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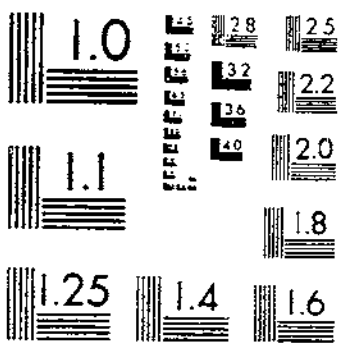
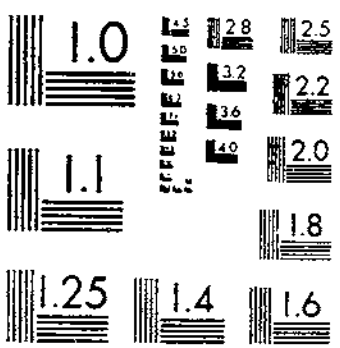


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



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NATIONAL BUREAU OF STANDARDS-1963-A

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Comparative Studies of Varietal Suitability For Freezing Preservation of Peas, Green or Snap Beans, Lima Beans, and Sweet Corn Grown Under Eastern Conditions [1]

By JOSEPH S. CALDWELL, *senior physiologist*, J. M. LUTZ, *assistant physiologist*, H. H. MOON, *assistant pomologist*, and C. W. CULPEPPER, *physiologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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INTRODUCTION

The preservation of vegetables by freezing in prepared form, ready for cooking and serving, is a relatively new and rapid development in the field of food preservation. The early experimental work was followed by immediate commercial application, with the result that the development of the industry has proceeded parallel with the investigational activities that have established principles, worked out proc-

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esses, and made it possible to standardize and perfect the product. In this respect the history of freezing preservation duplicates the early history of the canning industry. There is a further similarity in that the early work in both fields was concerned primarily with the technological problems involved in the devising of equipment and development of methods, and only minor attention was given to the study of the raw materials to be handled.

Freezing preservation has proceeded far enough to make evident the fact that the groups of varieties of the various fruits or vegetables present exactly the same problems that originally confronted canners, as the behavior under freezing treatment of a group of varieties of apparently equal merit will show a very wide range in retention of appearance and quality. Consequently, the only method of selecting those that have greatest suitability for the purpose is that of actually subjecting the individual varieties to comparative tests.

Although a considerable number of investigators have reported the results of such tests, it is generally true that the number of varieties of a given vegetable employed by any one worker was small as compared with the number in general cultivation and might also be entirely different from those used by another investigator working with the same vegetable. Hence the results had no common standard of comparison. Also, there has been a tendency on the part of both investigators and commercial packers to concentrate attention on varieties that have been found suitable for canning and to ignore others that are favorites in the fresh market and the home garden. The fact that the laboratories engaged in the work were widely scattered in districts having markedly different soil and climatic conditions has introduced into the results variations in the response of the material to these differing conditions and has thereby increased the difficulty of interpreting the results in common terms. The methods employed by workers have differed so widely in detail that direct comparisons of results are in some cases impossible. The various workers have employed different standards in judging their results, placing various degrees of importance upon market appearance of the product as compared with preservation of flavor and appeal to the palate.

For all these reasons the present knowledge of the varietal behavior of vegetables under freezing treatment and of varietal suitability for freezing preservation is somewhat fragmentary and confused. No disparagement of the excellent work that has been done in this field is intended; the situation is inevitable because of the newness of the field of investigation, the great assemblage of varieties to be studied in the case of each of the important vegetables, and in particular because of the multiplicity of methods of freezing employed and the lack of a standardized process for use in comparative work. There is need for a systematic survey or inventory of the varietal material of each of the important vegetable crops with reference to suitability for freezing purposes and retention of desirable quality after freezing, made by methods so standardized as to be easily reproducible. When such surveys by comparable methods have been made in several of the important vegetable-producing districts, the extent to which varietal responses to growth under widely differing soil and climatic conditions affect the results will become apparent, and the freezing

industry will have an approximate evaluation of the raw materials available for its use.[2]

PURPOSE AND SCOPE OF PRESENT WORK

The primary purpose of the work herein reported was to make a rather thorough comparative study of the behavior under freezing preservation of fairly large groups of varieties of each of a number of the more important vegetable crops. No attempt was made to assemble a complete collection of varieties of any vegetable, for dealing with such masses of material with the requisite thoroughness and attention to detail would have been impossible. Instead, selection of varieties was made primarily with reference to possession of high table quality and full, appealing flavor in the fresh material, and an attempt was made to include such choice varieties and to exclude mediocre ones. The old standard sorts were included, and also a few very widely cultivated varieties, without strict regard to their quality. Insofar as possible the selections represented the range of types to be found in the vegetable as grown in the eastern United States; 14 varieties of green or snap beans were used, 18 of peas, 8 of lima beans, and 35 of sweet corn. In order that the material might be properly comparable, it was grown under the immediate supervision of the authors and under uniform conditions of fertilization and cultivation, on soil areas for which there was available a complete record of crops grown and fertilizers and manures applied for many years previous to the work. As a further check on the uniformity of treatment of the material, harvesting, preparation, grading, and packing were done by the experimenters themselves, each person performing specific portions of the work. This arrangement secured close adherence to details of a standardized method of treatment for all the material of a given vegetable, and it was followed throughout the work.

As an essential phase of the work a rather careful study was made of the effects of the stage of development and degree of maturity of the material on its behavior in freezing and on the table quality and palatability of the product. Grading the material into a close series of advancing stages of development and packing each of these separately permitted determination of the effects of changes characteristic of advancing maturity on the quality of the frozen product, and thus permitted determination of the range of age or stage of maturity within which each variety is in optimum condition for use. The results show that stage of maturity is a factor of importance equal to that of variety in determining the quality of frozen vegetables.

[2] Since this bulletin was prepared for publication, a number of workers have reported tests of the suitability for freezing purposes of groups of varieties of vegetables. The varieties employed were usually those most generally grown in the particular State or district in which the work was done. Results of such regional studies of varietal suitability are reported in the following:

ARENGO JONES, R. W. THE PRESERVATION OF FRUITS AND VEGETABLES BY FREEZING. Dominion of Canada Dept. Agr. Tech. Bul. 12, 12 pp., illus. 1937.

DIEHL, H. C., and BIRDSEYE, MIRIAM. STORAGE OF FRUITS AND VEGETABLES IN COMMUNITY FREEZER LOCKERS. U. S. Dept. Agr. Misc. Ext. Pub. 47, 35 pp. 1938. [Mimeographed.] Also in Quick Frozen Foods 1 (9): 10–11, 34–35; (10) 21–26; (11) 22–24. 1939.

KNOWLES, DARLINE. SHARP FREEZING OF NORTH DAKOTA GROWN VEGETABLES AND FRUITS FOR COLD-STORAGE LOCKERS. N. Dak. Agr. Expt. Sta. Bimonthly Bul. 2, No. 5: 10–14. 1940.

MORRISON, GORDON. VARIETIES OF PEAS AND SWEET CORN BEST SUITED TO QUICK FREEZING. Quick Frozen Foods 1 (9): 12–13, 28. 1939.

——— SUPERIOR VARIETIES OF LIMA BEANS AND SNAP BEANS FOR THE QUICK FROZEN PACK. Quick Frozen Foods 1 (11): 16–18. 1939.

PLAGGE, H. H. REFRIGERATED LOCKER STORAGE FOR FRUITS AND VEGETABLES. Iowa State College Ext. Circ. 259, 16 pp. 1939. Also in Quick Frozen Foods 2 (3): 14–15, 33; (7): 30–31, 38–39. 1940.

TRESSLER, D. K., and DUBOIS, C. W. FREEZING AND STORAGE OF FOODS IN FREEZING CABINETS AND LOCKER PLANTS. New York State Agr. Expt. Sta. Bul. 690, 60 pp., illus. 1940.

Comparative studies of a considerable number of preparatory treatments, such as packing with and without the addition of liquid, freezing prior to packaging, and of a number of sizes and types of containers, both airtight and nonairtight, were made in order to determine the extent and character of the effects of these various treatments upon the preservation of quality in the product.

Another object of the investigation was to obtain information as to the nature of the micro-organisms present on the raw material used, the effects of the various preparatory treatments on their number and character, and the further effects of freezing and storage on them. For the purposes of this study, samples were taken from the raw material as brought from the field, at various stages in its preparation and packing, and from the material when removed for examination after freezing and storage. The results of this portion of the investigation have been separately reported (*50*).[3]

MATERIAL EMPLOYED

Sources

The seed used consisted of selected strains of the varieties concerned and was obtained from commercial sources, which are indicated in subsequent sections insofar as necessary to identify the strains. The various crops were grown in 1934 and repeated in 1935 on the Arlington Experiment Farm, Arlington, Va., on soils of medium fertility that had been rather intensively cultivated in experimental work for many years. No especial fertilizer treatments were used, and the various crops received only the usual cultivation of good practice. The seasonal conditions during the period of growth of the crops were, as a whole, good except for a deficiency in rainfall that reduced yields of peas and corn in 1934; provision of an overhead irrigation system in 1935 prevented any injury from what would otherwise have been rather serious drought. The yields were, as a whole, good in both years, and there was exceptional freedom from disease except in the corn in 1934. The area used for planting corn in that year proved to be rather heavily infested with bacterial wilt, and some susceptible varieties were so seriously attacked that a second planting on another area was necessary.

Harvesting and Handling

All of the material was harvested in the early morning, only such amounts being gathered as could be worked up during the day. Harvesting was done in half-bushel or bushel baskets, which were transferred to the laboratory when filled in order that no heating from the sun might occur. Preparation for packing was begun immediately after harvesting, and the work was so organized that handling was practically continuous and without delays at any stage of the process.

GENERAL PROCEDURE IN PREPARATION

Washing and Grading

Omitting some details of the various treatments, which will be stated in the sections on the particular crops concerned, the general

[3] Italic numbers in parentheses refer to Literature Cited, p. 69.

procedure for preparing the material was as follows: Peas and lima beans were emptied into deep tanks and thoroughly washed by agitation in repeated changes of water, then spread on tables for draining prior to shelling. In the process, visibly diseased or overmature pods were discarded. Shelling of peas was done in part by machine and in part by hand, lima beans were shelled by hand. After they were shelled both peas and lima beans were separated into size grades by screening. In order that the effects of stage of maturity on quality and appearance of the frozen product might be studied in detail, both peas and lima beans were separated into all the size grades possible to make with a set of standard screens differing by one thirty-second of an inch in size of opening for peas and by two thirty-seconds of an inch for lima beans. Each of the size grades so obtained was subsequently prepared and packed separately. The peas and lima beans were again thoroughly washed prior to scalding. Snap beans were thoroughly washed before being tipped and snapped, then sorted into sizes, and again washed prior to scalding. Sweet corn was husked and trimmed by hand, the silks were removed by brushing, and the individual ears were thoroughly washed under running water.

Scalding [4]

All material used in the comparative varietal studies was scalded in boiling water for periods varying with the nature and stage of maturity of the particular material. Snap beans were scalded after being tipped and broken to the desired length, peas and beans after being graded into the various size grades, and corn was scalded on the cob. The volume of product scalded was so adjusted to the volume of water in the scalding tank that the temperature dropped 15° to 20° F. within 15 to 30 seconds after a batch was immersed in the tank but would return to boiling point within 60 to 75 seconds. The use of large squares of cheesecloth for holding the material while being scalded permitted practically instantaneous contact of the water with all portions of the material, and this was further insured by stirring the material thoroughly while holding it submerged.

Cooling

Scalding was followed in all cases by immediate cooling of the product to the lowest temperature available with the laboratory water supply. This was accomplished by placing the material as scalded in large pans under running water until thoroughly cooled and subsequently holding in cold water, frequently changed, until it was packed. The temperature of material so treated, when placed in the containers, ranged between 55° and 65° F., but rarely reached the upper limit. Experiments described in a subsequent section (p. 11) show clearly that prompt and thorough cooling after scalding is indispensable to retention of quality. It is also obvious that thorough cooling of products prior to packing will correspondingly reduce the time required to reach freezing temperature within the container after it is placed in the freezing room.

[4] The term "scalding" is used in this bulletin in place of the commonly used term "blanching," which, as pointed out by Magoon and Culpepper (44) in 1924, completely misstates both the purpose and the effect of the treatment.

Packing

Two types of pack were made. In the dry or so-called straight pack, the material, after being cooled and drained, was packed as closely as possible into the containers, which were then inverted to drain for a moment prior to closing. In the wet or brine pack, the container, after being filled and drained, received a sufficient quantity of liquid to fill the interspaces and cover the surface. A head space of one-fourth to three-eighths of an inch was left in both the dry and the wet packs to provide for expansion in freezing. For all products except corn, the liquid used in packing was a 2-percent solution of common salt; for corn a sweetened brine containing 2 percent of salt and 6½ percent of sucrose was employed.

The containers used were also of two types. For containers that could be hermetically sealed after being filled, sanitary tin cans of No. 2 and No. 10 size were used. These were in part of plain tin and in part lined with enamels of the types employed for corn and for berries. The nonairtight containers were of paraffined paper and were chiefly tub- or bucket-shaped cups of 1-, 5-, and 10-pint capacity. For dry packing, some use was also made of a folding rectangular carton of 1-pint capacity.

The quantities of material of a particular size or stage of maturity available were generally such as to allow the packing of a number of small containers and two or more of the larger sizes of both tin and paper containers; these were further subdivided by adding brine to a portion of each lot and omitting it from the remainder. This method of packing was used as a routine procedure, since it made it possible at the subsequent examination to compare otherwise identical material packed with and without brine in various sizes and types of package. Rather close evaluation of the effects of these various treatments on appearance and quality of the product was thereby made possible.

As a routine procedure, portions of the material of every variety of vegetable, and in many instances portions of each variety at each of the various stages of maturity used, were packed in No. 2 tin cans, exhausted, sealed, and processed by standard canning procedure. These canned samples were stored for subsequent use in the comparative studies.

Freezing

Freezing of the products was accomplished by transferring the containers promptly after they were packed to a room held at 15° F., in which rapid air movement was maintained by a fan. After a few days the material was removed to a room held at 0°, where it remained until removed for examination. This method of treatment was adopted only after adequate preliminary experimentation with duplicate lots of material (one of which was treated in this manner while the other was placed directly in a 0° room after it was packed) had shown that the two lots of material were indistinguishable in every respect, if precautions to insure prompt cooling were taken and the period of holding at 15° was limited to 2 to 4 days. The establishment of this fact made it possible to employ 15°, which was the lowest temperature obtainable in the experimental storage rooms, for daily freezing of batches of product as they were packed. When the containers were placed in the room, they were set in open rows on slat shelves in such fashion that a

strong current of air could be driven over and between them; they were allowed to remain 18 to 24 hours and were then stacked somewhat more closely to make room for incoming material. At intervals of 2 to 3 days the accumulated material was transferred to the 0° room of a commercial cold-storage plant, where it remained until it was removed for examination 5 to 7 months later.

Various precautions were taken to render this method of treatment safe by facilitating cooling to the freezing temperature. The material was thoroughly cooled prior to packing, the brine added to packs was also cold, and the transfer of material from packing room to the cold room was always prompt, in order to prevent any significant rise of temperature in the product after packing. There was ample room to place individual containers separately on the shelves in the 15° F. room so as to assure free movement of the air current about each container. As the room used had approximately a capacity of 900 cubic feet and the amount of material packed per day totaled only a few cubic feet, there was no appreciable warming of the room by the material placed in it. With this combination of favorable conditions it was possible to lower the temperature of the products packed in the smaller-size containers to freezing point quickly enough to prevent the occurrence of deteriorative changes. This was also true with most of the larger containers, but in some cases, which will be discussed in more detail later (p. 58), there were indications that cooling of the larger packages had not been sufficiently rapid.

