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A STUDY OF SOYBEAN
VARIETIES *With reference to*
THEIR USE AS FOOD

By SYBIL WOODRUFF
and HELEN KLAAS

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UNIVERSITY OF ILLINOIS
AGRICULTURAL EXPERIMENT STATION

Bulletin 443

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CONTENTS

	PAGE
PLACE OF SOYBEANS IN THE DIET.....	426
GREEN SOYBEANS.....	429
General appearance.....	429
Season for use.....	430
Sugar content.....	431
Method of cooking for palatability tests.....	431
MATURE SOYBEANS.....	433
General appearance.....	433
Method of cooking for palatability tests.....	433
RATING THE SOYBEANS FOR QUALITY.....	435
Judging the cooked soybeans.....	435
Field ratings and crop yields.....	436
VARIETIES HAVING SUPERIOR QUALITIES.....	439
CHEMICAL ANALYSES OF SOYBEANS.....	441
Methods used.....	441
Discussion of results.....	442
Chemical values of soybean oil.....	448
EXPERIMENTS IN PRESERVING GREEN SOYBEANS.....	448
Freezing preserved fresh qualities.....	448
Canned beans lost fresh qualities.....	449
Drying holds some promise.....	451
SOYBEAN FLOURS COMPARED.....	451
SUMMARY.....	453
LITERATURE CITED.....	454
APPENDIX: Detailed ratings of green and dry soybeans in Illinois tests...	456

A Study of Soybean Varieties With Reference to Their Use as Food

By SYBIL WOODRUFF and HELEN KLAAS*

SOYBEANS used whole as a food are still little known to people in the United States, even tho they have been a substantial part of the diet in Oriental countries for hundreds of years. Because of the enormous increase in the volume of soybeans produced in this country in recent years, there is a widening interest in their possibilities as a food. The rapid expansion of the acreage of this crop in Illinois in the last decade has given the Illinois Station special interest in this problem.

The number of types and varieties of soybeans^b is probably many hundreds, if not thousands. Among the many types and varieties are to be found wide differences in color, appearance, flavor, texture, and other characteristics which affect their acceptability as food. In the work reported in this bulletin, which has extended over three years, 466 varieties and selections have been tested for their possible use as food both at the green-vegetable stage and as mature beans. All these varieties and selections have been grown by the Department of Agronomy of this Station in their search for varieties that are adapted to this part of the United States. The majority of the beans are still known only by serial number and are being grown for experimental purposes in a few of the other agricultural experiment stations of the country also. They are called "vegetable types" because they were already being used as food in the Orient when the seeds were obtained by the Bureau of Plant Industry of the U. S. Department of Agriculture. A considerable number of field types, that have been grown for feed, crushing, or forage in the Illinois area, have also been included in the study.

As a result of these tests, seventeen varieties of soybeans have been chosen as having superior qualities for edible use. The selections have been based largely on palatability and not on relative nutritive value.

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^b"Soja max" under American rules of botanical classification.

Taste and texture, the authors believe, are of primary importance in making the first selections of varieties to be used as food, and any unique advantages in nutritive value which any of them may have can most profitably be sought later among the most palatable ones. The fact that in flavor and texture soybeans are unlike other kinds of beans with which the Occidental palate is familiar makes the palatability factor unusually important.

PLACE OF SOYBEANS IN THE DIET

Altho, as already stated, whole soybeans are not yet being used extensively in this country as a food, quantities of food products manufactured from soybeans are being so used. The principal products are salad oil made from refined soybean oil, and hydrogenated margarines and shortenings.^a The amount of soybean flour being used in food manufacture is also significant. And the long list of food novelties which derive more or less of their substance from soybeans indicates the versatile character of this legume.^{4, 5*} But notwithstanding these many uses, soybeans constitute today only a small part of the nation's food supply.

Vegetable soybeans have two potential uses in the United States. They would add further variety to the limited list of green vegetables available in many markets in the early fall. And the mature beans could be used to increase substantially the protein and the calorie contents of low-cost diets; they are already being used to some extent for this purpose. The future use of soybeans in this country as a low-cost food will depend upon economic conditions and the need of finding cheap sources of protein. It will also depend on the physiological tolerance of people in this country for soybeans should they be eaten regularly over long periods of time and in rather large amounts. This has not been determined experimentally, tho the fact that soybeans have served as the sustaining food in certain parts of the Orient for hundreds of years, where they have long been known as "poor man's meat," is in their favor.

The unusually high percentages of protein and oil in soybeans (Table 1) partly explain their unique nutritive value. In both green and dry forms they contain much more protein and fat than other legumes, but their carbohydrates are lower. Total ash, likewise cal-

*The U. S. Census figures for 1936 indicate a factory consumption in that year of 150 million pounds of soybean oil for food uses. In the same year 26 million pounds of this oil were used for industrial purposes.

TABLE 1.—PERCENTAGE COMPOSITION OF SOYBEANS AND SOME COMPETING FOODS

Food	Moisture	Protein N x 6.25	Fat	Total carbohy- drates by differ- ence	Total ash	Calcium	Iron	Calories per pound
<i>Green, shelled</i>								
Soybeans ^a	70.0	12.2	5.2	11.1	1.52	.072	.0029	636*
Lima beans ^b	66.5	7.5	.8	23.5	1.71	.028	.0024	595
Broad beans ^b	74.1	8.1	.6	15.8	1.40	.....	.....	460
Peas ^b	74.3	6.7	.4	17.7	.92	.028	.00207	460
<i>Mature, dry</i>								
Soybeans ^a	7.0	40.6	16.5	30.9	5.0	.212	.0103	1 973*
Lima beans ^b	10.4	18.1	1.5	65.9	4.1	.071	.0086	1 586
Navy beans ^c	12.6	22.5	1.8	59.6	3.5	.158	.0079	1 564
Peas ^c	9.5	24.6	1.0	62.0	2.9	.084	.0057	1 612
<i>Flour</i>								
Soybean ^d	5.1	42.5	19.9	24.3	4.5	.....	.....	2 026*
Wheat ^e	12.4	11.2	1.0	74.9	.5	.021	.0008	1 603

^aAnalyzed in authors' laboratory. Figures represent an average of 12 samples of green and 22 samples of dry soybeans grown in 1935 and 1936.

^bAnalysis is from U. S. Dept. Agr. Circ. 146 (1931) except for calcium and iron, which were taken from Sherman.

^cAnalysis is from Sherman, *Food Products*.^{31*}

^dAnalysis is by Street and Bailey^{36*} and is an average of 7 commercial flours.

^eNo correction has been made for carbohydrates which may not be utilized by the body.

cium and iron, compares very favorably with that of the other competing foods listed. In fact the calcium and iron of both green and dry soybeans make very favorable showings in any list of foods which are generally considered rich sources of these two elements.

The literature on the nutritive value of soybeans is either incomplete or conflicting to such degree that comprehensive laboratory tests with present-day technics are needed. Expressions of vitamin values are particularly open to criticism owing to the fact that different investigators, reporting frequently on one vitamin only, have used various feeding technics and have fed different parts of one unidentified variety of soybeans. The soybean products have in turn been processed differently. All this makes a brief summary of findings on the vitamin content of soybeans a well-nigh impossible undertaking. Vitamins A, B, and G have been reported by various investigators to be present in mature soybeans. Mitchell,^{24*} however, in a communication concerning unpublished work, expresses doubt that vitamin A is present in significant amounts. It has even been claimed by some investigators that soybeans have a component that is inimical to the functioning of vitamin A.^{14, 37*} Such unfavorable opinions are offset by numerous reports that soybeans in some form have served as a good source of each of the vitamins. One is obliged to await still further work on the subject. The only evaluation of vitamins in green cooked

soybeans is that of Miller and Robbins,^{23*} who reported them to be a very good source of vitamins A, B, and G and a poor source of C.

It seems to be within the limits of accuracy to say that soybeans in a mixed diet are a good source of calcium and iron, whether they are compared with other legumes or with other plant foods which are generally classed as being rich in these elements. Moreover, soybeans as a source of iron have been reported by Sherman, Elvehjem, and Hart^{32*} to be in a class with liver as an agency for regenerating hemoglobin in anemic rats.

Only a few experiments have been reported in which the utilization of soybean proteins has been determined by feeding to human subjects, but there are countless records of the feeding of soybeans and soybean oil cake or meal to all kinds of farm animals and to small laboratory animals. The experiments with animals have shown that far better use of their proteins is made if the beans are cooked or heated before they are fed.^{34*} Hayward, Steenbock, and Bohstedt^{35*} demonstrated that heating soybeans caused the cystine fraction of the protein to become more available to rats, after Mitchell and Smuts^{25*} and Shrewsbury and Bratzler^{33*} had pointed out cystine deficiencies of soybean proteins. But there also appears to be some fluctuation in the amino-acid distribution and cystine content of the proteins of different varieties of soybeans.^{9, 10*} Soybean protein has been said by McNaught *et al*^{21*} to be excellent for blood plasma regeneration in dogs and by Plimmer *et al*^{28*} to be superior to proteins of certain other plant and animal sources for growth of chicks. Mitchell^{24*} has recently found the biological value of proteins of autoclaved soybeans fed to young growing rats to be about the same as for proteins of whole wheat and cottonseed.

