucepan for which the scores are means of 10 values (2 replicates scored by 5 judges). For interpretation of numerical values, see table 18.

[2] Mean of 3 values for beans cooked in a pressure saucepan, mean of 2 values for beans cooked in a glass saucepan.

TABLE 22.—*Palatability scores and rehydration ratios for great northern, large lima, pinto, and red kidney beans cooked in a pressure saucepan and for comparable beans cooked in a glass saucepan*

Variety of bean	Method of cooking	Cooking time, in minutes	Mean palatability score [1]						Rehydration ratio [2]	
			Intensity of natural flavor	Absence of off-flavor	Texture		Appearance	Acceptability	Soaked beans	Cooked beans
					Skin	Cotyledon				
Great northern	At 15 pounds steam pressure	3	4.2	5.0	4.9	4.8	3.7	3.6	2.08	2.47
	At 15 pounds steam pressure	5	4.2	4.9	5.0	4.4	3.7	3.6	2.09	2.50
	In glass saucepan	90	4.3	5.0	5.0	4.8	4.0	4.0	2.11	2.53
Large lima	At 15 pounds steam pressure	3	4.2	4.9	5.0	4.6	4.3	4.0	2.30	2.43
	At 15 pounds steam pressure	5	4.2	4.9	5.1	4.5	4.2	4.1	2.33	2.46
	In glass saucepan	60	4.1	4.9	5.2	4.8	4.2	4.0	2.33	2.44
Pinto	At 15 pounds steam pressure	5	4.5	4.9	5.0	5.2	4.8	4.2	2.04	2.34
	At 15 pounds steam pressure	10	4.7	5.0	5.1	5.1	4.8	4.4	2.03	2.37
	In glass saucepan	120	4.3	4.7	5.0	4.8	4.2	4.0	2.05	2.38
Red kidney	At 15 pounds steam pressure	3	4.5	5.0	4.8	3.2	3.2	3.3	2.02	2.63
	At 15 pounds steam pressure	5	4.3	4.9	4.8	3.5	3.4	3.4	2.03	2.62
	In glass saucepan	75	4.7	5.0	5.2	4.7	4.1	4.2	2.03	2.46

[1] Mean of 15 values (3 replicates scored by 5 judges), except for beans cooked in a glass saucepan for which the scores are means of 10 values (2 replicates scored by 5 judges). For interpretation of numerical values, see table 18.

[2] Mean of 3 values for beans cooked in a pressure saucepan, mean of 2 values for beans cooked in a glass saucepan.

Large Lima Beans

Palatability scores and rehydration ratios were practically identical for large lima beans cooked 3 minutes at 15 pounds steam pressure and those cooked 1½ hours in a covered saucepan. Beans cooked in the pressure saucepan for 3 minutes were as good as those cooked for 5 minutes.

Pinto Beans

Pinto beans cooked for 10 minutes at 15 pounds steam pressure were superior to those cooked 2 hours in a covered saucepan. The rehydration ratios were the same for beans cooked by either method. Since pinto beans required longer cooking by the usual method than any other variety of beans included in this study, the use of the pressure saucepan for cooking them is a decided advantage.

Red Kidney Beans

Texture of cotyledon of red kidney beans cooked for either 3 or 5 minutes was too soft and the beans were moderately broken in appearance. Skin was tender and flavor was good. Perhaps the cooking time could be shortened to 1 or 2 minutes for red kidney beans.

Summary of Studies on Cooking Dry Beans in a Pressure Saucepan

When dry beans were cooked in a 4-quart pressure saucepan after soaking for 1 hour in hot water, the time required for the different varieties, in addition to the 25 minutes required to reach 250° F. and go down to 212°, was found to be as follows: For great northern, large lima, and red kidney beans, 3 minutes; for pea beans held for 1 year at 40°, 5 minutes; for pea beans stored for 1 year at 75°, 10 minutes; for pinto beans, 10 minutes.

Palatability scores for large lima beans and pinto beans cooked in a pressure saucepan were comparable to those for beans cooked in a covered saucepan. Palatability scores for the other varieties of beans were only slightly lower.

In close agreement with the results of palatability tests, the rehydration ratios of the beans cooked in a pressure saucepan for the optimum length of time were practically the same for a given variety of bean as the rehydration ratio for the same variety cooked in a covered saucepan. Red kidney beans which were slightly overcooked reached a higher rehydration in 3 minutes at 15 pounds steam pressure in the pressure saucepan than those cooked for 105 minutes in a covered saucepan.

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