It was obvious that this method had a very narrow margin of safety even under the exceptionally favorable conditions prevailing in the experiments. As these conditions could scarcely be duplicated under ordinary commercial factory practice, it would be highly unwise to attempt commercial freezing of vegetables by a process involving preliminary freezing at temperatures above 0° F. Immediate transfer from the packing room to a temperature of 0° or at the highest not more than 5° should be used instead.

TIME REQUIRED TO FREEZE THE MATERIAL

No determinations were made of the rate of cooling or of the time required to freeze the material. In the course of earlier studies on the freezing of fruits (*13, 14, 43*) many determinations were made of the time required to bring the temperature at the center of 1-pound containers of the type used in these studies, filled with berries or sliced peaches, from 65°–75° to 26°–28° F. in still air in a room held at 15° to 17°. The time required for the various materials and the different conditions of experimentation ranged between 4½ and 7 hours. Joslyn and Marsh (*36, 37, 38*) have made very extensive investigations of rate of cooling and time required to reach freezing temperature in a number of fruits and vegetables packed in various sizes and types of containers. Their results show no very great differences in time required for freezing such fruits as berries and such vegetables as peas and cut string beans when packed in containers of like size and type. It may be assumed from their data that the 5-pint and 10-pint containers used in these experiments reached freezing temperature at the centers in 8 to 11 hours and the 1-pint containers in 4½ to 6 hours, as the use of a fan to drive a rapid current of cold air over the containers considerably accelerated the cooling as compared with what would have occurred in still air.

FREEZING AFTER PACKING CONTAINERS INTO CARTONS

No experiments were made in which the individual containers were packed into shipping cartons prior to placing them in the freezing room. The only purpose such experiments would have served would be to secure data as to the degree of slowing down of the cooling process that is brought about by such treatment. Joslyn and Marsh (*36*) have investigated this subject very thoroughly and their results have shown that the insulating effect of a shipping carton was sufficient to retard the cooling of the contents to freezing temperature for many hours or even for days, as compared with individual containers freely exposed to the air. Further demonstration of the thoroughness with which such a practice necessarily defeats all measures designed to bring about prompt and uniform cooling of the material after packing seemed to be unnecessary.

METHODS OF EXAMINING AND GRADING THE MATERIAL

The frozen products were examined after a period of storage that approximated 6 months. This period was chosen as being fairly representative of what would ordinarily occur with commercial products, and as being sufficiently long to develop any defects due to methods of preliminary treatment or packing. The routine method followed in the examination was designed to accomplish several different but related objects. One of these was the determination of the effects of the various preparatory treatments, methods of packing, and types of container on the material considered as a whole. This was made possible by the fact that the pack of practically every variety contained material prepared and packed by all the different methods of treatment from portions of a single lot of raw material. Cross comparisons between these various packs from variety to variety of a vegetable permitted determination of the relative efficiency of the different treatments in preserving desirable qualities in the product.

A second object of the examination was the determination of the comparative or relative suitability of the various varieties of each vegetable for preservation by freezing, as shown by their appearance in the frozen condition and their appearance, texture, and palatability and flavor when cooked.

Finally, it was hoped to determine for each variety the portion of its period of development in which it was of the highest quality, all factors being considered, for freezing purposes.

The method of examination employed to achieve these purposes was standardized at the outset and was closely adhered to throughout the work. It involved the detailed examination of representative containers of each lot of all the material of each vegetable packed, a variety at a time, and the separate grading of samples representing all the stages of maturity, types of pack, and sizes of container. The individual samples were given separate ratings under four general heads: (1) Color and general appearance of the frozen material; (2) color and attractiveness after cooking; (3) texture and consistency; and (4) palatability and desirability of flavor. Under these general heads were combined everything that could contribute to or detract from the attractiveness and appeal of the material as it would be viewed in the frozen condition by prospective purchasers and also

all that would favorably or unfavorably affect consumers to whom it would be presented after cooking. The system of grading was a numerical one, employing a scale of 10 in which 1 denoted highest excellence in the factor concerned; the range from 1 to 4, employing fractions if necessary, covered very good, good, and fair; and numerical values higher than 4 indicated poor, unacceptable, and the like.

In examining the material, containers of all the lots of a variety were brought out of the freezing room together, opened, and the contents of each emptied into a white enameled pan. These were ranged side by side on the laboratory tables under full natural light and were immediately examined and graded for general appearance, retention of color, and degree of attractiveness in the frozen condition. While this was in progress, portions of each lot of material, or in some cases the contents of duplicate containers, were removed, cooked, and placed beside the corresponding uncooked samples. The grading of the cooked samples was then begun. They were first gone over and graded for color and general appearance after being cooked, the presence of the corresponding frozen samples aiding materially in the process. They were then gone over again and tasted and graded for texture or consistency, palatability, and naturalness and fullness of flavor, the results being summed up and recorded under the appropriate heads.

This method of handling permitted the examination of 35 to 50 individual samples each working day, and made it possible to place the material of 2 or 3 varieties upon tables and examine them in order. This permitted cross comparisons, which increased the accuracy of the grading. Additional unopened material of all the packs was held in reserve in the freezing room, so that it was possible to repeat the examination of material already gone over when comparison with that reached later in the work was desirable. Although somewhat laborious, this method of conducting the examinations justified itself by its results, as it permitted close evaluation of the effects of various treatments and of small differences in stage of maturity within a variety, as well as detection of small differences in appearance or flavor between varieties. Some such method of detailed grading upon a comparative scale is indispensable to accuracy in dealing with large assemblages of rather closely similar material.

Methods Employed in Cooking Samples

The cooking of all samples for examination and organoleptic testing was done by one person, an experienced cook. Gas-heated hot plates that could be very closely regulated and were of such size that 8 to 12 samples could be cooked at one time were used. All the lots of material were quickly thawed by emptying the frozen material into boiling water and placing over a moderate flame. As some of the material had been packed in brine and other lots were dry-packed, the additions of water and salt for cooking were so adjusted as to make the liquid and salt content of all samples equal. No additions other than water and salt were made, because it was found that such additions, as, for example, butter added to sweet corn, might increase the palatability but at the same time tended to disguise and prevent detection of differences in flavor. Although the time required for

cooking lots of different varieties of the same vegetable at a like stage of maturity varied only slightly, no attempt to cook for uniform and predetermined periods was made, but instead directions were given to cook each sample until thoroughly done as determined by tasting. The judges were convinced, by a number of comparative tests, that they were able to make more accurate estimates of texture, palatability, and flavor, and finer discriminations between products of nearly equal quality when the samples were thoroughly cooked. With green vegetables, such as peas, lima beans, and green snap beans, thorough cooking, of course, resulted in greater loss of green color than from a shorter period of heating. Since the destruction of chlorophyll and development of brownish discoloration in these vegetables under heating is a progressive process that increases with time, the method of cooking was considered fair to all varieties, because the color and attractiveness of the cooked material was proportionately reduced in all lots somewhat below what it would have been under less thorough cooking; consequently, the comparative ranking of the varieties in respect to this factor was little if at all affected. Observation of the changes occurring in the green vegetables during the cooking process appears to bear out this conclusion.

Relative Weights Given the Various Factors in Grading the Products

Before the several varieties of a vegetable could be ranked with respect to their comparative suitability or desirability for freezing, it was necessary to determine the effects of different treatments, types of pack, and stages of maturity on the basic or inherent quality of each variety. This could be accomplished with a considerable degree of accuracy by cross comparison. After this was done, it was necessary to determine the relative weights to be given to color and appearance of samples in the frozen condition and to appearance, palatability, and flavor when cooked and served. The method adopted gave the appearance of the frozen material a weight of 20 percent and its appearance, texture, palatability, and flavor after being cooked a weight of 80 percent in determining its final rank.

This method was decided upon advisedly and with full knowledge that it differed considerably from commercial practice and from most score cards for preserved foods, which give equal or greater weight to appearance than to texture or quality. One reason for the decision was the fact that, with the exception of certain lots of material that were intentionally subjected to mistreatment in packing or storage, or that were known to be undermature or overmature when packed, practically all the products would have passed existing commercial standards for frozen vegetables, many of them with a very considerable margin. This fact supported the preexisting conviction of the authors that as the frozen-pack industry develops, considerably greater and constantly increasing emphasis must be laid upon the retention of high table quality and attractive and appealing flavor in the product as served. Consumer demand for such quality will inevitably increase as the distribution of frozen products widens to the point at which they no longer have the attraction of novelty. It would seem to be the part of wisdom to anticipate keener discrimination and a more critical attitude on the part of the consuming public by laying especial stress, in experimental studies of varietal material,

upon high table quality in the product. If this is done, without any lowering of standards in respect to market appearance of the frozen material, it will result in the narrowing of the vegetable material packed to those varieties that combine choicest table quality and finest flavor with an attractiveness of appearance in the frozen condition that will insure them a favorable reception in the markets. The products here dealt with have been graded with this purpose in mind.

COMPARISON OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING

A considerable number of variations in the preparatory treatments given the material and in the methods of packing were used in the course of the work in order to determine their effects upon the preservation and quality of the products as compared with the results of the routine treatments and methods of packing. These were made necessary by the dearth of information in the literature as to the effects of variations in these factors on the quality of the products. It was found that these effects differed with the kind of vegetable to a degree that will require discussion in subsequent sections dealing with specific products. However, certain general effects may be stated here.

The Scalding Process

In some of the early attempts to preserve vegetables by freezing, the material was packed and frozen without preliminary scalding or steam treatment, with the idea that the fresh appearance and flavor of the material could be preserved unchanged. Vegetables so treated developed an abnormal, haylike odor and disagreeable flavor and became inedible after a few months unless held at temperatures of −20° to −25° F. (*11*, *55*). That these undesirable changes may be prevented by partly precooking the vegetables was pointed out by Kohman (*41*, *p. 187*), but no details as to materials or methods of treatment were given.

Joslyn and Cruess (*35*) were the first workers to report in detail upon experimental studies of the freezing of vegetables. Their paper, published in 1929, described successful preservation at 0° to 15° F. of previously scalded globe artichokes, corn on the cob, asparagus, string beans, and spinach, packed in brine, whereas duplicate lots of material packed without being scalded but receiving identical treatment in all other respects underwent prompt and extensive deterioration in appearance and flavor. Joslyn (*34*), a year later, reported upon the work in greater detail, attributing the deterioration in odor and flavor in unscalded frozen vegetables to enzymatic action. Work of essentially identical character with a number of vegetables, including asparagus, beans, and peas, was being carried out at the same time by Barker and Morris at the Low Temperature Research Station, Cambridge, England. In reports published in the years 1930–33 (*9*, *10*, *47*, *48*, *49*), these workers showed that preliminary scalding to inactivate enzymes is indispensable to satisfactory preservation of vegetables by freezing, and that properly scalded vegetables may be preserved for long periods without the use of temperatures below 0°.

Since the publication of the work of Joslyn and Cruess, and Morris and Barker, there have been numerous publications dealing with the

effects of scalding preparatory to freezing (*4, 11, 22, 23, 24, 25, 26, 39, 40, 51, 52, 54, 55*) that have made it clear that the benefits of the process arise from the inactivation of oxidizing and hydrolyzing enzymes and the consequent prevention of autolytic changes that are not completely arrested by freezing and storage at subzero temperatures without such previous treatment. Diehl, Dingle, and Berry (*26*) found that the enzyme systems of various unscalded vegetables were very active after several months in storage at temperatures between 20° and −5° F., and Morris and Barker (*48, 49*) found that the action of these enzymes was not inhibited in vegetables that had been subjected to the temperature of liquid air (−313°).

Although scalding is now recognized as absolutely necessary to satisfactory preservation of frozen vegetables, as yet no general agreement has been reached by investigators as to details of method or time and temperature that are best for any particular vegetable. Joslyn and Marsh reported (*39*) that they found "a critical temperature range, somewhat different for each vegetable, at which the color, flavor, and texture were most benefited by heating," and these temperature ranges were from 160° to 170° F. for peas, 180° to 195° for string beans, and 165° to 180° for spinach. In a more recent paper, Arighi, Joslyn, and Marsh (*8*) modified this recommendation, finding that 2 minutes' scalding at 80° to 95° C. (175° to 204° F.) gave better preservation of texture, color, and flavor in Telephone peas than either lower or higher scalding temperatures when the material was subsequently held for 2 years at 0° F. Diehl and Berry (*22*), using No. 3 cannery size Alderman peas eleven thirty-seconds of an inch in diameter, found 30 seconds' scalding at 210° adequate to inactivate enzymes, whereas longer treatment caused softening of the peas and fading of color. Later they, with Pentzer and Asbury, recommended scalding in flowing steam for 30 to 90 seconds, depending on the size of peas, as factory practice (*27, 28, 29, 30*). In 1936, Diehl, Campbell, and Berry (*25*) reported that scalding Alderman peas, No. 6 cannery size (fourteen thirty-seconds of an inch up) for 85 seconds in steam or 60 seconds in boiling water insured stability in peas frozen at 0° but did not completely destroy enzymes or prevent deterioration when the peas were stored at higher temperatures. Inactivation of catalase in peas was complete after 30 seconds' exposure to 200° or 212° but was not accomplished by 3 minutes' exposure to 160° to 180° (*4*). It is of considerable interest in this connection to note that Smart and Brunstetter (*51*) have found that catalase inactivation became complete in young, nearly full-grown Henderson Bush lima beans only after more than 6 minutes' exposure to 190°, and in older, nearly mature beans only after more than 9 minutes' exposure. The best preservation of the quality of the product was obtained in these same lots of beans by scalding for 3 minutes at 212°.

In the first year of the present work such recommendations as could be found in the literature as to time and temperature of scalding were tentatively followed, but a considerable amount of experimentation with various methods and periods of hot-water treatment was also done. Measurements of catalase activity as an index of heat penetration and consequent destruction of enzymes by the method developed by Diehl and his associates (*22, 26*) were used as a check upon the results. Some of these experiments will be discussed in subsequent sections in connection with the different vegetables, but as a generaliza-

tion that holds for the various products studied by the authors, it may be stated here that complete inactivation of the enzyme systems and satisfactory preservation of quality in the material required somewhat longer treatment, irrespective of the product concerned, than has been recommended by Diehl and his coworkers. The reasons for this difference are not apparent, but the fact was very evident, and commercial operators in the Eastern States are strongly advised to employ the scalding schedules here recommended rather than shorter periods.

In the present experiments the use of a large volume of boiling water into which the material could be plunged while enclosed in a loosely woven bag gave almost instantaneous contact of the water with all parts of the material and resulted in very uniform scalding. It also made possible very quick transfer to cold water to stop the action of heat. It was therefore used as standard procedure throughout the work. No experiments with scalding in steam were made.