Soybean-flour proteins, when fed to young men for several days as almost the sole source of protein in the diet, were shown by Holmes^{17*} and by Mendel and Fine^{22*} to be utilized to the extent of about 85 percent of the amount fed, which was but slightly less than the coefficient of digestibility of the protein of a mixed diet. Lyman and Bowers^{19*} found the coefficient to be even as high as 91 percent when fed to one man. Rose and MacLeod,^{30*} however, reported that one young woman utilized only 76 percent of the nitrogen she ate as soybean curd, tho that part of the nitrogen which was used appeared to be efficient in maintaining nitrogen equilibrium.

Current information about the nutritive value of the proteins of cooked soybeans appears to be favorable to the use of soybeans if they are taken in combination with other foods which supplement them.

Soybeans have for some time been recognized as having special dietetic value where allergies to cow's milk and wheat flour exist. A milky suspension, resembling cow's milk in outward appearance and containing proteins and other constituents, can be removed from soybeans with water and is one form in which soybeans may be fed to infants who are allergic to cow's milk. Soybean-flour preparations have been used successfully in infant feeding by Rittinger, Dembo, and Torrey,^{29*} by Stearns,^{35*} and also by Hill and Stuart.^{16*}

The many ways in which soybean flour is now being used in the ordinary human dietary have recently been enumerated by Bailey, Capen, and Le Clerc.^{4*} Owing to the presence of only a trace of starch, if any, soybeans, and particularly soybean flour, were frequently referred to, in the days before the use of insulin, as a diabetic food. However, mature soybeans contain about 30 percent total carbohydrates, of which Adolph and Kao^{1*} have found about two-fifths to be utilized in the animal body. They should not, therefore, be looked upon as a carbohydrate-free food.

Because of the absence of gluten and starch, soybean flour, substituted wholly for wheat flour, produces a baked product very different in appearance and texture from the usual one.

GREEN SOYBEANS

General appearance. Soybeans are ready to be used as a green vegetable as soon as the pods have filled out but while they are still about as green as those shown in the color plate opposite page 432. As the pods turn yellow and become dry, the seeds change color also, but the immature soybean seed is always green no matter what the color of the dry seed is to be. However, in beans which are to be black, mottled, or of various other dark colors on maturing, tinges of red, blue, purple, and olive brown appear within a few days after the beans have developed to an edible stage. Beans that will be yellow when dried show a gradual fading of their bright-green color to a yellow-green or a green-yellow as they pass the best stage for use as a green vegetable.

The actual size of three of the best vegetable types photographed on September 11, 1936, is shown in the accompanying color plate. Imperial (81780) (top) was at an undermature stage on this date, and the other two were approaching the end of the best stage for vegetables. Differences due to this fact are to be seen in the plate in both color of pods and size of beans.

How the color of the fresh beans is intensified by cooking is shown by a comparison of the two rows of shelled green beans. All three varieties are, when fully mature, yellow colored and almost spherical, as shown in the plate.

Two-seeded pods were chosen for the photograph because they were found to predominate, amounting to 57 to 74 percent of the total pods counted. The remainder consisted of one- and three-seeded pods.

Season for use. As grown in central Illinois, some varieties are ready for use as a green vegetable soon after the middle of August, others not until the last week of September. Some variation may also occur from year to year owing to date of planting and weather conditions; moreover, their rate of maturing may possibly not be the same in small garden plantings as in fields.

TABLE 2.—DATES AT WHICH EIGHTEEN VARIETIES OF SOYBEANS WERE AT SUITABLE GREEN STAGE FOR USE AS FOOD

Maturing habit	Variety ^{a, b}	Date for best use ^c	
		1935	1936
Very early.....	Giant Green.....	.....	Before Aug. 26
	80494.....	Before Aug. 30	Aug. 27
Early.....	81029 (Fuji).....	Sept. 4	Aug. 31 to Sept. 4
	85666 (Hokkaido).....	Sept. 16	Aug. 31 to Sept. 8
	81031 (Bansel).....	Aug. 30	Aug. 31
Intermediate.....	Illini.....	Sept. 16 to 22	Sept. 1
	81044-1 (Willomi).....	Sept. 9 to 21	Sept. 1 to 15
	87615 (Jogun).....	Sept. 3 to 11	Sept. 3 to 9
	84979.....	.....	Sept. 4
	87617.....	.....	Sept. 8
	89162.....	.....	Sept. 8
	87606.....	.....	Sept. 9
Late.....	80490-1.....	.....	Sept. 10
	97155.....	.....	Sept. 11 to 16
	Funk Delicious.....	.....	Sept. 10 to 25
	Illington.....	Sept. 12	Sept. 12
	Higan (80475).....	Sept. 22	Sept. 18
	81780 (Imperial).....	Sept. 16	Sept. 21

^aThe serial numbers used thruout these tables are those of the Division of Plant Exploration and Introduction (formerly known as Division of Foreign Plant Introduction), Bureau of Plant Industry, U. S. Department of Agriculture.

^bThese are the same varieties that are listed in Table 4 as having superior qualities for edible use, except that a variety called Giant Green, which did not rank with the 17 superior varieties, is included in this table because it was the earliest maturing green soybean among those studied.

^cWherever one date only is given, the soybeans might be used a few days before and a few days following that date. The exact range was not determined.

The dates when seventeen varieties chosen as being superior were ready for use as green vegetables in 1935 and 1936 are given in Table 2. Altho not ranked with the superior varieties, Giant Green is included in the table because it was the earliest maturing green soybean. These varieties had all been planted either in rod rows or in "increase plots."

Each variety remained green long enough to be gathered over a period of several days, some even for ten days. By planting varieties with different maturing habits, the season for green soybeans could be extended to at least four weeks longer.

Sugar content. Sweetness is one important point of excellence in the flavor of green soybeans just as it is in green peas and lima beans. A more complete discussion of the sugars present in soybeans is included later in this bulletin, but it is appropriate to point out here that the total sugars of green soybeans begin to diminish immediately after harvesting, tho loss of a sweet taste does not become pronounced until the beans have stood in the pods at room temperature for about 24 hours. Diminution in sugar content of two varieties which

TABLE 3.—DECREASE IN PERCENTAGE OF TOTAL SUGARS IN GREEN SOYBEANS STORED IN THE PODS AT ROOM TEMPERATURE^a
(Moisture-free basis)

Time after harvesting	Total sugars in two varieties	
	Hokkaido (85666)	Illini
	<i>perct.</i>	<i>perct.</i>
0-1 hour.....	16.44	15.25
4 hours.....	15.30	9.02
24 hours ^b	10.44	7.09
48 hours.....	11.13	6.44
72 hours.....	7.79	5.45

^aBoth varieties were gathered at the same time in the morning.

^bThe change in sweet flavor was not marked until after the first 24 hours of storage.

were harvested at the same time in the morning and then analyzed at once and again at intervals up to 72 hours after harvesting, is shown in Table 3. The field type of bean (Illini) lost its sugar even more rapidly than did the vegetable type, the sugar content of the former dropping from 15.25 to 7.09 percent in 24 hours and that of the latter from 16.44 to 10.44 percent in that time. This points to the necessity of using green soybeans as promptly as possible after the pods are removed from the plant.

Method of cooking for palatability tests. The fibrous pod of the soybean cannot be eaten, but the beans can be cooked either in the pod and shelled later, or they can be shelled and then cooked. Because of the greater ease of judging them when hot, the second method was used for all the tests. Shelling was facilitated by pouring boiling water over the pods and allowing them to stand in it for 5 minutes. The hot water was drained off and the beans were cooled with water from the tap. With one motion the pod was broken open and the beans squeezed out.

Green Soybeans Photographed on September 11, 1936
And One Row of Mature Beans

Upper group: F.P.I. 81780 (Imperial)

Center group: F.P.I. 85666 (Hokkaido)

Lower group: F.P.I. 87615 (Jogun)

The beans of Imperial were much less mature on this date than were those of the other two varieties, which were at their best for edible use.

Shelled Beans

Left row: as they come from the pod

Center row: green color intensified by cooking

Right row: mature beans



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A skilful laboratory assistant was able to shell a pound of soybeans of the vegetable type (weighed in the pods) in 9 to 12 minutes. One pound yielded about half a pound of shelled beans. Many of the field types required longer shelling time.

The shelled beans from 100 grams (weighed in the pods) were cooked in glass beakers covered with watch crystals for 9 minutes after boiling started. For this amount 36 cc. of distilled water and 4 cc. of a 10-percent solution of sodium chlorid were used. At the end of the cooking period the small amount of remaining water was drained away and the beans were ready to be judged. This small amount of salt was believed to make more noticeable any slight differences in flavor.