There were several reasons that made adjustment of the length of the scalding period to the stage of maturity of the green vegetables necessary. With peas, the time of immersion ranged from 1 minute for sizes held by $\frac{5}{32}$- or $\frac{6}{32}$-inch screens to 2½ or 3 minutes for those held by the $\frac{13}{32}$-inch screen. In larger-seeded varieties of lima beans the scalding period was 2 minutes for the two or three smallest sizes separated by the screens, 3 minutes for the two or three intermediate sizes, and 4 minutes for the one or two largest sizes. For the three sizes of green beans packed, periods of 2, 3, and 4 minutes were used for youngest, intermediate, and oldest stages, respectively These periods seemed to give better results than any others.

Best preservation of green color was obtained when the scalding period was held to the minimum that would completely inactivate the enzymes. The periods specified for the various age sizes were adequate for this purpose, and longer scalding resulted in injury to color, greater absorption of water, and more rupture and collapse or wrinkling of seed coats on freezing. On the other hand, the longer periods employed with the older and larger sizes, although adequate, were near the minimum that would adequately heat the material; reduction of the period for these older stages resulted in greater firmness and less pleasing texture, and in some cases in deterioration in flavor also. It was not possible to find a scalding period that could be used with entirely satisfactory results for ungraded peas, lima beans, or snap beans that differed greatly in size and stage of maturity. If the treatment was sufficiently long to scald the larger sizes adequately it injured color and caused collapse and splitting of the smaller ones; if it were short enough to prevent injury to younger and smaller sizes the older and larger ones were not adequately heated. Consequently, it seems necessary to advise that these vegetables be graded for age and size prior to their being scalded so that the treatment can be adjusted to the different requirements of older and younger stages.

A number of experiments were carried out with green snap beans in which the temperature of the scalding bath and the time of immersion were varied. In a series in which the temperature of the bath was boiling at the time each batch was immersed and the time of immersion was varied, it was found that shortening the period from 3 to 2½, 2, or 1½ minutes resulted in considerable bleaching in the frozen beans and, in the lots given the shorter periods, in abnormalities of flavor similar to those found in untreated beans. Extension of the

scalding period by steps of 1 minute each up to 10 minutes resulted in progressively increasing loss of green color and replacement by dull, opaque brown as the period was increased. In the lots scalded 8 to 10 minutes there was rather general loosening and shredding of the cuticle of the pods, and the flavor of all lots scalded more than 4 minutes was inferior to that of the lot given standard 3-minute treatment. In another series of experiments a quantity of beans (Giant Stringless Green Pod in the intermediate stage of development) was divided into seven portions, which were given the following treatments:

Lot 1—Standard 3-minute immersion in boiling water, average temperature of bath during immersion 205° F. (96° C.).
Lot 2—3 minutes in water at 194° F. (90° C.).
Lot 3—6 minutes in water at 194° F.
Lot 4—6 minutes in water at 176° F. (80° C.).
Lot 5—12 minutes in water at 176° F.
Lot 6—10 minutes at 162° F. (72° C.).
Lot 7—20 minutes at 162° F.

All lots were packed in 1-pint paper containers without brine, frozen and stored in the usual manner, and examined after an interval of approximately 7 months. Lot 1 was very good in color while frozen, and when cooked was fairly good in color, excellent in texture, and very good in flavor. Lots 2 and 3 were like lot 1 as to color in both frozen and cooked condition, but were very tough and flavorless. Lots 4 to 7 had a dull brownish-olive color suggestive of canned beans while still frozen, becoming whitish brown when cooked, and were so tough and flavorless as to be very nearly or quite inedible.

In another experiment, a quantity of beans of the older stage of one variety, Full Measure, was divided into eight lots, one of which received no scalding treatment whereas the others were scalded in a large volume of boiling water for periods of 1, 2, 3, 4, 6, 8, and 10 minutes, respectively. All were then packed dry in 1-pint paraffined paper tubs. When examined after approximately 7 months in storage at 0° F., the unscalded beans had the characteristic haylike odor of raw frozen vegetables and a very disagreeable, repellent flavor when cooked; those scalded for 1 or 2 minutes were considerably whitened in appearance and were somewhat abnormal in flavor; those scalded 3 or 4 minutes were the best of the series in color and texture and were good in flavor. Those scalded for 6 minutes or more became progressively a darker, duller brown in color with increased scalding time, and the cuticle of the lots scalded 8 and 10 minutes was loosened and became detached in cooking, giving them a very unattractive appearance; they were also decidedly inferior in flavor to the lots scalded 3 or 4 minutes. A similar experiment with the intermediate stage of Burpee Stringless Green Pod in which the scalding periods were 3, 4, and 5 minutes gave similar results; the lots scalded 3 and 4 minutes were satisfactory in texture and flavor and good in color; the lot scalded for 5 minutes was inferior, showing loosening of cuticle and a dull, opaque brown color that improved on cooking, but the flavor was not equal to that of the other lots.

Corn was scalded on the cob in boiling water for a 4-minute period under such conditions that the temperature of the water did not drop below 195° F. when the corn was immersed and resumed boiling within 90 seconds or less. Under these conditions, a 4-minute scalding period was adequate for corn that was to be cut from the cob,

regardless of the size of ear or depth of grain, and this was consequently used with all varieties regardless of ear size. In corn to be frozen on the cob rather thorough penetration of the heat into the cob as well as into the grain is necessary, and this requires a longer time. It appears that for corn grown under eastern conditions 4 minutes' scalding is the absolute minimum that should be employed with small-eared varieties, such as Golden Bantam, which are packed on the cob, and that the period should be extended to 6 minutes for large-cobbed, many-rowed varieties. In one experiment in which a quantity of Country Gentleman corn was divided into lots that were scalded for 4, 5, 6, and 7 minutes, the lots scalded for the 6- and 7-minute periods were identical with the others in appearance but were slightly superior in flavor to the lots scalded for shorter periods. It seems probable that some extension of the scalding period for corn would result in improvement in quality. Some commercial packers are evidently making such extensions, as some commercial whole-ear corns recently examined have been so thoroughly cooked that they could be eaten without further cooking.

Hermetically Sealed and Nonairtight Containers

A comparison was made between lots of identical material packed in hermetically sealed tin cans and in paraffined liquid-tight but not airtight paper containers. Some of the latter were closed by pressing a paper disk into an annular groove near the top; others were subsequently passed through a machine that rolled the edge of the cup inward and applied molten paraffin to the line of juncture. Some of the cups were removed from the machine after the edge had been rolled but before the application of paraffin. Rectangular folding cartons of 1-pint capacity were also used for dry packs of some products.

When the dry packs of vegetables having green color were opened, there was a slight but rather consistent superiority in the appearance of the material in the hermetically sealed containers over that in the nonairtight packages. Dry packs of peas, lima beans, and green beans in sealed containers, viewed in the frozen state, had a freshness and brightness unequaled by the material in the nonairtight containers, which rather generally showed more or less yellowing and opacity of the surface layer. Dry-packed corn showed similar opacity and dulling of the surface, which was rather less pronounced than in products having green color. These differences disappeared in thawing and cooking, when the products from the two types of container became indistinguishable. The alteration in color in the green vegetables was in part due to incipient drying of the surface, as in snap beans, and in part to films of ice or a mixture of ice and air bubbles beneath the seed coats, as in peas and lima beans. In either case the green color of the underlying tissues was merely masked and more or less yellowed in tint by the presence of the opaque layer, and reappeared as thawing proceeded. In material that had been packed in brine it was impossible to distinguish between samples from the two sorts of containers, either before or after they were cooked, as appearance, color, consistency, palatability, and retention of flavor were identical.

It appears from these results that the only advantage gained from the use of airtight containers is a slightly more attractive appearance of the frozen material in dry-packed products, with no difference in the case of brine pack and with no consistent gain in preservation of table quality or flavor in either type of pack. For any ordinary period of storage under proper conditions, the dulling of color at the surface of dry-packed products is not sufficiently extensive or pronounced to provoke consumer resistance. It is chiefly due to a loss of moisture, and if this can be prevented complete exclusion of air is not a requirement for a satisfactory container for the vegetables studied; any container that protects the material from contamination from outside sources and that does not itself give up dissolved metal or odors or flavors to be absorbed by the contents will be satisfactory.

Plain and Enameled Tin Containers

Both plain and enameled tin containers were used. Some of the latter had standard corn enamel, the others a berry enamel. Plain tin was perfectly satisfactory for all the vegetables packed dry, but there was corrosion, ranging from moderate to rather severe, in the various packs in brine. The corrosion was very definitely localized at the liquid line, and in the cans of lima and snap beans, pieces of material lying in contact with the can at this level showed some discoloration. The enameled cans gave perfect protection to the contents in brine packs without regard to the particular type of enamel used, the only essential being that the metal was effectively shielded from contact with the solution.

Large or Institutional-Size Containers

The comparative studies upon varieties were based primarily upon material packed in 1-pint containers. Such containers are ideal packages for retail distribution for family use, but there is considerable use of frozen products by hotels, cafes, and institutions serving large numbers of people. Larger packages have very obvious advantages for these large-scale users provided that they can be employed without sacrifice of quality of the product. Some experiments were carried out to determine whether the methods of preparation and freezing here used could be satisfactorily employed with larger packages, or whether increased thickness and volume of package necessitates use of lower freezing-room temperatures. These experiments were intentionally planned to afford a rather severe test of the method of freezing employed. Some use was made of No. 10 sanitary tin cans, which contain a cylinder of material 6 inches in diameter and 6¾ inches in height; but the containers principally used were paraffined paper tubs of the roll-top type and of 5- and 10-pint capacity, with the internal dimensions stated in table 1. Walls, bottoms, and tops were impregnated with paraffin and with the exception of the tops were covered on both surfaces with a rather thick film of paraffin. Bottoms and tops of all sizes were countersunk one-half inch, so that each package had a dead-air space beneath it when standing on a flat surface.

TABLE 1.—*Internal dimensions and wall thickness of paper containers used*

Capacity of container (pints)	Inside diameter		Inside height	Thickness	
	Bottom	Top		Wall	Top
	Inches	*Inches*	*Inches*	*Inch*	*Inch*
1	3½	4⅜	2¾	0.031	0.050
5	5½	7	4⅞	.035	.057
10	6¾	8¾	7¾	.069	.085

The use of these containers introduces several factors tending to reduce the rate of cooling of the contents. Among these are increase in all dimensions of the mass of material and consequent increase in time required for transmission of internal heat to the surface, reduction of radiating surface in relation to mass, and increased insulating effect of the container due to greater thickness of walls. If very rapid cooling is essential to preservation of quality in the vegetables here dealt with, that fact should be very apparent when otherwise identical material packed in the various sizes of containers is compared.

The large containers were handled in all the details of packing and freezing exactly as were the smaller ones. The amounts of material and of added brine, where brine was used, placed in the two sizes were 5 and 10 times those placed in the small tubs. In placing the packed containers in the freezing room, care was taken that large and small sizes should be equally exposed to the current of air from the fan.

The products packed in both 5- and 10-pint containers included peas, green beans, cream-style corn, and corn on the cob. Green lima beans, whole-grain corn, and succotash were packed in the 5-pint size but not in the larger size. Both dry and brine packs were made with all products. In addition to the straight or dry pack of corn on the cob a modification was introduced in that some of the ears in the dry-packed material were individually wrapped in cellophane or in waxed paper and aluminum foil before they were placed in the container.

The results will be discussed in detail in connection with the individual vegetables, but certain general statements may be made here. All of the material packed in No. 10 tin cans, whether with or without brine, was perfectly preserved in all respects and compared favorably with the check lots in small containers. This was also generally true of the material in the larger paper containers, with some exceptions. In the straight packs, the larger containers showed somewhat more pronounced dulling and opacity than the small ones, owing to greater drying of the surface, but this difference disappeared on cooking. In a few lots of lima beans, the material at the center of the container showed a slight bleaching or fading of color as compared with check lots in pint containers, but there was no difference in odor or palatability and flavor. No such differences in color were observed in the other green vegetables. Much the greater portion of the corn packed on the cob was excellent in flavor, but occasional lots irregularly distributed through the pack showed abnormality in flavor varying from that which was just perceptible to very pronounced. This con-

dition was only rarely present in the brine packs, was somewhat more frequent in the straight packs, and was general in the wrapped straight packs. The irregularity of its distribution made it clear that it was not related to variety or age of sample, size of ear, or method of packing, and suggested that it might have been due to combination of two or more factors. One of these was the use of a 4-minute scalding period, which might have been too short to insure inactivation of enzymes in the cob tissues; another was the use of containers having such thickness in all dimensions that escape of heat from their centers was retarded. It is thought that these factors brought the material so near the danger line at which deterioration in quality and flavor could begin that variations in cooling of the material prior to packing, inequalities in exposure to air currents from the fan, and other variations in the treatment of otherwise identical material might determine the distribution of deterioration through the pack.

The results have very considerable practical significance. The fact that most of the products were perfectly preserved in spite of the severe and unfavorable conditions of the tests is a conclusive demonstration that freezing vegetables in institutional-size packages is feasible provided that the temperature of the freezing room be 0° F., that provision for free circulation of the air about the packages be made by stacking them in open order, and that the containers be of reasonable size and made of material that will facilitate heat transfer. It may be pointed out that containers may be of any desired size in two of their dimensions, provided they are kept thin in the third dimension in order to permit rapid transfer of heat from the interior to the surface of the package. If the freezing is carried on in still air, such packages should be stacked with adequate space between for air movement, and a fan should be provided to aid air movement between the stacks. Unless containers of the form and character indicated are to be used, freezing prior to packing may be a preferable method (p. 20).

Dry or Straight and Brine Packs

Parallel packs of all the vegetables were made from identical lots of material, in most cases in all the various sizes and types of containers, with and without the addition of brine. Results of detailed comparisons of the two packs for each vegetable will be stated in the sections on the different vegetables, but the study of the material as a whole led to some conclusions that are sufficiently general to be stated here.

When viewed in the frozen condition, peas and lima beans frozen in brine were a clearer, brighter green than the dry-packed duplicates, and the color was very uniform throughout the container. The interior of the mass of dry-packed material compared very favorably in color with that of the duplicate packs in brine, but the surface of the dry-packed material was a duller, less intense green with more or less yellowing. This was not due to destruction of chlorophyll, but to superficial drying of the seed coats and to the presence beneath them, especially in the area surrounding the hilum, of a thin film of ice containing bubbles of air. The opacity of this layer more or less completely masked the green color of the underlying tissues so long as the material remained frozen, but there was a progressive deepening of color as the material thawed, and the cooked material was usually

indistinguishable from the corresponding lot that had been packed in brine.

The dry-packed cream-style corn showed a similar opacity and dulling of color at the surface caused by incipient drying, and in the whole-grain corn a similar condition extended rather generally through the whole mass. In corn on the cob, there was an intensification of color and development of a faint bronze tinge on the outer ends of the grains in yellow corn and a slight yellowing or browning on those of the white corn. As in the condition described in peas and lima beans, the differences disappeared on cooking, leaving dry and brine packs indistinguishable in appearance in the cooked condition. Green snap beans presented a contrast to other vegetables with respect to preservation of color in the frozen material, which will be discussed in the section on that vegetable (p. 31).

In cooking the products, the dry-packed samples received sufficient salt at the beginning of cooking to make them equal the brine packs in salt content. The judges who tasted and scored the products were asked to determine whether there were discoverable differences between the two series of samples in texture or consistency, palatability, and fullness, naturalness, and fineness of flavor. With respect to texture or consistency, there was general agreement that the two packs were indistinguishable except in the string beans, in which most of the brine-packed material was slightly tougher in texture. There was also general agreement that there were no constant and outstanding differences in palatability and table quality between the two packs considered as a whole. There was some difference of opinion as to whether flavor had been equally well preserved by the two methods. A minority of the group were unable to distinguish between the two sets of samples by tasting them, and they considered preservation of flavor equally good in both, except in the corn, where all were agreed that the brine pack was somewhat superior in flavor. They also considered that the brine packs, as a whole and without regard to the particular vegetable concerned, showed a slight but consistent superiority over the dry-packed material. It seems most probable that this difference was due to the fact that in the products in brine the salt had diffused into the material and become blended with it before it became frozen to a degree that could not be duplicated by adding salt to the straight packs at the time of cooking. This conclusion is borne out by the work of Lanman and Minton (*42*) who found that addition of salt to fresh vegetables prior to cooking gave a better flavor than when a like amount of salt was added at the middle or end of the cooking period.

In summarizing, the chief differences between dry and brine packs were a somewhat better preservation of color in peas, lima beans, and sweet corn in brine packs; in snap beans, color preservation was somewhat better in dry packs than in brine, and there was considerable splitting of pods in brine that did not occur in anything like the same degree in dry packs. In texture and consistency of the products after cooking there were no significant or consistent differences, nor in palatability and table quality of the two packs. There was, however, a slight but consistent superiority of flavor in brine packs, which seemed to be due to a more perfect blending of salt with the material rather than to any loss of flavoring constituents in the dry-packed material. This difference in quality was somewhat less pronounced

than the differences between fruits packed straight and those packed in sirup, first pointed out by Cruess and his coworkers (*17, 35*).

It was obvious that the differences in appearance observed between dry and brine packs in the frozen condition were due chiefly to the fact that the interval between packing and freezing had been sufficient to permit some drainage of water absorbed in the scalding process from beneath the seed coats of peas and beans and its partial replacement by air. Reduction of the interval between packing and freezing would, of course, reduce the amount of this effect. It was in part due to the drying of the surface of the material in storage, which occurs to some extent in hermetically sealed packages but to a much greater extent in nonairtight containers. Changes in appearance due to this cause progress with time and ultimately make dry-packed products held for long periods rather unattractive in appearance.

Freezing Prior to Packing

A rather limited number of experiments on freezing prior to packing were made in the course of the present work. The method employed comprised scalding, cooling, and then spreading the material on trays covered with cheesecloth; care was taken that individual pieces were not in contact, and the trays were placed in the 15° F. room in such position that the air current from a fan swept directly across them. The material was usually placed in the room in late afternoon and allowed to remain overnight, an interval of 12 to 16 hours, when it was removed from the trays and placed in containers after which it remained in the same room for a few days prior to removal to the 0° room for storage. In all cases the material so treated was part of a larger lot, the remainder of which was packed by the methods used in preparing packs for comparative study.

Various lots of peas and lima beans of different ages and size grades were individually frozen. Peas required 30 to 45 minutes and lima beans 40 to 85 minutes to become frozen to the center, the time increasing with age and size. They showed a very slightly yellowed or faded coloration when removed for packing, and this had become much more pronounced when the material was examined after 6 to 7 months' storage in 1- or 5-pint paper containers. All the material in the container then showed the dull opaque appearance and yellowish-green to whitish-green color characteristic of the surface layer of dry-packed peas or beans. This was due, as in dry-packed material, to the presence of films of ice or ice and air beneath the seed coats around the hilum and radicle and to partial drying of the seed coats themselves. As the material thawed, the color improved, and the cooked material was indistinguishable in every respect from duplicate lots packed straight and frozen in the container.

Corn on the cob was frozen by exposing the ears on trays before the fan for 12 to 16 hours. Some of the ears were individually wrapped in cellophane, others in waxed paper with an outer wrapping of aluminum foil before exposure, still others were not wrapped. At the subsequent examination, all the ears, whether wrapped or not, showed some dulling and darkening of color in the white varieties and intensification of the yellow color with development of an orange tint in the yellow corns. This was caused by a drying effect confined to the exposed outer ends of the kernels and was only slightly more pro-

nounced than that seen in straight-packed ears frozen in the container. It disappeared on cooking. All the corn individually frozen was equal to, but in no way superior to, corresponding packs frozen in the container, with the exception that no abnormality of flavor was present in any of the individually frozen ears. This method of freezing corn on the cob has very distinct advantages over freezing in the container. The product has no superiority in quality provided the freezing in the containers has been sufficiently rapid, but individual freezing permits the use of individual wrappings, which have distinct sanitary and aesthetic advantages, and the employment of packages or cartons of almost any desired practical size and character.

COMPARISON OF FROZEN AND CANNED PRODUCTS FROM IDENTICAL RAW MATERIAL

As stated on page 6, portions of material of practically every variety and of most of the different stages of maturity of each variety of vegetable were canned and stored for comparison with the frozen products. As a result it may be stated in general that, although all the canned products ranged as good to very good or excellent, all the judges, with the exception of one, decidedly preferred the frozen product because of the greater freshness and naturalness of flavor. One of the judges expressed a preference for the canned beans, and it developed that he preferred the flavor of canned beans to that of the fresh product as prepared directly from the garden. With this exception the judges were unanimous in their statement that the frozen products were so superior to the canned material in their attractiveness and palatability that the two could not be measured by any common standard of comparison.

TEMPERATURES EMPLOYED IN FREEZING AND STORAGE

In practically all the experimental work herein reported, the products packed were given a preliminary freezing in a 15° F. room in which they remained for a few days prior to transfer to a 0° room where they subsequently remained until examined. As the material was here handled, this treatment, with the exception of some of the larger containers of certain products, resulted in the preservation of the product with an appearance and quality in every respect equal to that of check lots placed directly in the 0° room, and fully equal, and in some instances superior, to commercial frozen products purchased in the markets.

It must be very strongly emphasized, however, that the successful outcome of the experiments was made possible only by the fact that the conditions were experimental and of such character as it would be difficult or impossible to maintain in factory operations.

All products were thoroughly and uniformly cooled prior to being packed, the quantities packed per day were small, and packages could be so distributed in the freezing room that each received the benefit of the air current from a fan. The volume of product placed in the freezing room in any working day never exceeded more than 1 percent of its cubic capacity, and never raised the temperature of the room more than 2°, and that for a very short period. Notwithstanding these conditions, the results with some of the larger sized packages

show that the margin of safety was narrow and that the introduction of any condition that slowed the cooling of the larger packages endangered the appearance and quality of the contents. A temperature of 0° F. for both freezing and storage is regarded as the highest permissible in practical freezing operations with vegetables if the work is to be conducted with a reasonable factor of safety for the product. Also, the refrigerating equipment should have such capacity that it can maintain this temperature with an increase of not more than 3° to 5° with maximum loads of material present in the rooms.

Effects of Prolonged Storage at 15° and at 0° F.

Various lots of all the vegetables packed were held in the 15° room for 6 to 7 months after being packed and were then compared with check lots that had been held for the same period at 0°. In all the material held at 15° there had been pronounced deterioration in appearance, quality, and flavor; this was greatest in the nonairtight containers but had also occurred in tin. All the green vegetables were very unattractive in appearance because of the breaking down of chlorophyll and formation of phaeophytin, as described by Campbell (*15*) in peas; the color of corn had also darkened, and the flavor of all of the vegetables was so altered that they were barely edible. Further holding at 15° for a total period of 12 months carried the deterioration to a point at which the material could no longer be consumed.

Some of the material packed in the first year of the work was brought out of 0° F. storage at the time of the examination, held in the 15° room for 5 to 6 weeks, and then returned to the 0° room, where it remained until the examination of the second year's pack. It was then examined, 18 to 19 months after packing. The results varied with the different vegetables. Corn showed no deterioration in appearance except increased drying at the surface of straight packs, and there was little or no lowering of quality. Green beans, peas, and lima beans showed an amount of deterioration about equal to that which occurred in similar material held 6 months at 15°, had practically lost characteristic flavor, and were barely or doubtfully edible. Deterioration of the beans in the mixture had brought about essentially the same conditions in the succotashes. None of the material had any abnormal odor. As these deteriorative changes do not occur in material held constantly at 0° for long periods, it seems clear that their occurrence in this material is attributable to the period of storage at higher temperature. It was concluded, therefore, that in order to obtain satisfactory preservation of vegetables, it is necessary that the storage temperature be held constantly very near or at 0° and that no prolonged rise in temperature of the storage room above this level occur at any time during the period of storage.

Smart and Brunstetter have reported successful preservation of Henderson Bush lima beans for periods of 15 months (*51*) and of spinach and Siberian kale for periods of 9 to 15 months at a storage temperature of 15° (*52*), but some loss of quality was apparent in their material and they consider this storage temperature too high for safe preservation of these products.

RESULTS OF COMPARATIVE STUDIES OF THE VARIOUS PRODUCTS

Green Snap Beans

The earliest successful experimental work on the freezing preservation of green beans reported in the literature is that of Joslyn and coworkers (*34*, *35*, *36*) in California, and that of Morris and Barker (*9*, *10*, *47*, *48*) in England. In work carried on independently, beginning in 1929, these two groups of workers developed methods of preparation, packing, and freezing that gave satisfactory preservation of the material for considerable periods. Both groups emphasized the necessity of adequate scalding before packing as a means of preventing deterioration and the development of abnormal, haylike odor and flavor in storage. Woodroof also reported successful results with the freezing of green beans (*57*, *58*). Wallace and Tanner (*56*) included green beans in the list of vegetables that they froze after various preparatory treatments and held for considerable periods in order to study the changes in microbial content and in appearance and quality of the products. All of these workers were concerned primarily with the development of methods or with the effect of various treatments on the preservation of quality in the material, and none of them recorded the variety or varieties employed in their experiments. Diehl and his associates (*27*) are the first workers who have reported the results of comparative studies upon a number of varieties of green beans; they found that Kentucky Wonder, Blue Lake, Refugee, and an unnamed variety of wax bean, all grown in the Puget Sound section of Washington, were satisfactory for freezing purposes.[5]

VARIETIES EMPLOYED

There were 14 varieties used in the present work. Nine of these (Burpee Stringless Green Pod, Asgrow Stringless Green Pod, Giant Stringless Green Pod, Mosaic-Resistant Stringless Green Refugee (Idaho Refugee), Full Measure, Tendergreen, Asgrow Stringless Valentine, Round Pod Kidney Wax, and Keeney Improved Stringless Wax) were grown in both years. The variety, since introduced as U. S. No. 1, was used in 1934 only, and 4 varieties, Konserva, Black Valentine, Tennessee Green Pod, and Kentucky Wonder Pole, were used only in 1935. Of the 14 varieties, 9 are old, widely known varieties most of which were stated by Tracy to be in rather general cultivation when his descriptive catalog was published in 1907 (*53*); the others are comparatively recent introductions. The varieties were grown side by side on fairly uniform soil and received identical treatment in the details of planting and cultivation. All varieties gave good growth and satisfactory yields with the exception of Mosaic-Resistant Stringless Green Refugee (Idaho Refugee), which produced an exceptionally luxuriant growth of vines in both years, with a very light crop of beans in 1934 and only scattered pods in 1935.

[5] Results of comparative tests of groups of varieties of green beans adapted to the particular districts concerned have recently been reported by workers in Iowa, Michigan, New York, North Dakota, and the Province of Quebec, Canada. For citations see footnote 2, p. 3.

STAGES OF MATURITY OF BEANS PACKED

In 1934 beans were packed at two different stages of maturity, as determined by diameter and appearance of pods. The younger stage was made up of pods up to and including those judged to contain seeds one-fourth of their size at maturity; the older stage began at this lower limit and included pods up to seven-eighths of their adult size. Both sizes were snipped and packed without being cut, that is, as entire pods.

In 1935 beans were packed at three stages of maturity. The youngest of these consisted of pods that had reached approximately full length but in which the swelling of the seed had not become noticeable; the second or intermediate stage corresponded rather closely with the younger stage of the preceding year, and the third stage contained chiefly beans corresponding with the older stage of the preceding year but had also a small percentage of pods in which the seeds were full-grown. The youngest stage was snipped and packed unbroken; the intermediate and older stages were broken into lengths approximating 1 inch.

DETAILS OF PREPARATION AND PACKING

Various experiments with green beans in which different lengths of scalding period and different temperatures of the scalding bath were used have already been described (p. 13). The scalding periods for the two stages of maturity packed in 1934 were 2 and 3 minutes for the younger and older, respectively. The results, with those of the experiments on other periods and temperatures of scalding, led to the use of scalding periods of 2, 3, and 4 minutes for the three stages of maturity packed in 1935, the volume of water used being such that the average temperature of the bath for the three periods was about 202°, 206°, and 209° F., respectively. Scalding was followed in all cases by very rapid cooling to the temperature of the water supply and holding at that temperature until the material was packed.

As containers, paraffined paper tubs of 1-, 5-, and 10-pint capacity, rectangular paraffined paper cartons of 1-pint capacity, and No. 2 plain tin cans were used. All of the 5- and 10-pint tubs and some of the 1-pint size were closed by pressing a paraffined disk into place in an annular groove near the top of the tub; some of these were further sealed by rolling the edge and covering the line of closure with a layer of molten paraffin.

Both dry and brine packs were prepared in all the types and sizes of container except the rectangular pint cartons, which were not liquidtight. No attempt to pack a uniform predetermined quantity of material into a given size of container was made; all the containers were filled as completely and closely as possible without actually resorting to placing the pods one by one.

The handling of the material in the freezing room, the period of storage, and the methods employed in examining and grading the products have been stated (p. 6).

COMPARATIVE SUITABILITY OF VARIETIES FOR FREEZING

The results of the detailed study and grading of the material used in the varietal comparisons are summarized in table 2, in which the numerical values given for the various factors in the original examination records have been replaced by the equivalent terms "excellent," "very good," "good," "fair," "poor," and "very poor." The results of the comparisons have been separately stated for each of the stages of development at which the variety was packed, because these different stages in a variety may vary rather widely in the ratings they receive; also these variations may take different forms from one variety to another. In the last column of the table the variety is given a ranking by placing it in one of four groups as to its suitability for freezing. This ranking was arrived at by taking into consideration the appearance and quality of the material at all stages of maturity and in all sizes of container and types of pack, in comparison with other varieties similarly considered.