MATURE SOYBEANS

General appearance. There is great variation in the color, shape, and size of different kinds of soybeans in their mature stage. Only the yellow or light-colored ones have been given superior rating in this study, for it was believed that popular prejudice against the others might be expected. Crushing mills use only light-colored beans because of the better color of the resulting meal and flour. There are, however, many black varieties, others brown, gray-green, mottled and variously marked. All the latter discolor the cooking water and many become discolored themselves during cooking. The yellow beans are but little darker than navy beans after they are cooked.

A few varieties of soybeans are somewhat flattened when dry, tho the majority are very nearly spherical, as shown in the color plate. As they absorb water during soaking or cooking, they elongate to a shape not greatly different from navy and lima beans. This change in shape during swelling is illustrated by the photograph on page 434, which also shows two varieties of yellow soybeans that are at two extremes of size, the Illini being quite small and Hokkaido (85666) being one of the largest vegetable types with which the authors have worked. For comparison the plate shows a sample of navy beans and also another well-known field type, Mansoy, which differs from Illini in having a distinct black hilum.

Method of cooking for palatability tests. Most dry soybeans, excepting some of the black field types, swell and cook to a tender condition even more readily than do other kinds of beans. People have been misled into thinking this is not so by the fact that when the soybean has reached its maximum degree of softness it is rather nut-like in texture and not "mushy" like a navy bean.

DRY BEANS



SOAKED BEANS



NAVY

F. P. I. 85666

ILLINI

MANSOY

Mature Soybeans of Three Varieties Compared With Navy Beans

The vegetable type of bean, F.P.I. 85666 (Hokkaido), is the largest bean in the photograph. Illini, a field type, is the smallest. Almost spherical when dry, soybeans swell to an elongated, somewhat flattened shape when soaked in water. The swollen beans shown above were in water overnight.

In these tests preliminary soaking was not essential, so far as softening effects were concerned, for the beans cooked almost as quickly when not soaked. But the seed coats of unsoaked beans slipped off more readily during cooking, giving the beans an unsightly appearance. Both color and volume of the cooked beans were somewhat improved by the soaking, and furthermore the soaking water seemed to remove some of the strong flavor which otherwise was noticed. Four of the large edible varieties weighing an average of 171 grams per cupful dry increased on soaking to 2.58 times their weight and 2.75 to 3.0 times their volume. Illini soybeans, a small field type, increased on soaking from 174 grams per cupful dry to 2.38 times their original weight and to 2.5 times their volume.

For these tests 25 grams of dry beans were soaked overnight in distilled water. The next morning they were drained and 117 cc. of fresh distilled water was added, together with 8 cc. of a 10-percent solution of sodium chlorid. The beans were found to cook equally well in distilled and in hard tap water. They were cooked in glass beakers covered with watch crystals for 1 hour and 15 minutes, and then judged.

RATING THE SOYBEANS FOR QUALITY

Judging the cooked soybeans. Both green and mature cooked soybeans were judged for quality both while hot and after they had cooled, inasmuch as certain characteristics were more pronounced at one temperature than another. Each variety was cooked and judged on at least two or more different occasions by each of two or three experienced judges, and the final judgment was a composite of all. It was concluded that the opinions of the same few judges, working thruout the period devoted to the tests, were worth more in detecting points on which soybeans are apt to meet with disfavor than was the occasional sampling by persons unacquainted with the peculiarities of the product. Volunteer judges were out of the question, anyway, for judging the green beans, because of the large numbers of samples handled and the necessity for devoting eight hours a day to the work.

There were times when larger numbers of both men and women were asked to check the opinions of the official judges. On one such occasion all 16 judges, except one woman, agreed on the soybean sample which, among three, had the best qualities. Four of six men and five of ten women agreed on rating one as the poorest. Otherwise their opinions varied so widely that no more confidence could be placed

in the average opinion of the many judges than in the opinion of a few experienced judges.

The ratings given in this bulletin to the soybean varieties tested should be looked upon merely as the composite judgments of one group of persons and certainly not as the infallible and only order of goodness. Wherever the senses are being relied upon to the extent they were here, the resulting ratings are necessarily open to disagreement from other groups of judges.

The best idea of the standards of quality on which the judges based their decisions can be given by defining each rating. The judges kept in mind that people in rural areas of this part of the United States prefer foods which are not strong or highly flavored. A rating of "very good" was given only to samples which were bright green when immature and light colored or yellow when mature; that had a sweet, pleasing flavor; and that were tender but not "mushy" in texture. Testing by this standard eliminated large numbers having little in their favor as food.

Shelling time was also considered in rating the green beans, for it is a factor of some importance to the homemaker and deserves consideration where varieties are being selected for introduction as garden vegetables.

The two record sheets used in judging the food qualities of the soybean samples are shown on pages 437 and 438. The most desirable characteristic of each item is placed at the extreme right in the chart and the least desirable farthest to the left. At the bottom is a line where the composite rating is indicated. This rating was obtained somewhat as a weighted average is obtained. For example, a rating of "very good" in the green beans meant that the shelling time per 100 grams (weighed in the pods) was 2.5 to 3 minutes and that each of the other qualities was checked in position 5. A rating of "good" meant that a variety was slightly inferior on two points or definitely inferior on one point. A "fair" rating meant that it had fallen down markedly on two points or slightly on three points. A rating of "poor" was given when a variety fell below on all points or when its flavor was particularly unpleasant. The cooked dry soybeans were rated in similar fashion but of course without reference to shelling time.

Field ratings and crop yields. For the purposes of this study the agronomic behavior of the soybeans was of little importance; hence plant characteristics and seed descriptions are not included in this bulletin. Nevertheless a soybean variety which is very palatable as food would have little interest to growers if it did not yield well and have

RECORD SHEET FOR COOKED GREEN SOYBEANS

Date harvested.....Sample No.....

Date cooked.....Number of pods per 100 grams.....

Shelling time for 100 grams.....Weight of beans, percent.....

Pod condition.....

Color of uncooked seed coat.....

Size and shape of beans.....

Appearance of cooking water.....

Splitting, etc., of cotyledons.....

Method of cooking.....

Item		Qualities					Remarks
		1	2	3	4	5	
(a) Skin		Much breaking and sloughing	Broken with slight sloughing	Wrinkled	Slightly broken	Intact and smooth	
(b) Color	Quality	Mottled	Black	Olive	Yellow-green	Green	
	Intensity	.....	Slight	Moderate	Very	....
(c) Texture	Quality	Mushy	Hard	Waxy	Mealy	Nutty	
	Intensity	.....	Slight	Moderate	Very	....
(d) Flavor		Strong	Flat	Mild	Sweet	Sweet-nutty	
Items rated low		Shelling time	(a) Skin	(b) Color	(c) Texture	(d) Flavor	
Composite rating for food use.....		Very poor	Poor	Fair	Good	Very good	

Remarks:.....

Recorded by.....

RECORD SHEET FOR COOKED DRY SOYBEANS

Date cooked.....Sample No.....

Size and shape of dry beans.....

Color of dry beans.....

Weight of dry beans.....Weight after soaking.....

Volume of dry beans.....Volume after soaking.....

Length of soaking period.....Weight after cooking.....

Volume of water used in soaking.....Volume after cooking.....

Size and shape of cooked beans.....

Appearance of cooking water.....

Method of cooking.....

Item		Qualities					Remarks
		1	2	3	4	5	
(a) Skin		Much breaking and sloughing	Broken with slight sloughing	Wrinkled	Slightly broken	Intact and smooth	
(b) Color	Quality	Mottled	Black	Brown	Green	Yellow	
	Intensity	.....	Slight	Moderate	Very	....
(c) Texture	Quality	Mushy	Hard	Waxy	Mealy	Nutty	
	Intensity	.....	Slight	Moderate	Very	....
(d) Flavor		Strong	Flat	Mild	Sweet	Nutty	
Items rated low . . . .		.....	(a) Skin	(b) Color	(c) Texture	(d) Flavor	
Composite rating for food use		Very poor	Poor	Fair	Good	Very good	

Remarks:.....

Recorded by.....

good field possibilities, tho of course certain unfavorable features might be corrected thru breeding. For the varieties having superior qualities as judged on the basis of palatability, the Department of Agronomy of the University of Illinois has furnished data on yields and has assigned field scores, taking into account the general appearance of the plants and their tendencies to lodge and to shatter.

VARIETIES HAVING SUPERIOR QUALITIES

During the three years of these tests 466 varieties or selections of soybeans were subjected to palatability tests and, in the case of green beans, to shelling-time tests. The data on ratings may be summarized as follows:

Very good	6
Good.....	11
Good (less promising).....	59
Fair.....	259
Poor.....	131
Total.....	<u>466</u>

Complete records of the tests are given in Table 10, pages 456 to 467. It will be noted that many of the varieties were tested only in 1936, and some were used in one form only, either as green or as dry mature beans. More varieties were tested in 1934 than is indicated by the table, but because the testing methods had not been refined at that time some of the results for that year are omitted.