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TABLE 2.—*Results of comparative studies of market appearance in the frozen condition and in appearance, texture, and flavor when cooked, of 14 varieties of green snap beans at selected stages of maturity*

Variety	Size	General appearance and color in frozen condition	Characters after cooking			Comparative rank for freezing
			Appearance and color	Texture	Flavor	
Asgrow Stringless Green Pod.	Small	Very good to excellent	Poor, browned	Excellent	Fair	Group 2.
	Intermediate	Very good. Mottled with yellow	Fair. Light green	do	Good	
	Large	Fair. Opaque and yellowed	Fair to poor. Olive brown	do	do	
Burpee Stringless Green Pod.	Small	Fair to good	Fair. Brownish green	do	Very good to excellent.	Do.
	Intermediate	do	Fair	do	Very good	
	Large	Poor, yellowish, watersoaked	Poor. Browned	do	do	
Giant Stringless Green Pod.	Small	Good	Very good	Very good	do	Group 1.
	Intermediate	Fair to good. Light green	Good. Somewhat browned	Excellent	Good to very good	
	Large	Poor. Yellowish green	Fair. Brownish yellow	do	Very good	
Asgrow Stringless Valentine.[1]	Small	Excellent	Poor. Olive brown	Good. Somewhat stringy.	Good	Group 3.
	Intermediate	Very good	do	Fair to good. Stringy	do	
	Large	do	do	Very poor. Tough, stringy.	Very good	
Black Valentine	Small	Excellent. Extremely deep, dark green.	Fair. Dark olive green	Fair	Fair, not outstanding.	Group 4.
	Intermediate	Excellent. Good light green	Fair. Olive green	Poor. Woody	Fair	
	Large	Not packed				
Tendergreen [1]	Small	Good to very good light green. Much splitting.	Fair to poor. Browned	Excellent	Good to very good	Group 3.
	Intermediate	Poor. Light yellowish green	Poor. Much splitting	Very good. Slightly tough.	Very good	
	Large	do	Poor. Browned	do	Excellent	
Full Measure	Small	Excellent	Fair. Browned	Very good	Fair	Group 4.
	Intermediate	Good	do	Good. Slightly tough	Good	
	Large	do	Poor. Very brown	Poor. Tough, woody.	do	
Mosaic-Resistant Stringless Green Refugee (Idaho Refugee)	Small	Excellent. Uniform light green	Excellent	Excellent	Excellent	Group 1.
	Intermediate	Very good. Uniform light green	Very good	do	do	
	Large	Good. Uniform light green	do	Very good	do	
Konserva	Small	Very good. Very deep dark green	Fair. Olive green	do	Fair	Group 3.
	Intermediate	Good. Slightly browned	Fair. Much splitting	do	Good to very good	
	Large	Fair. Somewhat browned	Fair	do	Very good	
Tennessee Green Pod	Small	Excellent. Bright fresh green	Poor. Very brown	Good. Slightly stringy	Excellent	Do.
	Intermediate	Very good. Slight yellowing	do	Good. Somewhat stringy	do	
	Large	Not packed				
U. S. No. 1	Small	Very good	Good	Excellent	Very good	Group 2.
	Intermediate	Good	Fair. Browned	Very good	Excellent	
	Large	Fair	do	do	Good to very good	

Keeney Improved Kidney Wax	Small	Poor. Bleached	Poor. Whitish	Excellent	Very good	Group 3.
	Intermediate	Very good. Bright yellow	Fair. Whitish	Very good	do	
	Large	do	Fair	Poor. Stringy, tough	Good, not full-flavored.	
Round Pod Kidney Wax	Small	Very good. Attractive green and yellow.	Poor. Brownish yellow	Excellent	Very good	Group 2.
	Intermediate	Excellent. Bright yellow	Fair. Whitish yellow	do	Excellent	
	Large	Not packed				
Kentucky Wonder Pole	Small	Excellent. Best green color	Fair to good	Excellent	Very good	Group 1.
	Intermediate	Excellent	Fair. Browned	Very good	Excellent	
	Large	Very good	do	do	do	

[1] See discussion of these varieties in the text (p. 30).

The placing of a number of varieties together in one group in table 2 does not imply that they are equal in merit in all the factors considered in the grading. The rating in the last column is a general average, and it is obvious from the preceding columns that two varieties may have the same general average yet have different values for most of the factors considered in making up the average. In determining final ranking of a variety, greater weight was given to palatability, texture, and flavor of the cooked material than to appearance in the frozen condition, in the belief that a variety, no matter how attractive its appearance may be, is unsuitable for freezing unless it also has high table quality and appeal to the palate when consumed. On the other hand, a variety of very high table quality may be of doubtful value for freezing if its appearance and color in frozen condition are unattractive. For these reasons, varieties having desirable color and appearance but not high table quality are given places determined primarily by their texture and flavor.

GROUP 1. EXCELLENT.—Three varieties, Giant Stringless Green Pod, Mosaic-Resistant Stringless Green Refugee, and Kentucky Wonder Pole, were clearly superior to all others in their general averages. They were fully equal to the best in texture and flavor and were distinctly better than the others, with two exceptions (one of which was not consistent) in their retention of fresh, natural color and appearance in the frozen condition. The color of the three differed considerably in quality or tint; that of Mosaic-Resistant Stringless Green Refugee was a rather light green which was quite uniform at all stages of development in the frozen material and which underwent a minimum of change in cooking.[6] Giant Stringless Green Pod was similar in the character of its color in the younger beans while frozen, but faded to a somewhat yellowish green in the oldest stage used. In the frozen condition, Kentucky Wonder Pole had an exceptionally attractive green color in younger stages and was a very good color in the oldest stage. Both Giant Stringless Green Pod and Kentucky Wonder Pole became somewhat brown on cooking but were very much more attractive than canned beans prepared from the same lots of material. In texture and flavor, the differences between the three varieties were so small that each was considered best by some of the judges.

In packing these varieties the upper limit in size or age to be used in the case of Giant Stringless Green Pod should be that at which the seeds are not more than two-thirds full size, because the color of older beans becomes yellowish green on freezing and turns to brownish yellow on cooking. Only very young stages of Kentucky Wonder Pole can be packed whole; older pods retain their color exceptionally well but become very much curved and wrinkled as they enlarge. As cut beans, they may be packed up to the stage at which the seeds are about two-thirds full size.

GROUP 2. VERY GOOD.—Four varieties, Asgrow Stringless Green Pod, Burpee Stringless Green Pod, U. S. No. 1, and Round Pod Kidney Wax, are placed in group 2 because each of them, although equally as good as the varieties of the first group in most respects, were not quite up to them in some essential character. In most of these varieties

[6] There is a possibility that the results obtained with Mosaic-Resistant Stringless Green Refugee (Idaho Refugee) may have been affected by the luxuriant growth of the plants and the relatively light crop of beans borne by them.

texture and flavor were good to very good or excellent, ranking with the first group varieties; the deficiency was one of color, either in the frozen stage or after being cooked or in both conditions, which made them somewhat less attractive in appearance than the first group. In the young stages, the appearance of varieties of group 2 was generally very satisfactory, but the color became much browned on cooking. In the older stages, the color of the frozen material was a less intense, more or less yellowish green, which turned to yellowish brown when the material was cooked. Some of the Round Pod Kidney Wax beans used in the younger stage remained green, others were yellow, and the appearance of the frozen material was considered very attractive by some of the judges. When cooked, the green pods became somewhat brown and the yellow faded to whitish yellow, making a rather unattractive mixture. In older material of this variety the bright yellow of the frozen beans became lighter on cooking but remained attractive.

All the varieties of this group, both while frozen and after being cooked, were fully equal in color and appearance to commercial packs of frozen beans obtained on the market and cooked by the same person and for the same period. All were good to excellent in texture and flavor. All were markedly superior to canned beans prepared from the same material and to commercial fancy grade canned beans in color, palatability, and flavor.

By rigidly limiting the material used to young beans in which the lightening of color caused by decomposition of chlorophyll has not yet begun, it would be possible to prepare packs of the varieties of this group, with the possible exception of Round Kidney Wax, that would be nearly equal or equal in attractiveness of appearance in the frozen condition to packs of varieties of the first group at a like stage of development. If the older stages are packed, it should be done with an understanding on the part of the packer that the product will not be quite so attractive in appearance as that made from the varieties of group 1, and that this might prove a handicap in marketing the product if it were offered the public in direct competition with them.

GROUP 3. FAIR.—The varieties placed in group 3 are Asgrow Stringless Valentine, Tendergreen, Konserva, Tennessee Green Pod, and Keeney Improved Kidney Wax. The gap between group 3 and group 2 is considerably wider than that between groups 1 and 2, because the varieties in group 3 do not fully measure up to those of group 2 in any respect. None of them is particularly outstanding or appealing in flavor, all except Konserva becoming somewhat tough and woody in texture as soon as the seeds have developed appreciable size, and some are rather stringy. Asgrow Stringless Valentine and Konserva have very attractive color in the younger stage while frozen, but they become an unattractive olive green to olive brown when cooked. The younger stages of Tendergreen are moderately attractive while frozen, the older ones less so; but all become brown and rather uninviting when cooked. Keeney Improved Kidney Wax does not become attractive in the frozen condition until the pods have attained considerable size, and all stages become bleached and whitish yellow when cooked. Taken together, the varieties of group 3 proved to be rather mediocre in all respects in these tests. The cooked

products were palatable and decidedly better in quality and freshness of flavor than canned beans of the same or other varieties, but their quality as compared with that of groups 1 and 2 was such as to make them unpromising material for freezing purposes.

Asgrow Stringless Valentine and Tendergreen showed greater variability in appearance and quality of the frozen products in the 2 years of the work than did the other varieties. In 1934 the pack of Asgrow Stringless Valentine was considerably better in color and somewhat better in texture than in 1935. The 1934 pack of Tendergreen was inferior in texture throughout all stages to that of 1935, with little or no difference in other respects. Differences in quality of the other varieties in the 2 years were much less, but because such variations occurred, the rating given the variety in the table is based on the results of the year in which the material was of poorest quality.

GROUP 4. DEFINITELY UNSUITABLE.—The two varieties placed in group 4, Black Valentine and Full Measure, should be avoided for frozen-pack use. Although of very attractive color and appearance while frozen, Black Valentine becomes a repellent olive green, and Full Measure a dark, dull brown after being cooked. Both are slightly tough in the intermediate stage and decidedly tough and woody as they become older; neither is particularly appealing or distinctive in flavor.

In the light of the results of this study, the varieties placed in group 4 and preferably also those of group 3 should be dismissed from consideration as material for packing by freezing methods, and attention should be centered on those of groups 1 and 2 as having greatest promise for the purpose.

RELATION OF STAGE OF MATURITY TO QUALITY

There was a decided difference of opinion among the judges as to the stage of development at which the snap bean is of most desirable quality for table use. A minority preferred beans in which the seeds had not begun to enlarge appreciably, approximately the youngest stage here packed; the majority preferred those in which the seeds were one-fourth to seven-eighths full size, approximately the age of the oldest stage here packed. There are very marked differences in composition and in food value of the material at these different stages of maturity, as has been shown by Culpepper (*18*). This difference of opinion among the judges did not prevent agreement on their part as to the relative merits of varieties; it merely resulted in the selection of the younger stage by one group and of the older stage by another, as that which had highest and most desirable flavor and quality.

EFFECTS OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING ON QUALITY OF MATERIAL

In many respects the results of the various modifications of preparatory packing treatments were identical in character with those observed in other vegetables and have been sufficiently discussed in the sections on general results (p. 11). In certain particulars the results with green beans differed from those with other vegetables, and these differences will be stated.

PACKING WITH AND WITHOUT BRINE.—Green beans differed from other green vegetables in that packing in brine did not result in better preservation of color in the frozen condition than straight or dry packing. Many of the beans of the straight packs were slightly superior in color to those of the corresponding brine packs, which appeared slightly yellowed. When material was cooked the situation was reversed, as much of the straight-pack product underwent greater change of color and somewhat greater browning than did that of the lots in brine. In a few instances the material from the brine pack was somewhat tougher in texture than that from the corresponding straight packs, and in others the flavor of the brine pack was considered slightly more pleasing; but these differences were neither great nor consistent. The most outstanding difference between the two styles of pack was in the amount of splitting of pods. Some splitting of entire pods of younger beans occurred in the straight packs but was almost entirely absent in cut beans. It was very generally present in both entire and cut beans in brine packs and was nearly universal in entire pods of some varieties. It was due to expansion of water inside the pod during freezing, which opened the sutures with the result that the valves of many of the pods became entirely separated during cooking. In straight packs, opportunity was afforded for draining away water absorbed during scalding, with the result that mechanical splitting of pods owing to ice formation inside them was comparatively rare.

DIFFERENCES BETWEEN SEALED AND UNSEALED CONTAINERS.—Material packed in brine in hermetically sealed containers and in nonairtight paper cups was generally indistinguishable in appearance and quality. A few plain tin cans showed some corrosion of the can at the liquid line, and darkening of the beans in contact with the corroded area had occurred. Although this was neither general nor serious, it would be well to avoid it by using lacquered cans if frozen beans are to be packed in brine in tin. In the dry packs the surface of the material showed the dullness and opacity generally characteristic of dry-packed material in nonairtight containers, but it did not detract from the appearance of the product to the same degree as in corn and peas. It disappeared on thawing and cooking and the cooked product was indistinguishable in every respect from that from hermetically sealed tin cans. Nonairtight containers of watertight types appear to be perfectly satisfactory for either brine or dry packing of beans, and those of the folding carton type are equally satisfactory for dry packs.

EFFECTS OF SIZE OF CONTAINER.—There were no significant or consistent differences in appearance, texture, or flavor after cooking between portions of a given lot of beans that had been packed in 1-, 5-, and 10-pint containers, either in dry or brine packs. In brine packs, the material was equally indistinguishable in the frozen condition; in dry packs examined in frozen condition there was somewhat greater dulling and whitening of color, with the result that frozen appearance was usually graded slightly lower than that of identical material in small containers. As the differences entirely disappeared on thawing and cooking, there seems to be no reason why larger size containers may not be successfully used provided the form be such as to facilitate transfer of heat out of the package (p. 18).

Peas

VARIETIES EMPLOYED

The 18 varieties of peas employed in the tests were selected from a much larger number of varieties and strains that had been under study by one of the authors for several years as to their comparative suitability for canning. Most of them were chosen because they appear to combine more than average quality and attractiveness of flavor with a satisfactory degree of vigor and yield, but a few were included without regard to their inherent quality because of their wide distribution and commercial importance. They were so chosen that the various classes and subgroups of both wrinkled and smooth peas were fairly well represented.

The material was grown at the Arlington farm. The locality is at the southern border of commercial pea production and the occurrence of high temperatures in the late spring frequently causes partial or complete failure of the crop. In order to minimize danger from this source, plantings were made as early in the spring as soil conditions would permit. Climatic conditions were favorable in both years, and crops of normal size and good quality were obtained from nearly all the varieties.

DETAILS OF PREPARATION AND PACKING

All peas were picked by hand. Shelling was done partly by machine and partly by hand, care being taken during picking and shelling to exclude overmature pods but to include all material of usable stage of maturity present on the plants. The care exercised in the handling rendered brine flotation to remove overmature peas unnecessary.

In order to permit subsequent detailed study of the effects of stage of maturity upon quality and appearance of the product after freezing, the shelled peas were separated by standard screens into sizes differing by one thirty-second of an inch in diameter and ranging with the different varieties from eight thirty-seconds to fifteen thirty-seconds of an inch, or from the smallest recognized canner's size to two or three sizes above the largest. All these various sizes were prepared and packed separately for all the varieties. They are designated in the discussion by the size of screen by which the peas were held, not by that through which they passed.

Scalding.—There is a considerable literature dealing with the preparation, especially the scalding, of peas for freezing, to which reference has been made (p. 11). It was found necessary, in order to secure inactivation of enzymes and satisfactory preservation of color and quality, to use a schedule of scalding periods in boiling water somewhat longer than those that have been recommended by other workers (*22*, *25*). The schedule adopted began with 3 minutes' scalding for the largest sizes of a variety (usually those held by the $^{13}/_{32}$- or $^{12}/_{32}$-inch screen) decreasing to 2½ minutes for the next smaller size, then to 2, 1½, 1¼, and 1 minute for successively smaller sizes, so that those held by the $^{8}/_{32}$-inch screen received 1 minute of treatment. In small-seeded varieties, such as Green Admiral, the scalding periods were adjusted to the stage of maturity rather than to screen size.

TYPES AND SIZES OF CONTAINER AND TYPES OF PACK.—The types of containers used included all the sizes of paraffined paper tubs of the snap-top types described on page 6, 1-pint roll-top paper tubs sealed with molten paraffin, and No. 2 enameled tin cans. Duplicate packs with and without addition of 2-percent brine were made from identical material in all the sizes and types of container and for the various size grades of each variety, with the exception of the smallest and largest sizes of some varieties.

In the first year of the work, a pack was prepared with a sweetened brine containing 2 percent of salt and 5 percent of sugar, but in the subsequent examination it became evident that the presence of added sugar masked differences in flavor and increased the difficulty of forming correct estimates of the quality of the material. For that reason the use of sweetened brine was not continued into the second year's work.

With slight variations due to varying size of peas, the different containers received uniform quantities of peas, which were 11 to 11½ ounces for the 1-pint cup, 3 pounds 10 ounces for the 5-pint size, and 7½ pounds for the 10-pint size. The liquid added in the brine packs was 6 ounces, 1½ pounds, and 2 pounds 10 ounces, respectively, for the three sizes of containers; these quantities sufficed to fill interspaces and just cover the surface of the peas.

The methods employed in freezing and in the examination of the material have been sufficiently described on page 8.

COMPARATIVE SUITABILITY OF VARIETIES FOR FREEZING

The results of the detailed studies of the 18 varieties used are summarized in table 3 as fully as the tabular method of treatment permits. Additional facts that could not be presented in this way are given in the following paragraphs.

In the examination of any variety, the five to seven size grades that had been packed were separately judged and scored. When detailed ratings were assembled for tabulation, it became evident that the various size grades could be recombined into three or occasionally into two groups. As a rule, the two smallest sizes of a variety differed by less than a unit of the scale of grading used in their color, either frozen or after being thawed, and their texture and flavor after being cooked. The two largest sizes usually showed equally close agreement in their ratings. The intermediate sizes might have shown slightly wider ranges of difference in some of the factors but usually agreed within a point on most of them. The various sizes have consequently been combined into groups in table 3. In preparing the table, numerical ratings have been replaced by words; excellent replacing 1; very good, 1½ to 2; good, 2½ to 3; fair to mediocre, 3½ to 4; and definitely unsuitable, ratings numerically greater than 5. The result has been to divide the varieties into groups designated "excellent," "good," or the like. No attempt has been made to arrange the varieties within each of these groups in order of excellence, since this would have involved an attempt to evaluate small differences in texture, color, and flavor, for all of which there are no absolute standards of comparison. The differences, both in appearance and in quality, between varieties

TABLE 3.—*Results of comparative studies of appearance in frozen condition and of appearance, flavor, and palatability in the cooked condition of 18 varieties of peas*

Variety	Size in thirty-seconds of an inch [1]	Appearance and color in frozen condition in		Character in cooked condition			Values for freezing and remarks
		Brine pack	Dry pack	Appearance and color	Texture	Flavor	
Alaska	8	Poor, yellowish	Poor, grayish	Poor, grayish	Fair	Poor, somewhat bitter	Group 4.—Definitely unsuitable for freezing.
	9, 10	Poor, pale green	Fair	Poor, grayish white	do	Poor, slightly starchy	
	11	Fair	do	Fair, olive green	Poor	Poor, intensely starchy	
Alderman	8, 9, 10	Very good	Very good	Fair to poor, yellowish olive.	Excellent	Fair, rather bitter, watery.	Group 2.—Very good except for smaller sizes.
	11, 12	do	do	Good	Very good	Excellent	
	13, 14	Good	do	do	Fair to good	Good, somewhat starchy.	
American Wonder	8, 9	Good, light green	Good	Poor, grayish green	Excellent	Fair to good	Group 3.—Fair to good, though somewhat grayish green in color.
	10, 11	Good	do	Fair to good, grayish	do	Good to very good	
	12, 13	do	do	do	Good	Good, slightly starchy	
Asgrow No. 40	9, 10	Very good	Very good	Very good	Excellent	Excellent	Group 1.—Very good to excellent; free of bitterness in small sizes and of starchiness in large sizes.
	11, 12	do	do	do	do	do	
	13, 14	do	do	Good	Good to very good	Good to very good	
Champion of England	8, 9	Poor, light yellow	Poor, yellow	Poor, brownish yellow	Very good	Very good	Group 4.—Unsuitable, very unattractive color.
	10, 11, 12	Poor, yellow green	Poor	Fair, faded green	do	Very good, slightly starchy.	
Dark Podded Telephone	9, 10	Excellent	Excellent	Fair	Excellent	Excellent	Group 2.—Very good; good flavor and good color except in larger sizes.
	11, 12, 13	Very good	Very good	Very good	do	do	
	14	do	do	Poor, brownish olive	Very good	Fair, somewhat starchy.	
Dwarf Telephone	11, 12	Poor, grayish	Poor, grayish	Poor, grayish green	do	Fair, not high in flavor	Group 4.—Unsuitable for freezing.
	13, 14	Poor, opaque grayish	Poor, opaque grayish.	Very poor, olive gray	Poor	Poor, very starchy	
Green Admiral	8, 9	Light green, yellowed	Yellowed	Poor, browned	Excellent	Good, slight bitterness	Group 3.—Fair to poor in color, otherwise good.
	10, 11	Good, light green	Good, light green	do	do	Excellent, slight starchiness.	
Improved Pilot	9, 10	Very good	Very good	Good to very good	Good	Good, slight bitterness	Group 3.—Fair, color better than quality.
	11, 12	Very good, dark green	do	Poor yellowish green	Fair to good	Fair, slightly starchy	
	13	Very good	do	Poor, light olive green	Poor, starchy	Poor	
Improved Stratagem	9, 10, 11	do	do	Fair to good	Excellent	Excellent	Group 3.—Color fades badly on cooking, otherwise very good to excellent.
	12, 13	Good	do	Fair	do	do	
Laxtonian	9, 10	do	Good	Poor, olive brown	Very good	Very good	Group 4.—Unsuitable for freezing; develops starchiness early, color poor when cooked.
	11, 12	do	do	do	Fair to good	Fair, slightly starchy	
	13, 14	Fair	Fair	Very poor, much browned.	Fair to poor	Poor, starchy	
Laxton Superb	9, 10, 11	Very good	Very good	Very good	Excellent	Very good	Group 2.—Very good except largest sizes.
	12	do	do	Fair to good	Fair to poor	Poor, hard, starchy	

Market Surprise	9, 10	do	do	Good	Very good	Good	Group 3.—Unusually good color in all sizes when frozen. Quality poor in larger sizes.
	11	do	do	Fair	Fair	Fair, somewhat starchy.	
	12, 13	do	do	Poor, brown	Poor, hard	Poor, starchy	
Nott Excelsior	8, 9	do	Very good	Poor, faded grayish white.	Excellent	Good	Group 3.—Larger sizes unsuitable; smaller sizes good but of poor color when cooked.
	10, 11	Good	Good	Fair, faded green	Very good	do	
	12, 13	do	do	Fair to poor	Fair	Fair, somewhat starchy.	
Onward	8, 9, 10	Very good	Very good	Very good	Excellent	Excellent	Group 2.—Very good. Exceptionally good color in all sizes when frozen.
	11, 12	do	do	Good	Good to very good	do	
	13, 14	do	do	Fair to good	Fair to good	Fair to good, slight starchiness.	
Pedigree Extra Early	8, 9	Poor, yellowed	Poor	Poor	Good	Fair, flavor lacking	Group 4.—Definitely unsuitable for freezing.
	10, 11	Fair, yellowed	Fair, yellowed	Poor, yellow brown	Fair	Poor, very starchy	
Thomas Laxton	9, 10	Excellent	Excellent	Very good	Excellent	Excellent	Group 1.—Excellent.
	11, 12	do	do	Good to very good	do	do	
	13, 14	Good	Very good	Fair to good	Very good	Good	
Wisconsin Early Sweet	8, 9	Fair	Fair	Poor, whitened	Good	Poor, bitter	Group 4.—Mediocre and unsuitable for freezing.
	10	Fair to good	Good	Fair	do	Good	
	11, 12	Fair	do	Fair, brownish	Fair	Fair, starchy	

[1] The screen sizes given are those by which the peas were held, not those through which they passed.

classed as very good and good, for example, were such as were immediately evident to all the examiners. The final rankings were not determined wholly by the inherent good or poor quality of the varieties considered as fresh material, but by degrees to which desirable qualities were preserved through the processes of freezing and subsequent preparation for the table. They also take into account the behavior of the different sizes of the variety and the extent to which some of these must be excluded in order to maintain good quality.

GROUP 1. EXCELLENT.—Thomas Laxton and Asgrow No. 40 stand above all the others in their general excellence for freezing. Both varieties are exceptional in several respects. Thomas Laxton has in all sizes a very uniform dark-green color that is exceptionally well retained in the frozen condition and that undergoes a minimum of change in cooking. Asgrow No. 40 has a somewhat lighter but very uniform green color in all sizes and becomes very little browned when cooked. The larger sizes of both varieties become somewhat opaque and mottled at the surface of the frozen mass when packed dry, but retain attractive green color when thawed and cooked. Both varieties are free from astringency and bitterness in the smaller sizes and do not become objectionably starchy in the largest sizes; texture and flavor are very good to excellent at all stages. These are the only varieties used in this work having such uniformity and desirability of color, texture, and flavor throughout the whole development that all sizes might be packed together without detracting from the quality of the product.

GROUP 2. VERY GOOD.—The varieties making up this group are Dark Podded Telephone, Onward, Alderman, and Laxton Superb, all of which develop qualities at certain stages of their growth that make them compare very favorably with the first-rank varieties. At other stages, either in the largest or the smallest sizes or in both, some essential character is deficient or lacking, with the result that the sizes concerned must be graded out if a pack of high quality is to be made. There are some differences between the varieties in the nature and degree of these defects, so that the members of the group differ considerably in their desirability for freezing when the proportion of the total yield that is of prime quality is considered.

Laxton Superb has an exceptionally uniform green color in all sizes in the frozen condition, and the color remains very good when cooked in all but the largest size. Texture and flavor are excellent in the youngest peas and very good in all sizes up to the largest, which are somewhat hard, deficient in flavor, and decidedly starchy, and hence must be graded out.

Dark Podded Telephone in the frozen condition is uniformly very good in color in all sizes, but when cooked the smaller sizes fade somewhat and the largest size becomes an unattractive brownish olive in color. Intermediate sizes retain their color well. Texture and flavor are excellent in all sizes except the largest, which are somewhat starchy and should be graded out.

Onward has excellent color when frozen and retains it well when cooked except in the two largest sizes, which become considerably browned. These sizes are also somewhat starchy although agreeable in flavor, and the seed coats are rather noticeable and somewhat tough.

Alderman had good color both when frozen and after being cooked except in the $\frac{8}{32}$- and $\frac{9}{32}$-inch sizes, which became yellowish olive

when cooked. These sizes also have considerable astringency and bitterness, and should be graded out. The two largest sizes were somewhat firm and slightly starchy but were quite good in flavor; they might be included in an ungraded pack without lowering the quality if they made up only a small proportion of the total.

If the sizes specified are excluded from the pack it is believed that it is possible to prepare packs of these varieties that will compare very favorably in all respects with those made from the first-rank varieties. The individual grower will of course take into consideration the factors of comparative productiveness, adaptation to his particular locality and conditions, and the like, in determining whether it may be more profitable to grow one of the first-rank varieties with the expectation of packing the entire crop, or to choose one of the second-rank varieties with the expectation of grading out the undesirable sizes.

GROUP 3. FAIR TO MEDIOCRE.—The varieties placed in this group are Green Admiral, American Wonder, Market Surprise, Improved Pilot, Improved Stratagem, and Nott Excelsior. These varieties differ rather widely in quality when prepared for the table directly from the garden, but as material for freezing all have defects that group them together. Generally speaking, these defects are of the same nature as those of the second-rank group, but are more pronounced in degree. As a whole, the group is characterized by less uniform green color in the various sizes in the frozen state and by greater fading or yellowing and browning on being cooked than occur in the varieties of the second group.

American Wonder in the frozen condition has a fairly good but rather light green color in all sizes up to the largest, which is slightly yellowed; when cooked, all sizes become faded grayish green; fading is especially pronounced in the smallest size, which is also lacking in flavor. All other sizes up to the largest are very good in flavor, but starchiness is evident in the next to the largest size and very pronounced in the largest. These and the smallest sizes must be removed in order to produce a pack of highest quality. The remaining sizes have good quality and flavor but are rather unattractive in the cooked condition because of poor color.

Improved Pilot is an attractive dark green in all sizes when frozen. When cooked, the smaller sizes remain a good green color, but the largest tend to become light olive green. The $^{9}/_{32}$-inch size has a slight but not objectionable bitter flavor. Texture and flavor are good in small and intermediate sizes; the two largest sizes were firm, decidedly starchy, and deficient in flavor. Their removal is prerequisite to production of a pack of highest quality.

Nott Excelsior had very good color while frozen and the intermediate sizes were fairly attractive when cooked; the smaller sizes faded to grayish white and the larger sizes became somewhat brown. Texture was very good except in the two largest sizes, which were firm and starchy and should be graded out, as should the $^{8}/_{32}$-inch size. Flavor was not especially pronounced at any stage in the series but was mild and without objectionable character.

Improved Stratagem had excellent texture and flavor throughout the series of sizes but was a rather dull, unattractive green when frozen and became somewhat grayed when cooked. Not very much improvement in color would be obtained by selection of certain sizes because of their exceptional uniformity in color when cooked.

Green Admiral in the frozen condition was a rather light green throughout the size series with some yellowing in the largest peas. When cooked, all sizes became uniformly a dull olive brown that was distinctly unattractive. The entire series had excellent texture, even in the largest and smallest sizes, and flavor was very good at all stages, with slight starchiness only in the largest size and faint but not objectionable bitterness in the smallest. Were it not for the very poor color of the cooked product the variety would be entitled to a place in the second-rank group.

Market Surprise in the frozen condition had an unusually deep, clear-green color at all stages of development, which made the material very attractive. The sizes up to eleven thirty-seconds of an inch retained very good color when cooked and were very good to good in texture and flavor. In the $^{11}/_{32}$-inch and larger sizes, the color turned to an unattractive brownish green when they were cooked, there was pronounced starchiness, and the peas were unpleasantly firm. A pack of high quality and acceptable color could be made only by grading out the three largest sizes, which might necessitate discarding so much of the crop as to be impractical.

It will be clear, therefore, that products of very acceptable appearance and good to very good table quality can be made from most of the varieties of this group provided that the grading of the raw material be made drastic enough to remove the undesirable sizes. Whether attempts to pack these varieties should be made will depend in very considerable degree upon what use can be made of the portion of the crop not suitable for freezing.

GROUP 4. DEFINITELY UNSUITABLE.—Alaska was poor in appearance in frozen condition, the smaller sizes being whitish green, the larger, yellowish green. When cooked, the smaller sizes became grayish olive, the larger ones an unattractive olive green. The smaller sizes had an undesirable bitterness, the larger ones were decidedly starchy and deficient in flavor. Texture was only fair in the smaller sizes and became progressively poorer with increase in size.

Wisconsin Early Sweet while frozen had very good green color in the larger sizes, shading off to light green in the smaller ones. When cooked, the larger sizes were brownish green and the smaller were a faded, whitish green. The smaller sizes were distinctly astringent and bitter, the larger were starchy and deficient in flavor, only the $^{10}/_{32}$-inch size had sufficiently good texture, color, and flavor to be considered acceptable.