More complete information about the seventeen varieties that seemed to have the greatest possibilities is given in Table 4, page 440. It will be noted there that all those in the "very good" group had either high or medium yields. In scoring these seventeen varieties for field behavior, all were compared with Illini, whose field behavior was placed at 100. The field scores of several of the seventeen were satisfactorily high in 1935 but all were fairly low in 1937.^a It is noteworthy that those which shatter little in the field, Illini for example, are more difficult to shell as green beans than most of the vegetable types and their rating for food use was lowered on that account. Attention is called again to the time at which these varieties matured to the proper stage for green vegetable use, which is discussed on page 430 and on which data are presented in Table 2.

The six varieties ranked "very good" were all large yellow-colored

^aIt will be noted in Table 4 that field scores are for 1935 and 1937; yields for 1935 and 1936.

TABLE 4.—SEVENTEEN VARIETIES OF SOYBEANS CHOSEN FOR THEIR SUPERIOR QUALITIES FOR FOOD USE

Rating	Variety	Years study was made	Palatability characteristics	Field score ^a		Crop yield ^a			
				1935	1937	1935 ^b	1936		
Very good.	81044-1 (Willomi)	1934, 1935, 1936	All in this group are large yellow beans of good flavor; very good also as green beans	98	80	High	Medium ^e		
	81780 (Imperial)	1935, 1936		90	80	Medium	High ^e		
	85666 (Hokkaido)	1934, 1935, 1936		94	70	High	Medium ^e		
	87615 (Jogun)	1934, 1935, 1936		91	80	High	Medium ^e		
	97155	1936		...	75	.....	.....	High ^e	
	Funk Delicious	1935, 1936		...	80	.....	.....	High ^e	
	Good	80490-1		1936	Somewhat flavorless, some sloughing of skins	...	75	.....	Low ^e
		80494		1936	Somewhat flavorless	...	80	.....	Medium ^e
		81029 (Fuji)		1934, 1935, 1936	Imperfect color	70	70	Medium	.....
		81031 (Bansai)		1934, 1935, 1936	Only medium size, somewhat flavorless	84	...	.....	High ^e
		84979		1936	Sloughing of skin	...	65	.....	Medium ^d
		87606		1936	Somewhat flavorless, hard	...	75	.....	Low ^d
		87617		1936	Somewhat flavorless, hard as green beans	...	70	.....	Medium ^d
		89162		1936	Somewhat flavorless, imperfect color	...	70	.....	Medium ^d
		Higan (80475)		1935, 1936	Somewhat strong flavor	94	75	High	Medium ^e
		Illini		1934, 1935, 1936	Small size, slightly hard in texture	100	100	High	High ^e
	Illington	1935, 1936		Somewhat strong flavor	86	65	Medium	Medium ^e	

^aField scores and crop yields were furnished by the Department of Agronomy. The field score takes into account general appearance, lodging, shattering, etc., the performance of Illini being taken as 100.

^bYields in 1935 were determined by replicated rod rows.

^cGrown on "increase plots" $\frac{3}{4}$ to $\frac{1}{2}$ acre in size. High yield = above 24 bushels per acre; medium = 19 to 24 bushels per acre; low = below 19 bushels per acre.

^dGrown in rod rows. High yield = above 29 bushels per acre; medium = 19 to 29 bushels per acre; low = below 19 bushels per acre.

beans when they reached the dry mature stage. Hokkaido, which is shown in both plates, is typical of the appearance of all. It might be mentioned that as a green bean Fuji (81029) had good flavor and was well liked but its color when mature was a muddy green. Kura (81042) which has been favored by judges elsewhere, was not approved both because of an unpleasant flavor and because of a black saddle marking which, after cooking, gave the bean a "dirty" color.

This total of seventeen superior varieties offers a wide choice from which to make still more specific selections on the basis of other qualities than those considered here. It is the belief of the writers that any of the varieties in the "very good" group might easily be accepted as new vegetables by the American public, whether on the basis of their food value or because of their being a palatable green vegetable. Dry soybeans can be used in any of the ways in which navy and lima beans are now eaten. The varieties listed as "good" were less uniformly praiseworthy, tho all had good possibilities.

The stock of seeds of these vegetable types is still limited but is being built up as rapidly as possible. Distribution of samples for garden planting has been made by the Department of Horticulture of this Station for the past two years, but so far as known, seeds of these varieties are not at present purchasable.^a

CHEMICAL ANALYSES OF SOYBEANS^b

Methods used. With the exceptions noted, the official methods of the Association of Official Agricultural Chemists were followed in making the chemical analyses of all soybean samples. In the moisture determinations drying was continued for 24 hours at 80° C. in vacuo, with a slow current of dry air passing thru the oven. The material was ashed at 600° C., and in the calcium determinations potassium permanganate solution of .01 N. concentration was used in titrating. For iron analyses the samples were ground in a porcelain mill, sifted thru bolting cloth, and the thiocyanate colorimetric method of Farrar^{13*} with some modifications was used. The material was ashed in the same pyrex beakers in which solution was later made; calcium carbonate was not added, and 2 drops of .5 percent potassium permanganate was used for the final oxidation instead of hot nitric acid. A mixture con-

^aThe one exception to this statement is the variety listed as Funk Delicious.

^bAcknowledgment is made of the assistance rendered by Rosalind E. Mills and Hazel R. Coe in the analytical part of this study.

sisting of 40 percent diethyl ether and 60 percent n-amyl alcohol was used to extract the color produced by a 10-percent solution of potassium thiocyanate.

Fat was extracted by continuous dripping of petroleum ether (b.p. 30° to 60° C.) for 24 hours over ground material which had been air-dried only.

For sugar determinations the green beans were placed at once in 75 percent ethyl alcohol, using 500 cc. per 100 grams of beans, and were boiled 10 minutes. At the time of analysis the alcohol was poured off and saved; the beans were ground in a mortar and transferred with fresh 75 percent alcohol to a flask where they were boiled for one hour. This alcohol was filtered off and the process repeated four times. These four extracts and the original one were combined, with precautions against loss, and the alcohol was then evaporated on a water bath. The remaining solution was made up to known volume, and after the usual process of clarification with lead acetate, aliquots were hydrolyzed with hydrochloric acid and the reducing sugars present were determined by the Lane and Eynon volumetric method.

Discussion of results. The analyses of green soybeans which are given in Table 5 include three varieties not included in the superior group—80488-1-1, Kura, and 87633. There was no particular reason for analyzing any of these three excepting Kura which, tho not rated in this laboratory as "good," has been found by investigators in other sections of the United States to have good flavor. Several varieties which, after the tests were complete, were found to rate high in palatability had not been subjected to analysis at the green stage; these were Nos. 97155, 80490-1, 80494, 84979, 87606, 87617, Bansei (81031), and Illington.

At a stage of maturity deemed suitable for soybeans that are to be used as a green vegetable, the twelve varieties analyzed had a moisture content of about 70 percent, tho they could have been used when they contained as high as 79 or as low as 67 percent. They showed too little variation in the distribution of other constituents, or such differences were too irregular, for it to be at all likely that any superiority of one over another could be explained on basis of composition. The three varieties mentioned above as not belonging to the superior group were a possible exception to this statement, their sugar contents being well below average. The percentages both of iron and of calcium fluctuated to about the same extent in all twelve varieties.

When the soybeans were nearing the correct stage of maturity for use as a green vegetable, the percentage of water in them was found to

TABLE 5.—PERCENTAGE COMPOSITION OF TWELVE VARIETIES OF SHELLED GREEN SOYBEANS, EACH AT A SUITABLE STAGE OF MATURITY FOR FOOD USE

Variety*	Moisture	Protein N x 6.25	Fat	Carbohydrates			Ash		
				Total (by diff.)	Fiber	Sugars	Total	Calcium	Iron
80488-1-1.....	73.3	10.78	5.05	9.45	1.34	2.80	1.43	.089	.0023
81029 (Fuji).....	70.7	11.60	5.92	10.17	1.25	4.81	1.57	.086	.0027
81042 (Kura).....	69.1	12.70	5.22	11.52	1.48	3.80	1.49	.069	.0033
81044-1 (Willhorn).....	69.2	13.14	4.96	10.96	1.28	4.55	1.77	.061	.0030
81780 (Imperial).....	71.6	11.30	4.15	11.48	1.13	4.24	1.44	.069	.0029
85666 (Hokkaido).....	71.3	11.38	4.66	11.22	1.12	4.72	1.48	.068	.0027
87615 (Jogun).....	67.7	13.32	6.99	10.21	1.36	3.99	1.73	.063	.0036
87633.....	68.0	13.23	4.96	12.34	1.51	3.70	1.42	.073	.0030
89162.....	68.8	13.25	4.66	11.67	1.35	4.85	1.60	.079	.0029
Funk Delicious.....	73.0	11.06	4.14	10.50	1.03	4.85	1.33	.060	.0027
Higan.....	67.6	13.42	6.35	11.12	1.36	3.78	1.52	.076	.0033
Illini.....	69.0	11.82	5.60	12.16	1.43	4.73	1.46	.070	.0027
Average.....	70.0	12.25	5.22	11.07	1.30	4.18	1.52	.072	.0029

*This list includes nine of the varieties listed in Table 4 as having superior qualities for edible use. Nos. 80488-1-1, Kura, and 87633 included above are not in the superior group.

be diminishing rapidly and likewise the amount of sugars. The steady increase in the percentage of protein and oil, on the moisture-free basis, is shown in Table 6. When compared at two different levels of moisture content, the changes in the amount of sugar in each variety were quite similar to the changes in the sums of the percentages of protein and oil. The different ash constituents were laid down in the bean in about the same percentage of dry substance at all stages of maturity.