Pedigree Extra Early was uniformly poor and yellowish in the frozen state and unattractive brownish or yellowish green when cooked. The smaller sizes were watery and flavorless, and this condition passed over rather abruptly into starchiness in the larger sizes. None of the various size grades was more than barely acceptable in appearance or quality.

Laxtonian had moderately good color while frozen in all but the largest sizes, but all sizes developed a brownish color when cooked. Texture and flavor were very good in the smaller sizes, no bitterness being observed, but falling off in flavor and the presence of starchiness were apparent unusually far down in the size series, and all of the larger sizes were mediocre or poor in quality.

Dwarf Telephone was an unattractive opaque grayish green while frozen and became olive brown when cooked, all sizes being very much

alike in this respect. Flavor and texture were good only in the smaller sizes, starchiness and decrease in flavor becoming apparent in the $^{11}/_{32}$-inch size and pronounced in the larger sizes.

Champion of England was light green with considerable opacity and yellowing in all stages in the frozen condition and became a faded, unattractive brownish yellow when cooked. Although very good in texture and flavor, its poor color at all stages would appear to bar it from successful use for freezing.

It is of course quite probable that when some of these varieties are grown in cooler latitudes they may prove to be better adapted for freezing, but experimental demonstration that this is true should precede any attempts to produce and pack them on a commercial scale.

RELATION OF STAGE OF MATURITY TO QUALITY OF MATERIAL

The method adopted for grading separated the material of each variety into four to seven sizes. Packing and subsequent cooking and examination of these size grades separately permitted determination of the relation of advance in maturity to the development and subsequent decline of desirable color, texture, and flavor with an accuracy not possible in ungraded or less closely graded material. Such detailed comparisons furnish information on some questions of great practical importance to the packer of frozen peas; they determine the upper and lower limits of size and stage of maturity that may be included in the pack without detracting from its quality; they show how far it may be desirable to carry grading of a variety as a means of obtaining or maintaining optimum quality; and they indicate to what extent varieties differ from one another in these respects.

As a general rule, the smallest sizes of a variety, usually those held by the $^{8}/_{32}$- and $^{9}/_{32}$-inch screens, are rather light green in color when frozen and become grayish green or somewhat olive green after being cooked. Considerable collapse and breaking of seed coats occur during cooking, and the seed coats, although tender, are rather evident to the tongue. The peas are watery and deficient in flavor at this stage, and many varieties have a more or less astringent, bitter flavor. Progressive improvement in color, texture, and flavor occurs with increase in size and age. With attainment of maximum size, however, some breaking down of chlorophyll and yellowing of color in the frozen condition, with development of browning when cooked, usually occur. The seed coats are somewhat tough, the texture of the cotyledons is firm and somewhat mealy, and the characteristic flavor is reduced or obscured by the presence of starch. Between the upper and lower limits of size there is a range within which color, texture, and flavor are at or near the optimum for the variety. The extent of this range varies considerably among varieties, and development of color, texture, and flavor do not proceed at equal rates nor reach their respective optima at the same stage of development in all varieties.

A few varieties present exceptions to these general statements in one or more respects. Several varieties have a deep, bright-green color that is well retained nearly up to development of full size and that shows relatively little fading and browning when cooked. A few varieties are comparatively free from bitterness or astringency in the smallest sizes, and a few are very tender in texture, free of an objectionable degree of starchiness, and good to very good in flavor when

fully grown. In one or two varieties, as has been shown in discussing the results of the varietal comparisons (p. 33), all these desirable characters are combined in an unusual degree over a larger portion of the period of development than in the other peas here studied; this makes these varieties exceptionally valuable for frozen packing.

In table 3 and in the discussion that follows, the changes occurring in varieties in the course of their development and early maturity are followed through by the size grades as found in the material. The upper limit of size that a variety of peas may reach varies considerably with the conditions under which the crop is grown, and under certain conditions may be considerably higher than in this material. Under such conditions, the statements made about the largest sizes of seeds continue to apply, but there will be some shifting of the range of sizes of a variety that will be in optimum condition for use. The course of physiological changes in the seed of a pea is of the same character and occurs in the same sequence whether it ultimately reaches thirteen thirty-seconds or seventeen thirty-seconds of an inch in size, and screen sizes are merely convenient means of designating stages in the course of these changes.

EFFECTS OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING ON QUALITY

The nature and causes of certain differences in appearance between dry and brine packs of peas as examined in the frozen state have been stated (p. 18). It has been pointed out that peas in brine were superior in appearance to peas dry packed because of greater uniformity of color and its brighter, clearer quality. This difference disappears in cooking and the two types of pack become indistinguishable in all respects. When both types were examined in the frozen state, peas from hermetically sealed containers had a freshness and brightness of color that was distinctly more appealing than the somewhat opaque and yellowed surface of duplicate lots in nonairtight containers. After being cooked there were no differences in quality between the two packs. In the brine packs there were no differences in appearance or quality either in the frozen or the cooked state between sealed and unsealed containers, or between the large and the small containers.

The preservation of texture, flavor, and quality in peas frozen on trays prior to packing was as good as, but in no respect superior to, that of duplicate lots frozen in the containers. Freezing prior to packing appears to have no particular advantages over freezing in the package insofar as small containers in which rapid cooling is easily obtainable are concerned. For larger-size packages it has the obvious advantages of permitting more rapid freezing, of allowing the use of any desired size and type of container, and of making possible easy removal of portions of the contents without disturbing the remainder.

Green Lima Beans

VARIETIES EMPLOYED

A study of comparative suitability for freezing of a number of varieties of lima beans was undertaken because the only variety that has been extensively used for commercial packing has been Henderson

Bush, a small-seeded variety which is extensively grown for canning but which is seldom grown for use as a fresh bean. Its almost exclusive use for canning and freezing apparently were determined by factors such as productiveness, uniformity in size, and adaptability to harvesting and shelling by machine, rather than by any outstanding table quality of the product. Its rather small size has led to the general use of the somewhat misleading term "baby limas" as a designation for frozen lima beans. The large-seeded and potato-type lima beans are very generally preferred by the fresh markets. The present work was undertaken to determine the extent to which the qualities making these varieties so popular in the fresh form are retained through the freezing process, in the belief that some of them might yield products comparable in quality and appeal to the fresh material.

Eight varieties, six of the bush or dwarf type and two of the pole type, were used in the present work. The pole varieties, King of the Garden and Giant Podded, are large-seeded, as is the dwarf variety Burpee Improved. Fordhook and Dreer Bush are large-seeded beans of the potato type; New Philadelphia, Wood Prolific, and Henderson Bush are small-seeded dwarf types, the seeds of Henderson Bush being slightly smaller than those of the others. The varieties were grown together for two seasons under closely identical conditions as regarded soil, fertilization, and cultivation. The yield was good to heavy, and there was almost entire freedom from disease in all varieties in both years.

DETAILS OF PREPARATION AND PACKING

After they were harvested and shelled by hand, all the varieties except Henderson Bush and Dreer Bush were separated into size grades by passing over screens differing by two thirty-seconds of an inch in size of opening, which gave seven size grades for the large-seeded varieties, and four or five for the small-seeded. In order to permit subsequent study of the effect of increase in size with advancing maturity on the behavior of the beans in freezing and the quality of the product, each of these sizes was subsequently prepared and packed separately, and is designated in the following discussion by the size of screen by which it was held; that is, beans termed "22/32" passed through the 24/32-inch screen but were held by that with 22/32-inch openings. The beans of Henderson Bush and Dreer Bush were so uniform in size that separation by screens was not possible. With such varieties, brine flotation is necessary in order to remove overmature beans. In the present work, Henderson Bush was divided into three grades, those floating in 8-percent brine (specific gravity 1.058), those in 18-percent brine (specific gravity 1.135), and those remaining submerged in 18-percent brine. These were packed separately and designated as grades 1, 2, and 3, respectively.

The scalding period was graduated according to the size and age of the beans. For the large-seeded varieties it was 2 minutes in boiling water for the two or three smallest sizes, 3 minutes for the next largest, and 4 minutes for the two or three largest. For small-seeded varieties not graded for size, the 3-minute period was used, and it was also used for the three grades into which Henderson Bush was sepa-

rated by brine flotation. Smart and Brunstetter, in work done independently and concurrently (*51*) have found that 3 minutes' scalding in boiling water gave best preservation of quality in frozen Henderson Bush lima beans, reporting also that catalase activity was still detectable in young and full-grown beans after exposures of 6 and 9 minutes at 190° F.

Parallel dry or straight and brine packs were made from all varieties and all size grades in 1- and 5-pint containers of the snap-top type and in No. 2 sanitary cans that were hermetically sealed after filling. No 10-pint containers were used. The 1- and 5-pint containers received 11 and 55 ounces of beans, respectively, the No. 2 tin cans 14 ounces. Material of a number of varieties and at several stages of maturity was individually frozen on trays in the manner employed with peas (p. 20) and subsequently packed dry in 1-pint containers. Methods of freezing, length of storage period, and details of method used in examining and grading the beans did not differ from those used with the other products.

COMPARATIVE SUITABILITY OF VARIETIES FOR FREEZING

The chief results of the detailed studies of the material are summarized in table 4. For the sake of compactness, the five to seven size grades into which a variety was separated were combined into two or three groups in the table, because the sizes combined into any one group were so closely identical in all essential respects as to be practically indistinguishable.

The varieties employed showed a degree of individuality in behavior under freezing treatment that cannot be adequately stated in the table and that makes it somewhat difficult to group them into classes as first best, second best, and so on. It consequently seems necessary to discuss them in some detail in order to convey an adequate idea of some of these individual varietal characteristics.

TABLE 4.—*Results of varietal comparisons in frozen lima beans*

Variety	Size in thirty-seconds of an inch [1]	Appearance and color in frozen condition	Characters of cooked material		
			Appearance and color	Texture	Flavor
Burpee Improved	26	Rather poor, some yellowing	Poor	Good	Poor, overmature.
	24, 22, 20	Fair, some yellowing	Fair	Very good	Fair.
	18, 16, 14	Very good	Very good	Excellent	Fair to good.
	Unscreened	Fair to very good	Fair	Good	Fair.
Dreer Bush	Unscreened	Excellent; light, bright green	Very good	Excellent	Excellent.
Fordhook	26, 24	Fair, yellowish but fresh looking	Fair	Fair, somewhat starchy	Fair to good.
	22	Good, greenish yellow	Fair to good	Good, slightly starchy	Good.
	20, 18, 16, 14	Excellent, attractive green	Very good	Excellent	Excellent to very good.
	Unscreened	Very good	Fair, whitened	Fair, somewhat starchy	Fair.
Giant Podded (pole)	26	do	Very good, slight browning	Excellent	Very good.
	24, 22, 20	do	Very good	do	Do.
	18, 16, 14	Excellent	do	do	Excellent.
	Unscreened [1]	Fair to poor, whitened	Fair	Very good	Good to fair
Henderson Bush	Grade 1	Good	Very good	do	Good.
	Grade 2	Fair; yellow and green	Fair	Good	Do.
	Grade 3	Poor; whitish yellow	Poor, bleached	Fair, starchy	Fair to poor.
	Ungraded [1]	Fair; yellow and green	Poor to fair	do	Do.
King of the Garden (pole).	26	Very good; a few yellowed beans	Very good	Excellent	Very good.
	24, 22	Very good	do	do	Do.
	20, 18, 16	Excellent, bright dark green	do	do	Excellent.
	Unscreened [1]	Poor to fair	Fair	Fair to good	Fair to good.
New Philadelphia	20, 18	Poor, many white beans	Poor, white	Good	Good.
	16, 14	Fair; greenish white	Poor, whitened	do	Very good.
Wood Prolific	18, 16	Poor, many white beans	do	Fair	Good.
	14	Fair to good	Fair, whitened	Good	Do.
	13, 12	Good; bright clear green	Very good	Very good	Excellent.

[1] The unscreened and ungraded packs were prepared from beans developed later in the season than those used for the screened packs.

The two pole varieties, King of the Garden and Giant Podded, were somewhat superior to the bush varieties in respect to color, both in the frozen state and after being cooked. In contrast to most of the other varieties used, the seeds of these varieties retained very good green color until they had very nearly or quite reached maximum size. There was very little yellowing or bleaching in color in the frozen product or during cooking, even in the largest size grade, so that the older beans were more uniform in color and attractive in appearance than those of other varieties. The texture was excellent and the flavor very good in the larger beans of both varieties (those held by the $^{23}/_{32}$- to $^{26}/_{32}$-inch screens); both texture and flavor were excellent in the smaller sizes. The smaller sizes of King of the Garden had an exceptionally fresh, attractive, dark-green color; the corresponding sizes of Giant Podded were not so attractively colored but had an especially fine, appealing flavor. The unscreened packs of both varieties, which contained a mixture of beans of all sizes and which, in some instances, were made from beans developed later in the season, were less attractive, either frozen or cooked, than the individual size grades, because the various sizes of beans differed considerably in color. The 4-minute scalding period used with unscreened lots, which was necessary in order to properly scald the larger beans, had caused some collapse of tissues and bleaching of color in the younger beans in the frozen state, and the longer period necessary to cook the older beans overcooked the younger ones, causing some disintegration and loss of flavor. The consequence was that the unscreened packs were not equal in appearance or flavor to the screened packs.

Dreer Bush, which is a thick-seeded or potato type having short, thick seeds intermediate in size between those of the pole and the bush lima beans used, was packed unscreened after removal of overmature and whitened beans. It was slightly superior to the other bush varieties. The fresh material was a very uniform dark green in color and became somewhat lighter but remained fresh and attractive when frozen, both in straight and brine packs. The cooked beans retained their color exceptionally well in the straight pack but became somewhat browned in the brine pack. The beans from the brine pack were excellent in texture and very good in flavor, whereas those from the straight pack were considered superior to any others examined in the course of the work, regardless of variety or stage of maturity. This variety seems exceptionally promising for packing straight after brine flotation to remove overmature beans.

Henderson Bush was employed in a number of experiments because it is so generally used for commercial freezing. The material was divided into three grades by brine flotation (p. 41). The beans in grade 3 were practically all white and obviously overmature but not yet beginning to dry when packed; they were packed to obtain information as to their texture and flavor after being frozen and their consequent effect upon a pack in which they might be included. All three grades were scalded for 3 minutes. In the frozen condition, grade 1 had fairly uniform color with occasional whitened beans, and color, texture, and flavor of the cooked product were very good but not outstanding. Grade 2, viewed in the frozen state, had a larger number of whitened beans and the green ones had become a faded yellowish green that browned somewhat when cooked; texture and

flavor were good. Grade 3 was a pale yellowish white in the frozen state; when cooked it became almost white and was firm, distinctly starchy, and lacking in fresh flavor, suggesting dried beans. The ungraded samples were rather unattractive in the frozen condition because of the presence of a mixture of colors ranging from green to white, and older beans gave the mixture starchiness and firmness that made it deficient in flavor. Commercial packs of Henderson Bush obtained in the Washington market were intermediate in appearance in the frozen condition between grades 1 and 2, having slightly better green color than grade 2 but containing many more whitened beans than grade 1. In texture the commercial packs rated excellent, and in flavor, good to very good.