It can be said of the mature soybeans, as of the green ones, that no outstanding differences in the percentage distribution of constituents was observed in the different varieties reported in Table 7, with the possible exception of oil, which varied from 13.72 to 20.09 percent. The higher figure was for the field type, Illini. Since their moisture contents varied from 5 to 8 percent, all are reported on a 7-percent moisture basis.

While analyses of mature soybeans for protein and oil abound in the literature, there has been relatively little reported on the different ash constituents. Winton^{38*} has summarized several very early analyses of the minerals of soybeans; the more recent ones coming to the attention of the authors for both green and mature seeds are included in Table 8 for the purpose of comparing them with the results reported in this bulletin. The percent of iron found in mature vegetable soybeans in the present study was considerably higher than that given by either Wu^{39*} or McHargue.^{20*} The latter used ten different kinds of field soybeans. The various reports of calcium show considerable variation. The analyses of one variety of green soybeans by Miller and Robbins^{23*} were similar to the averages reported in this study.

Of the carbohydrates, only fiber and total sugars were determined in this study. The average amount of sugar in fresh green soybeans at a suitable stage of maturity for food use is reported in Table 5 as being 4.18 percent. On the basis of their dry substance, however, (Table 6) green beans were shown to contain on an average 18.2 percent of sugar, which is but little less than the amount (25 percent) green peas have been reported to contain in their dry substance. The soybean sugars are apparently converted into other constituents as the beans mature, since the amount of sugar was found to have fallen to 9.65 percent of the moisture-free substance by the time the beans were fully ripe. The sugar content of mature soybeans reported on a 7-percent moisture basis ranged from 7.18 to 9.62 percent, as shown in Table 7, and averaged 8.95 percent. The mature beans also tasted less sweet than the green beans. Comment was made earlier on the rapid

TABLE 6.—CHANGES IN PERCENTAGE COMPOSITION OF GREEN SOYBEANS AS THEY MATURED: DATA ON FIVE VARIETIES

Variety	Date of use 1936	Suitability for food use	Moisture content	Analysis on moisture-free basis									
				Protein N x 6.25	Fat	Carbohydrates			Ash				
						Total (by diff.)	Crude fiber	Sugars	Total	Calcium	Iron		
81029 (Fuji)	8-26	Undermature	79.0	38.93	16.62	38.44	4.24	23.34	6.01	.338	.0092		
	8-27(?)	Undermature	76.8	40.21	17.56	36.58	4.64	21.19	5.65	.312	.0094		
	8-31	Satisfactory	73.6	39.45	17.94	37.27	4.50	17.40	5.34	.270	.0120		
	9-4	Satisfactory	70.7	39.65	20.24	34.75	4.27	16.42	5.36	.295	.0091		
81044-1 (Willomi)	9-11	Overmature	67.7	42.46	20.79	31.61	4.09	15.29	5.14	.282	.0120		
	8-26	Undermature	83.9	39.96	9.42	44.87	4.30	31.66	5.75	.212	.0098		
	9-1	Satisfactory	79.2	39.37	12.25	42.71	4.97	22.01	5.67	.206	.0091		
	9-5	Satisfactory	77.1	39.13	13.10	42.53	4.86	20.02	5.54	.212	.0093		
85666 (Hokkaido)	9-15	Satisfactory	69.2	42.61	16.10	35.56	4.16	14.70	5.73	.199	.0098		
	9-21	Overmature	66.0	43.19	17.38	33.28	4.55	10.24	6.15	.196	.0098		
	9-25	Overmature	63.9	44.40	15.43	34.02	4.08	.....	6.15	.171	.0098	
	8-26	Undermature	81.4	40.83	10.74	42.94	5.66	26.90	5.49	.255	.0103		
Funk Delicious	8-31	Satisfactory	77.2	39.39	12.57	42.75	4.66	20.67	5.29	.0116	.0095		
	9-8	Satisfactory	71.3	39.58	16.21	39.07	3.88	16.44	5.14	.236	.0097		
	9-17	Overmature	67.2	41.79	17.11	35.71	4.10	9.02	5.39	.238	.0097		
Illini	9-5	Undermature	81.0	39.43	9.82	45.63	4.08	25.45	5.12	.196	.0089		
	9-10	Satisfactory	77.1	39.53	12.71	42.89	4.58	21.34	4.87	.205	.0110		
	9-17	Satisfactory	73.0	40.89	15.30	38.87	3.81	17.83	4.94	.221	.0102		
	9-25	Satisfactory	67.2	41.55	15.37	38.01	3.90	14.93	5.07	.215	.0096		
	10-3	Overmature	64.8	42.67	16.96	35.17	3.70	13.90	5.20	.199	.0094		
Illini	8-26	Undermature	77.4	37.61	10.23	47.01	6.69	21.22	5.15	.283	.0088		
	8-29(?)	Satisfactory	75.1	39.03	16.54	39.41	6.50	19.20	5.02	.300	.0092		
	9-1	Satisfactory	69.0	38.06	18.03	39.20	4.61	15.25	4.71	.224	.0088		
9-10	Overmature	63.2	41.11	19.06	35.22	4.10	12.30	4.61	.219	.0100			

TABLE 7.—PERCENTAGE COMPOSITION OF MATURE SOYBEANS ON THE BASIS OF 7 PERCENT MOISTURE CONTENT: DATA ON FOURTEEN VARIETIES

Variety	Year analyzed	Protein N x 6.25	Fat	Carbohydrates			Ash	
				Total (by diff.)	Fiber	Sugars*	Total	Calcium	Iron
80488-1-1.....	1935.....	40.37	18.35	29.47	4.79	8.26	4.81	.0111
	1936.....	41.19	14.02	32.88	4.12	8.26	4.91	.0111
81029.....	1935.....	39.33	18.56	29.95	4.28	8.17	5.15	.0094
	1936.....	40.39	14.69	32.99	4.62	8.17	4.93	.0094
81038.....	1935.....	39.91	18.93	29.00	4.21	.....	5.16	.....
81042 (Kura).....	1935.....	42.50	17.22	28.42	4.20	7.18	4.86	.0103
	1936.....	41.90	15.89	30.14	4.91	7.18	5.07	.0103
81044-1 (Willomi).....	1935.....	39.85	16.84	31.30	4.11	8.62	5.01	.0114
	1936.....	43.90	14.10	29.48	4.08	8.62	5.52	.0114
81780 (Imperial).....	1935.....	39.05	17.61	31.32	4.20	9.59	5.02	.0104
	1936.....	40.87	16.95	29.98	4.52	9.59	5.20	.0104
85666 (Hokkaido).....	1935.....	38.96	17.51	31.64	4.09	8.54	4.89	.0114
	1936.....	40.14	16.51	30.97	3.97	8.54	5.38	.0114
87615.....	1936.....	40.32	15.64	31.50	3.87	9.26	5.54	.0109
	1935.....	40.23	15.58	32.73	4.21	9.49	4.46	.0099
87633.....	1935.....	42.52	14.38	31.47	4.36	9.49	4.63	.0099
	1936.....	41.77	16.69	29.91	4.21	9.54	4.63	.0084
89162.....	1936.....	41.77	16.69	29.91	4.21	9.54	4.63	.0084
Eaycook.....	1935.....	40.95	16.28	31.09	4.59	.....	4.68	.....
Funk Delicious.....	1936.....	41.30	16.39	30.14	3.96	9.62	5.17	.0107
	1936.....	41.71	13.72	32.49	4.53	9.57	5.08	.0102
Illini.....	1935.....	36.33	18.15	33.77	4.75	9.61	4.75	.0100
	1936.....	39.18	20.09	28.90	4.56	9.61	4.83	.0100
Average.....		40.57	16.55	30.88	4.32	8.95	4.98	.0103

*Refers to total sugars soluble in 60 to 75 percent alcohol and hydrolyzed before they were analyzed as reducing sugars.

TABLE 8.—ASH ANALYSES OF SOYBEANS REPORTED IN THE LITERATURE

Kind of soybeans	Analyses				Reported by—
	Total ash	Calcium	Phosphorus	Iron	
<i>Green soybeans</i>	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>	<i>percl.</i>	
69.1 percent moisture.....	1.8	.063	.239	.00283	Miller and Robbins, 1934a*
70.86 percent moisture.....	1.58	.047	.189	.0047	Chung and Ripperton, 1929a*
94.7 percent moisture.....	2.2	.....	.....	.....	Chatfield and Adams, 1931*
70.24 percent moisture.....	1.92	.....	.....	.....	Piper and Moise, 1923a*
<i>Mature soybeans</i>					
10 percent moisture.....	5.54	.235	.670	.0067	Street and Bailey, 1915a*
8.8 percent moisture.....	5.0	.357	.371	.....	Hsien Wu, 1928a*
8 percent moisture.....	4.6	.....	.....	.0074	Bailey, Capen, and LeClerc, 1935*
0 percent moisture.....	.....	.....	.....	.....	McHargue, 1923a*
<i>Soybean oil meal</i>					
8.5 percent moisture.....	5.7	.273	.454	.....	Burlison, 1936*

disappearance of sugars from green beans as they stood in the pods after harvesting.

Identification of the sugars which are responsible for this sweet taste in soybeans has never been wholly satisfactorily made, nor has the exact amount of sugar present been fully agreed upon. It is quite possible that disagreement among writers as to quantity is due to their not having used methods of dissolving and hydrolyzing which would account for the little-known sugar stachyose, which is reputed to be present in soybeans^{26*} and which is a quite sweet, nonreducing tetrasaccharid, soluble in water and in alcohol of 80 percent or less concentration.^{3, 12*} Piper and Morse^{27*} reported green soybeans to contain 2 percent starch and 2.59 percent sugars. Street and Bailey^{36*} gave the sugar content of mature soybeans as 3.38 percent, and Bailey, Capen, and LeClerc^{4*} as 7.0 percent. The analyses in the present study have shown only a trace of reducing sugars to be present before hydrolysis, tho no further distinction between kinds of sugars has been made thus far.

Chemical values of soybean oil. There was no more fluctuation in the percent of oil in the different vegetable-type soybeans than is to be found in the commercial type. Likewise the iodine numbers, ranging from 124 to 134 (Wijs), and the thiocyanogen numbers (80 to 85) of these oils, as determined by the Regional Soybean Industrial Products Laboratory of the U. S. Department of Agriculture at Urbana, fell easily within the limits of variation which have been observed in other varieties. There appears to be no reason, therefore, for thinking that there is anything unusual about the quality of the oil taken from these vegetable types.

EXPERIMENTS IN PRESERVING GREEN SOYBEANS

Extending the season of green soybeans by freezing, canning, or drying them would obviously be as advantageous as it is with other fresh vegetables. All three methods have been tried, with varying degrees of success.

Freezing preserved fresh qualities. Seven varieties were preserved by freezing, and all that had good flavor as fresh beans retained their good qualities after freezing storage provided they were handled properly. The method found to be most satisfactory consisted of hulling the beans in the usual manner (page 431) within one hour after they were gathered; then precooking them in boiling water for one-half minute in order to stop enzyme action. The precooked beans

were cooled quickly by plunging them into cold water. After being drained, they were packed dry in paraffined pasteboard containers such as are used for handling dairy products, and within one hour entered the freezing room of the division of Dairy Manufactures, where the temperature was -20° F. for a few hours each day and the remainder of the time was about 0° F. After several months of storage the still-frozen beans were emptied into boiling salted water and cooked, the same proportions and the same time of cooking being used as for fresh beans (page 433). Their palatability was judged in the usual manner, also.

Green soybeans were stored successfully by this means from September until May. They were shown in the experiments, which were made with Hokkaido (Table 9), to be subject to the same deteriorations in color and flavor as frozen peas, the enzymatic changes in which have been studied quite extensively.^{2, 6, 11*} These undesirable enzyme activities in soybeans could be prevented, it was found, by a half-minute interval of precooking. Even the small amount of heating received during blanching for hulling was of some assistance in preserving color and flavor.

It was important to freeze the beans within a few hours after they were gathered, or they lost their natural sweetness before they even entered the freezer. Still lower temperatures of freezing than those obtained in the cold room were of no particular advantage; beans frozen at once with solid carbon dioxide were only slightly better than the others. A freezing temperature of about 0° F. is the one likely to be furnished in such commercially or cooperatively operated freezer-storage systems as are already in operation in some counties of Illinois, and would be adequate for successful home preservation by the freezer-storage method.

It made little difference whether the frozen beans were cooked before or after being thawed, tho the results were more certain when the beans were not thawed first. If beans are to be thawed first, they should be cooked at once after all the ice has disappeared.

Canned beans lost fresh qualities. Green soybeans gathered at undermature, satisfactory, and overmature stages of development, and those having different characteristics of color, size, and flavor, were in turn canned in pint- and quart-sized glass jars in a pressure cooker. The pressure used was in every case 10 pounds, but the processing time was varied from 30 to 90 minutes. Some of the beans were preheated for 2 minutes before they were packed in jars. One jar of each experimental pack was examined in November (they had been

TABLE 9.—QUALITY OF FROZEN GREEN HOKKAIDO SOYBEANS AS AFFECTED BY CONDITIONS OF HANDLING
(Beans hulled in usual manner before being precooked and frozen, see page 431. Stored from September to May)

Storage conditions after harvesting and before freezing	Blanched in pods ^a	Precooked after hulling	Pre-frozen 20 hours before entering freezer-storage ^b	Rating of quality	Remarks
	<i>minutes</i>	<i>seconds</i>			
Not stored but frozen at once.....	None	None	Yes ^c	Very poor	Flavor strong, disagreeable; color faded; texture soft and poor
	2	None	Yes	Fair	Flavor and texture fair; color slightly faded
	2	30	No ^d	Good	Flavor good; sweet; texture and color satisfactory
	2	30	Yes	Very good	Resembled fresh beans
Stored in pods at room temperature for—					
24 hours.....	2	30	No	Fair	Flavor good; lacking sweetness; texture and color satisfactory
48 hours.....	2	30	No	Poor	Tasteless; not sweet; dry
72 hours.....	2	30	No	Poor	Tasteless; not sweet; tough

^aThis was the usual treatment to make hulling easier.

^bThe temperature of the freezer-storage room was -20° F. for a few hours each day and was between -20° and 0° F. during the remainder of each day.

^cPre-frozen on solid carbon dioxide ("dry-ice") at once after pre-cooking and later placed in freezer-storage.

^dThose not pre-frozen were placed in freezer-storage within one hour after pre-cooking.

canned in September), and another examination was made the next June.

Every jar seemed to be totally free from spoilage but all, regardless of their treatment, had lost so completely the good qualities they possessed as fresh soybeans that there was nothing to generate any enthusiasm for this means of preservation. The green color had faded to an unattractive yellow or brown, the texture was mushy, the flavor not palatable. To be sure, other green vegetables also lose much of their goodness in canning. But it was the authors' judgment that well-cooked mature soybeans are so much better than the canned green beans that they are far preferable.^a

Drying holds some promise. Green soybeans were preserved by drying, in one test, at room temperature (30° to 35° C.), layers of them being suspended in the air in cheesecloth hammocks. Three to five days were required to reduce their weight to one-third of the original. In another test the green beans were dried in two days in an oven having a temperature of 40° to 50° C. Some were precooked for 30 seconds before drying, and some were given only the heating involved in the hulling process.

The dried green beans remained a bright-green color and on soaking, regained their original size very readily even many months later. During cooking, however, the beans faded to an unattractive color, the odor and taste were not good, and the texture was too hard to be acceptable. The precooked beans were the best of the lot, but even they were not wholly satisfactory.

This method of preservation holds some promise, for up to the time they were cooked, the beans appeared to have come thru the drying process successfully. Further attempts will be made to improve upon the methods of treatment.

SOYBEAN FLOURS COMPARED

A manufactured food product in which the flavor and color of the bean are of great importance is soybean flour. The two methods of manufacture most commonly used at present in this country are the "expeller" and the "solvent" processes. Descriptions of these and other manufacturing steps, including the disembittering of the beans, discussion of physical properties, chemical composition, and food uses of

^aCertain commercial canners have attained some degree of success in experimental canning of green soybeans.

soybean flours,^a can be found in detail in recent papers by Bailey, Capen, and LeClerc^{4*} and by Horvath.^{18*}

Soybean flours were made in the authors' laboratory from about twenty of these vegetable varieties for the purpose of learning whether measurable differences in flavor and other characteristics could be found between them and commercial flours manufactured from field types of beans. The laboratory method^b of making flour consisted of soaking 100 grams of soybeans in distilled water for 3 minutes, draining and letting the beans stand for 4 hours to effect an even distribution of moisture. Sufficient refined mineral oil was added to coat thinly the surface of the beans, which were then heated to and kept at a temperature of about 105° C. for 12 minutes. An oil bath surrounding a deep tin container holding the beans served as a means of heating them. The beans were stirred frequently while they were heating. This treatment successfully disemittered the beans and yet changed the color very little and produced none of the caramelized flavor which is so characteristic of the flours made by the expeller process; for this reason the natural sweetness of the soybeans was more apparent in these flours made in the laboratory than in the commercial flours. The beans were next cracked and the hulls blown away, then they were ground and sifted alternately until the flour passed thru a 60-mesh sieve. This flour was much coarser than commercial flour but served well for the palatability tests of the flour itself and for judging the flavor of baking-powder biscuits made from flour in which 33 percent of the wheat flour (by weight) had been replaced by soybean flour.

In 1935 twelve vegetable types and eight field types of soybeans were handled as described above, and in 1936 twelve vegetable types and one field type were so handled. The general conclusions were that the best-flavored flours came from some of the vegetable types; e.g., Imperial and Hokkaido. Most of the vegetable types gave better flours than the field types. Some of the field types—Dunfield, Manchu, and Mandarin—which are common crops today in the Illinois area, were rated "poor" for flour purposes. It appears likely that better flavored flour might be produced commercially if some of these vegetable types of soybeans should be substituted for the ones now being used in its manufacture.

^aA mimeographed circular, "Ways of Using Soybeans as Food," issued by the Illinois Extension Service, contains many recipes for the use of soybean flour as well as directions for cooking the beans themselves.

^bThis process is, on a small scale, essentially the patented one called the Goessel process.

SUMMARY

Because of the unique nutritive value of soybeans and the rapidly increasing acreage of them grown in the United States for farm and industrial purposes, the possibility of their becoming a more important food in the American diet has for some years been an interesting conjecture. One problem has been to ascertain which among the most promising varieties might prove acceptable to the American palate. This study, extending over the three crop years 1934, 1935, and 1936, was a step in this direction.

From a group of 466 vegetable and field types, seventeen have been selected by the authors as having the greatest promise for edible use. These are listed in Table 4, page 440. Flavor, texture, and general appearance and, in the case of green beans, shelling time also were the bases on which selection was made.

Six of the seventeen varieties showed special merit, and it is the belief of the writers that any of them might easily be accepted for table use by the American public. These are Funk Delicious, Hokkaido, Imperial, Jogun, Willomi, and F.P.I. 97155. The general appearance and color of representative superior varieties is shown in the color plate opposite page 432. The other eleven of the superior group were the most promising ones with a "good" rating. While less uniformly praiseworthy, there were good possibilities in all of them. Of the rest of the varieties tested, 59 rated good, 259 fair, and 131 poor.

The six "very good" varieties had field scores and yields that were not unfavorable to their future possibilities as food crops. Many of the superior varieties yielded flour that was more pleasing than available commercial soybean flours. From comparative tests of about twenty vegetable types and eight field types it appears to the authors that better flavored flour might be produced commercially if some of the vegetable types should be substituted for those now being used.

Twelve varieties subjected to chemical analysis both in the green stage and as mature beans showed differences that were too small or too irregular to indicate important variations in nutritive value. Nine of them were in the "superior" group.

Attempts to preserve green soybeans with freezing-storage methods were very successful. Canning and drying proved not so successful.

Many inquiries have been received at the Illinois Station as to the availability of seed of the vegetable types of soybeans. Altho stocks are not yet large enough for general distribution, they are being rapidly increased at various experiment stations in an attempt to meet the demands.

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TABLE 10.—Continued

Variety	Green			Dry			Composite rating, green and dry				Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time
	85604.....			F		F	F			F	F	x	x
85619.....			F		F	F			F	F	..	..	x	x	x
85626.....			F		F	F			F	F	..	..	x	x	x
85630.....			F		F	F			F	F	..	..	x	x	x
85664.....			VG		VG	VG			VG	VG	..	..	x	x	..
85671-1.....			G		G	G			G	G	..	..	x	x	..
85873.....			F		F	F			F	F	..	..	x	x	..
86007.....			P		P	P			P	P	..	..	x	x	..
86019.....			G		G	G			G	G	..	..	x	x	..
86022-1.....			F		F	F			F	F	..	..	x	x	..
86023.....			G		G	G			G	G	..	..	x	x	..
86025.....			F		F	F			F	F	..	..	x	x	..
86026.....			P		P	P			P	P	..	..	x	x	..
86027.....			P		P	P			P	P	..	..	x	x	..
86028.....			P		P	P			P	P	..	..	x	x	..
86029.....			P		P	P			P	P	..	..	x	x	..
86032.....			F		F	F			F	F	..	..	x	x	..
86038.....			P		P	P			P	P	..	..	x	x	..
86040.....			P		P	P			P	P	..	..	x	x	..
86047.....			F		F	F			F	F	..	..	x	x	..
86053.....			P		P	P			P	P	..	..	x	x	..
86089.....			P		P	P			P	P	..	..	x	x	..
86100.....			G		G	G			G	G	..	..	x	x	..
86101.....			F		F	F			F	F	..	..	x	x	..
86103.....			G		G	G			G	G	..	..	x	x	..
86103 early.....			G		G	G			G	G	..	..	x	x	..
86103 late.....			G		G	G			G	G	..	..	x	x	..
86113.....			F		F	F			F	F	..	..	x	x	..
86115.....			F		F	F			F	F	..	..	x	x	..
86116.....			F		F	F			F	F	..	..	x	x	..
86128.....			G		G	G			G	G	..	..	x	x	..
86129.....			F		F	F			F	F	..	..	x	x	..
86129-x.....			P		P	P			P	P	..	..	x	x	..
86130.....			P		P	P			P	P	..	..	x	x	..
86137-x.....			P		P	P			P	P	..	..	x	x	..
86137-x sel. 0.....			P		P	P			P	P	..	..	x	x	..
86137-x sel. 1.....			P		P	P			P	P	..	..	x	x	..
86137-x sel. 2.....			P		P	P			P	P	..	..	x	x	..
86137 early.....			F		F	F			F	F	..	..	x	x	..

TABLE 10.—Continued

Variety	Green			Dry			Composite ratings, green and dry					Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time	
86137 late.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86142.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86146.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86416-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 0.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 2.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 3.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 4.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86449 sel. 5.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86453.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86453-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86456.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86457.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86496.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86502.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86649.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86738.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86741-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86876.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86878-2.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
86978-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87167.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87524.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87530.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87531.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87571.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87606.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87615 (Jogun).....	G	G	..	G	G	VG	G	G	VG	VG	..	..	..	..	..
87617.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
87633.....	..	VG	..	..	G	..	..	G	..	G	..	..	..	..	..
88256.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88280.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88290-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88291.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88293.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88296.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88297-1.....	..	D	..	..	F	..	..	F	..	F	..	..	..	..	..
88298.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..
88298-1.....	..	F	..	..	F	..	..	F	..	F	..	..	..	..	..

TABLE 10.—Continued

Variety	Green		Dry			Composite rating, green and dry					Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time
	88301.....			G		F			G	F	F	x	x
88304.....			P		G			F	F	F	x	..	x	x	..
88307-1.....			P		F			F	F	F	x	..	x	x	..
88309.....			G		P			P	P	P	..	..	x	x	..
88310.....			G		F			G	G	G	..	..	x	x	..
88312.....			F		F			F	F	F	..	..	x	x	..
88335.....			F		F			F	F	F	..	..	x	x	..
88349.....			F		F			F	F	F	..	..	x	x	..
88350.....			F		F			F	F	F	..	..	x	x	..
88352.....			F		F			F	F	F	..	..	x	x	..
88353.....			F		G			F	F	F	x	..	x	x	..
88354.....			P		G			F	F	F	x	..	x	x	..
88355.....			P		G			F	F	F	x	..	x	x	..
88359.....					G			P	P	G	x	..	x	x	..
88443-1.....					P			P	F	F	x	..	x	x	..
88445.....					F			F	F	F	..	..	x	x	..
88446.....					G			G	F	F	..	..	x	x	..
88455.....					F			F	F	F	..	..	x	x	..
88459.....					F			F	F	F	..	..	x	x	..
88466.....					F			F	F	F	..	..	x	x	..
88481.....	P	F			P			F	F	P	x	..	x	x	..
88484.....					F			F	F	F	x	..	x	x	..
88486-1.....					F			F	F	F	x	..	x	x	..
88497.....					G			F	F	F	..	..	x	x	..
88782-1.....					F			F	F	F	..	..	x	x	..
88789-1.....					F			F	F	F	..	..	x	x	..
88793-1.....					F			F	F	F	..	..	x	x	..
88798.....					P			P	P	P	..	..	x	x	..
88803.....					P			P	P	P	..	..	x	x	..
88804-2.....					P			P	P	P	x	..	x	x	..
88805-4.....					F			F	F	F	..	..	x	x	..
88807.....					F			F	F	F	..	..	x	x	..
88808.....					F			F	F	F	..	..	x	x	..
88816.....					G			G	G	G	..	..	x	x	..
88819.....					F			F	F	F	..	..	x	x	..
88819-1.....					F			F	F	F	..	..	x	x	..
88823.....					P			P	P	P	..	..	x	x	..
88825.....		G			F			F	F	F	..	..	x	x	..
88965.....					F			F	F	F	..	..	x	x	..
88997-2.....					F			F	F	F	..	..	x	x	..

TABLE 10.—Continued

Variety	Green			Dry				Composite rating, green and dry				Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time	
88998-2	P	..	..	..	..	..	..	..	..	..	..	..	..
89000-1	P	..	..	..	..	..	P	..	..	..	..	..	x	
89004-3	P	..	..	..	..	..	P	..	..	..	..	..	..
89006	P	..	..	..	..	..	..
89055-1	P	..	..	..	..	..	..
89059-1	P	..	..	..	..	..	P	..	..	..	..	..	..
89060-2-1-1-1	P	..	..	..	..	..	P	..	..	..	..	..	..
89064-1	P	..	..	..	..	..	P	..	..	..	..	..	..
89068-2	P	..	..	..	..	..	P	..	..	..	..	..	x	
89075	
89128	G	..	..	..	..	..	G	..	..	..	..	..	..
89129	P	..	..	..	..	..	..
89138	P	..	..	..	..	..	..
89143	P	..	..	..	..	..	..
89146	..	F	..	..	..	..	..	..	..	..	..	..	..	..	..
89150-1	F	..	..	..	..	..	..	..	..	..	..	..	..
89153	G	..	..	..	..	..	..
89154	P	..	..	..	..	..	..
89156-1	P	..	..	..	..	..	..
89162	G	..	..	..	..	..	G	..	..	..	..	..	..
89167 sel. 1	
89171-2	F	..	..	..	..	..	..
90245-1	F	..	..	..	..	..	..
90249-1	F	..	..	..	..	..	..	..	..	..	..	..	..
90258	P	..	..	..	..	..	..
90369	P	..	..	..	..	..	..
90389	..	G	..	..	..	..	..	..	P	..	..	..	..	..	..
90392	P	..	..	..	..	..	..
90402	G	..	..	..	..	..	..
90407	F	..	..	..	..	..	F	..	..	..	..	..	..
90561	
90564-3	F	..	..	..	..	..	F	..	..	..	..	..	..
90566-1	P	..	..	..	..	..	..
90570-1	P	..	..	..	..	..	P	..	..	..	..	..	x	
90573-1	G	..	..	..	..	..	..
90579	P	..	..	..	..	..	..
90763	P	..	..	..	..	..	P	..	..	..	..	..	x	
90765	
91003	F	..	..	..	..	..	..	..	..	..	..	..	..
91089	F	..	..	..	..	..	F	..	..	..	..	..	..

TABLE 10.—Continued

Variety	Green			Dry			Composite rating, green and dry					Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time	
92466.....	G	..	..	F	..	..	G	F	..	..	x	..	..
92468.....	F	..	..	F	..	..	F	P	..	..	x	..	..
92470.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92558.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92561.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92563.....	x	..	..
92565-1.....	x	..	..
92567.....	x	..	..
92568.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92573.....	x	..	..
92584.....	F	..	..	F	P	..	..	x	..	..
92587.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92594.....	F	..	..	F	F	..	..	x	..	..
92598.....	G	..	..	G	..	..	G	G	..	..	x	..	..
92600.....	x	..	..
92601.....	G	..	..	F	..	..	F	F	..	..	x	..	..
92602.....	G	..	..	F	..	..	F	F	..	..	x	..	..
92603.....	G	..	..	F	..	..	F	F	..	..	x	..	..
92617.....	x	..	..
92627.....	F	..	..	F	..	..	F	F	..	..	x	..	..
92633.....	F	..	..	F	..	..	F	P	..	..	x	..	..
92637.....	x	..	..
92641.....	F	..	..	F	..	..	F	P	..	..	x	..	..
92649.....	G	..	..	F	..	..	F	P	..	..	x	..	..
92650.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92659.....	F	..	..	F	..	..	F	P	..	..	x	..	..
92672.....	G	..	..	G	..	..	G	G	..	..	x	..	..
92686.....	x	..	..
92687.....	F	..	..	F	..	..	F	F	..	..	x	..	..
92690.....	x	..	..
92691.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92694.....	x	..	..
92704.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92705.....	x	..	..
92706.....	x	..	..
92711.....	G	..	..	G	..	..	G	G	..	..	x	..	..
92717.....	P	..	..	P	..	..	P	P	..	..	x	..	..
92720.....	F	..	..	F	..	..	F	F	..	..	x	..	..
92722.....	F	..	..	F	..	..	F	F	..	..	x	..	..
92732.....	F	..	..	F	..	..	F	F	..	..	x	..	..

TABLE 10.—Continued

Variety	Green			Dry			Composite rating, green and dry				Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time
93563-2.....			P		P	P				P	x		x		x
93565.....			P		P	P				P	x		x		x
93996-1.....	P			F						P					x
96201.....			P		P	P				P					x
96322.....			P		P	P				P					x
96333.....			G		P	P				P					x
96377.....			P		P	P				P					x
96378.....			P		P	P				P					x
96549.....			F		F	F				P					x
96839.....			F		F	F				P					x
97155.....			G		G	G				VG					x
97224.....			F		F	F				VG					x
98243.....			F		F	F				F					x
98717.....					F	F				F					x
A K 125*.....		F			G					F					x
A K 146*.....		F			P					F					x
Black Eyebrow.....		F			P					P					x
Cayuga.....		P			P					P					x
Chestnut.....		P			P					P					x
Columbia.....		P			P					F					x
Dunfield.....	F	F		G	G					F					x
Early Indiana Laredo.....	G	P		G	P					P					x
Easycook.....	G	G		G	G					F					x
Ebony.....			F							P					x
Ebony sel. Stein.....					P					P					x
Ebony sel. 18*.....					P					P					x
F C 29333.....			F		F					P					x
Funk Delicious.....		G		G	VG					VG					x
Funman.....		F		F	F					F					x
Giant Green.....		F		F	F					G					x
Guelph.....	F	F		F	F					G					x
Haberlandt.....	F	F		F	F					G					x
Hamilton.....	G	F		G	F					F					x
Harbinsoy.....	F	F		F	F					F					x
Higan.....	F	G		G	VG					G					x
Hong Kong.....	F	F		F	F					G					x
Hurrebrink.....	G	G		G	F					F					x
Illington.....	F	G		G	VG					G					x
Illini.....	F	G		G	G					G					x

TABLE 10.—Concluded

Variety	Green			Dry			Composite rating, green and dry				Reasons for ratings lower than very good				
	1934	1935	1936	1934	1935	1936	1934	1935	1936	All years	Skin	Color	Texture	Flavor	Shelling time
	Itsoy.....	..	P	P	P	x	x	x	x
Ito San.....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
Kingwa.....	..	P	..	..	P	..	..	P	..	..	..	x	x	x	x
Leonard.....	P	G	..	F	P	..	P	G	..	..	..	x	x	x	x
Lexington.....	F	F	..	F	F	..	F	G	..	..	..	x	x	x	x
Macoupin.....	F	F	..	F	F	..	F	F	..	..	..	x	x	x	x
Mammoth Yellow.....	F	F	..	F	F	..	F	F	..	..	..	x	x	x	x
Manchu.....	F	F	..	F	F	..	F	F	..	..	..	x	x	x	x
Manchu (Thomas).....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Manchu (Wis.).....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
Manchuria 13-177.....	..	P	..	..	F	..	..	F	..	..	..	x	x	x	x
Manchuria 24026.....	..	G	..	..	F	..	..	F	..	..	..	x	x	x	x
Mandarin.....	..	P	..	..	F	..	..	F	..	..	..	x	x	x	x
Mansoy.....	F	G	..	F	G	..	F	G	..	..	..	x	x	x	x
Midunk.....	F	F	..	F	F	..	F	F	..	..	..	x	x	x	x
Midwest.....	F	F	..	F	F	..	F	F	..	..	..	x	x	x	x
Morse.....	G	P	..	F	F	..	F	F	..	..	..	x	x	x	x
Morse 230*.....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
Mukden.....	..	G	..	..	G	..	..	G	..	..	..	x	x	x	x
Peking.....	P	P	..	P	P	..	P	P	..	..	..	x	x	x	x
R-602 (T-117)*.....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
R-1017.....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
R-1026.....	..	C	..	..	C	..	..	C	..	..	..	x	x	x	x
R-1051.....	..	C	..	..	C	..	..	C	..	..	..	x	x	x	x
R-1052.....	..	C	..	..	C	..	..	C	..	..	..	x	x	x	x
R-1054.....	..	F	..	..	F	..	..	F	..	..	..	x	x	x	x
Sel. 54563-3 (Mo.).....	..	P	..	..	F	..	..	F	..	..	..	x	x	x	x
T-113*.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
T-114.....	..	P	..	..	P	..	..	P	..	..	..	x	x	x	x
T-117.....	..	F	..	..	G	..	..	F	..	..	..	x	x	x	x
Tortoise Egg.....	..	P	..	..	P	..	..	F	..	..	..	x	x	x	x
Virginia.....	..	P	..	..	P	..	..	P	..	..	..	x	x	x	x
Wilson V.....	P	P	..	P	P	..	P	P	..	..	..	x	x	x	x
Wisconsin Black.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total numbers tested.....	58	96	396	466											

*Numbered by the Plant Breeding division of the Department of Agronomy, University of Illinois.



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