In order to make a pack of Henderson Bush that will compare favorably in appearance with those here made from Dreer Bush, Giant Podded, and King of the Garden, it will be necessary to employ brine flotation to remove overmature beans and probably also to resort to hand sorting to remove beans that have lost green color before much change in their specific gravity has occurred. The variety is one in which a certain percentage of seeds lose color rather early, and the presence of these will materially detract from the appearance of the pack. Even when these are excluded, the product will not have the full, appealing flavor of the varieties just named, because the fresh bean is inferior to these varieties in palatability and flavor.

Fordhook, which is a potato type, appears to have possibilities for freezing if the largest beans are excluded from the pack. The beans held by the $^{26}/_{32}$- and $^{24}/_{32}$-inch screens were fresh looking but yellowish green while frozen, but when cooked they were starchy and considered as somewhat lacking in flavor by some of the judges, although others preferred them to the smaller sizes. Those held by the $^{22}/_{32}$-inch screen were better in color but were slightly starchy. There was a rather pronounced improvement in all respects in the beans held by the $^{20}/_{32}$-inch screen, which was also evident in the smaller sizes; all had very attractive, uniform green color while frozen, held it well when cooked, and were excellent to very good in texture and flavor, comparing favorably with King of the Garden, Giant Podded, and Dreer Bush. The unscreened pack was mediocre because of the starchiness and absence of flavor in the older beans in the mixture.

Burpee Improved is not especially well suited to freezing preservation. The unscreened pack was mediocre in all respects, and the larger sizes were only fair as separately packed. The smaller sizes were very good in color and texture but were distinctly lacking in flavor.

Wood Prolific and New Philadelphia are rather unfavorable material for freezing because of very poor color. In both varieties, loss of color begins relatively early in the development of the seed, and many beans before attaining full size reach a condition that causes them to become practically white when frozen. Such prematurely whitened beans have practically the same specific gravity as the green ones, hence cannot be removed by brine flotation. Their presence in the pack detracts very materially from its appearance while frozen, and further bleaching occurs in cooking. The smaller sizes of Wood Prolific have good green color and retain it well when cooked, and are also excellent in texture and flavor, but the larger sizes are only fair

in either respect. On the whole, neither Wood Prolific nor New Philadelphia is superior to Henderson Bush in quality, and both are inferior to that variety in color retention when frozen.

It is considered significant that the three varieties least satisfactory in appearance after freezing because of extensive loss of color are all closely related. According to Hedrick (*33*), Henderson Bush is of unknown parentage, Wood Prolific is a sport of Henderson Bush differing from the parent variety chiefly in its greater vigor, and New Philadelphia is apparently a selection from Philadelphia, which is a cross between Fordhook and Wood Prolific. All have these common characteristics: Many of the beans whiten prematurely before attaining full size, and a considerable percentage of beans that are apparently a very uniform and satisfactory color prior to packing will undergo an amount of bleaching and yellowing in freezing and storage that will materially detract from the appearance of the pack when opened. These changes are so much more extensive and pronounced in these varieties than in the others employed that it seems impossible to prepare a pack of any of them that will compare favorably in attractiveness of color with the other varieties used.

RELATION OF STAGE OF MATURITY TO QUALITY OF MATERIAL

In all lima beans a stage in the development of the seed is reached at which rapid increase in the amount of starch deposited in the cotyledons results in a firmness of texture considered undesirable in a fresh bean. Parallel with increasing starchiness and possibly largely because of it, the characteristic green-bean flavor diminishes and becomes suggestive of that of the mature dry bean. Together with the concurrent thickening and toughening of the seed coat these changes destroy the characteristic qualities for which green lima beans are prized.

The results of the study of the separately packed size grades here made demonstrate that in some varieties the above-mentioned changes do not become sufficiently pronounced to be objectionable until the seeds are nearly of maximum size, whereas in other varieties they are distinctly noticeable when the seeds are considerably short of full size. The largest size of Burpee Improved and the two largest sizes of Fordhook have lost in flavor and texture to a degree that makes it advisable to exclude them from the pack. In the other varieties there was no very appreciable lowering of texture or flavor in the largest sizes. In the pole varieties the largest beans obtained were free of starchiness and had the same texture as the smaller sizes. It is highly probable, if not certain, that the exact stage of development at which the seeds of any variety of lima beans begin to undergo these undesirable changes in quality will vary somewhat with seasonal conditions, load of pods on the plants, vigor of plants, presence of disease and of leaf-eating insects, and other factors affecting the well-being of the plants. For the production of a pack of highest possible quality, it is fundamental that the packer be on watch for the stage of development in his material at which decline in quality becomes apparent.

There were differences of opinion among the judges as to the stage at which lima beans are of highest table quality; some preferred those not more than two-thirds full size, and others as definitely preferred those ranging from this limit up to full size. In the green shelled-

bean market, the preference of purchasers seems to be for full-grown or nearly full-grown beans provided they show no whitening or other evidence of overmaturity. Whether the preference of purchasers of frozen beans will be for one or the other cannot be known until both have been offered; the present work indicates that packs of young or "baby" beans, of older, nearly full-grown beans, or packs containing both can be prepared from properly chosen varieties with retention of all the desirable qualities of the fresh material.

EFFECTS OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING ON QUALITY

When examined in the frozen condition, the brine packs of most of the varieties of lima beans were more attractive than the corresponding dry packs, in which the drying and opacity of the seed coats and the presence of ice films beneath them more or less masked the green color. After the dry-packed material was cooked, the color was frequently slightly better than that of identical lots from brine pack. In the case of Dreer Bush and older stages of some other varieties the straight packs had better color both before and after thawing and cooking. With all varieties texture, palatability, and fullness and freshness of flavor were as well preserved in straight as in brine packs. All factors being taken into consideration, the differences between the two types of pack were so slight that there appear to be no advantages from the use of brine warranting its use in packing lima beans.

Lima beans individually frozen on trays prior to packing closely resembled the corresponding straight packs in their dulling of color in the frozen condition, became brighter and greener in the same degree during thawing and cooking, and were indistinguishable when served from corresponding lots from straight or brine packs.

No advantage resulted from the use of hermetically sealed containers, the packs in nonairtight paper containers being equally good in appearance and quality. Rather severe etching at the liquid line occurred in tin, and beans in contact with the etched area became discolored in the brine packs; therefore such containers, if used, should be of the enameled type.

In comparing material from containers of different sizes it was observed that in some of the 5-pint containers the beans at the center, usually in young stages of deeply green varieties, showed a slight fading of color and development of a yellowish tinge as compared with portions of the same lots packed in pint cups. There was no abnormal odor, and when the central portion of the mass was removed and cooked it was indistinguishable in texture and quality from that from small packages, but it was still a little less attractive in color. These facts are believed to indicate that the cooling of the material to freezing temperature was not sufficiently rapid to prevent slight injury to color in the center of the larger packages. Prompt and thorough cooling of green lima beans is necessary in order to prevent deterioration in color. If lima beans are frozen in large packages, it will be necessary to employ containers of a shape and style permitting more rapid heat transfer than was possible in those here used. The necessity for a freezing-room temperature of 0° F. is also strongly indicated.

Sweet Corn

VARIETIES EMPLOYED

The number of varieties and strains of sweet corn employed in the present work was 35, of which 18 were yellow and 17 white. They included all the more widely grown standard canning and market sorts, a number of less well-known varieties reputed to be of high quality, and in particular, approximately a dozen recently developed hybrids and top crosses that appear to combine productiveness and disease resistance with high quality. About 30 of the number tested do not appear to have been previously used in comparative experimental studies of the freezing of corn found in the literature. Sayre (*1*) employed Golden Bantam, Crosgreen, Redgreen, and one of the Evergreen group, finding all of them satisfactory; Poole (*4*) reported results with Golden Bantam, Golden Cross Bantam, Golden Bantam × 1339, and Golden Sunshine × 1339, finding the two last named especially satisfactory; Diehl, Pentzer, Berry, and Asbury (*27, 28, 29, 30*) found Golden Bantam superior to Golden West, Stowell Evergreen, and Portland Early Market, which yielded fairly satisfactory but not outstanding products; and Yeager and Latzke (*59*) used Golden Sunshine. Thus far the varieties used commercially have been Golden Bantam, Stowell Evergreen, and a few other old and well-known varieties, and those studied experimentally have been recently developed hybrids with a few of the old standard varieties. Therefore, a comparative study of a fairly large group of varieties seemed to have considerable possibilities of value.

The corn employed in the work was grown from seed obtained from commercial seed houses. Two plantings were made in 1934, the first on May 24, the second on July 9; planting in 1935 was made on June 12 with the exception of three varieties planted June 25. The crop from the first planting of 1934 was somewhat reduced in yield by drought; that from the second planting was normal in yield. Both were good in quality. The 1935 crop of all varieties was exceptionally good, both in quality and yield, except in a few dwarf corns not adapted to this latitude.

DETAILS OF HANDLING AND PREPARATION

Stages of Maturity of Corn Packed.—In order to obtain corn of any desired age and stage of maturity, the plots were gone over as soon as the first silks appeared and at intervals of 1 to 2 days thereafter until silking had ceased, and all ears on which silks had appeared since the last inspection were tagged, a different color or shape of tag being employed for each day's tagging. This made it possible to harvest ears at any desired stage with certainty that the maximum variation in age of the sample was not more than 2 days. The size of plot of each variety was such that a series of pickings could be made at stages ranging from distinct immaturity onward through prime usable condition to overmaturity as evidenced by toughness of pericarps, starchiness, and loss of characteristic flavor. The usual range in age of the several samples of a variety so taken was from 14 or 15 days to 26 or 27 days from date of silking.

Culpepper and Magoon (*19, 20, 45, 46*) have shown that very definite correlation exists between the stage of development of the ear of

sweet corn and the texture, consistency, and flavor of the cooked or canned product, and that age in days from date of silking is a very accurate indicator of stage of maturity and consequently of the quality of the corn. Appleman and Eaton (7) have shown that temperature is the controlling factor determining the rate of development and that the rate of ripening is doubled with an increase of 10° C. (18° F.) over a wide range of temperature. On the basis of their data, Appleman (6) calculated the number of days during which corn would remain in proper canning condition at each mean temperature between 60° and 85° F., and employed the results in constructing a table indicating the probable duration of the canning stage at various periods throughout the season for about 30 stations distributed over the chief corn-canning districts of the United States.

SCALDING.—All corn used in the comparative varietal studies was scalded on the ear in boiling water for 4 minutes, the conditions being such that the water resumed active boiling within 90 seconds after the corn was submerged. In certain experimental lots, the time of scalding was intentionally varied; these will be discussed in a later section (p. 55). In other respects the details of packing, freezing, and preparation for examination did not differ from those stated in the section on general procedure (p. 6).

FORMS OF PRODUCT PACKED AND TYPES OF CONTAINERS USED.—Most of the varieties were frozen in three forms, as husked, trimmed ears to be prepared and served as corn on the cob, as whole-grain corn, and as cream-style corn. All were packed both with brine and as dry packs. In the dry-packed whole ears, some were placed in the container without wrapping, others were wrapped in cellophane, and others in an inner wrapper of waxed paper and covered with a second wrapper of light aluminum foil. Some ears were also individually frozen on trays prior to packing. Whole ears were packed in 5- and 10-pint paper containers and No. 10 plain sanitary tin cans; whole-grain corn and cream-style corn were packed in 1-, 5-, and 10-pint paper containers and No. 2 tin cans of both plain and C-enamel types.

When cream-style corn was packed, the paper containers received 13 ounces, 4 pounds, and 8 pounds, respectively, for the three sizes. If brine was added, the amounts used were approximately 2½, 16, and 32 ounces for 1-, 5-, and 10-pint containers, respectively. The weight of whole-grain corn that could be placed in the different size containers varied somewhat with shape of grain and stage of maturity, but was 11 to 16 percent less than for cream style; the amount of brine required to fill interspaces was approximately twice that added to similar containers, packed cream style. The quantities placed in tin cans were not weighed but were such as to leave about one-fourth of an inch head space.

COMPARATIVE SUITABILITY OF VARIETIES FOR FREEZING

The results of the detailed comparisons of the varieties are summarized in table 5, in which the ratings of each individual variety for each of the forms in which it was packed and upon each of the factors considered in the grading are first given, followed in the last column by a rating that sums up all the factors considered and assigns the variety to a group with others of a like degree of general merit.

TABLE 5.—*Results of comparisons of market appearance and table quality of 35 varieties of sweet corn after freezing and storage for 7 months at 0° F.*

Variety	Type of pack	Appearance and color in frozen condition	Characters of cooked material			Value for freezing
			Appearance and color	Texture or consistency	Flavor	
Yellow varieties:						
Bantam Evergreen (Golden Evergreen)	Cream style	Very good, uniform bright yellow	Very good; deep yellow	Excellent	Excellent	Group 1.
	On cob	Fair; deep yellow	do	do	Very good	
Bantam Evergreen Hybrid.	Cream style	Excellent; deep yellow	Excellent	Very good	Good to very good	Do.
	On cob	do	do	do	Good	
Burbank World Wonder.[1]	Cream style	Fair to good	Good	do	Good; not outstanding	Group 3.
	On cob	Very good	do	do	do	
Golden Bantam	Cream style	Excellent	Excellent	Excellent	Excellent	Group 1.
	On cob	do	do	Very good	Very good	
Golden Bantam, Improved 10-14-Rowed.	Cream style	Excellent; uniform bright yellow	do	Excellent	Excellent	Do.
	Whole grain	do	Very good	do	Very good	
	On cob	Excellent; uniform bright yellow; too large for this purpose.	do	do	do	
Gold Coin [1]	Cream style	Good; pale yellow	Fair; rather pale	Very good	Very good	Group 3.
	On cob	Fair; light pale yellow	Fair	do	Fair to good	
Golden Crosby [1]	Cream style	Fair; dull yellow	do	do	Fair	Group 4.
Golden Cross Bantam	do	Excellent; bright golden yellow	Excellent	do	Very good	Group 2.
	On cob	Excellent; a few clear grains	do	do	Good	
Golden Gem (Nugget)[1]	Cream style	Poor; dull yellow	Poor; dull	Fair	Poor	Group 5.
Golden Giant [1]	do	Very good	Very good	Good	Good; not outstanding	Group 3.
Golden Sunshine [1]	do	Poor; dull yellow	Poor	Fair	Poor	Group 5.
Golden Sunrise	do	Very good	Very good	Very good	Excellent	Group 2.
	On cob	do	do	do	Very good	
Kingscrost Golden Bantam.	Cream style	Excellent; very small ears	do	do	Good; not outstanding	Do.
Sweet Orange	do	Very good; uniform light bright yellow.	Very good; light yellow	do	Good	Group 3.
	Whole grain	do	do	Good; pericarps prominent.	Fair; not high-flavored	
	On cob	Very good; too large for this purpose.	do	do	do	
Top Cross Bantam, Asgrow.	Cream style	Excellent; bright golden yellow	Excellent	Excellent	Excellent	Group 1.
	Whole grain	do	Very good	Very good	Very good	
	On cob	do	Excellent	Excellent	do	
Top Cross Spanish Gold.	Cream style	Very good; uniform bright yellow	Very good; light yellow	do	Excellent	Group 2.
	Whole grain	do	Good; slightly darkened	Very good	Very good	
	On cob	do	Very good	Excellent	do	
Top Cross Whipple's Yellow.	Cream style	Excellent; uniform light yellow	Very good; light yellow	do	Excellent	Group 1.
	Whole grain	do	Very good	do	Very good	
	On cob	do	Excellent	do	do	
Whipple's Early Yellow.	Cream style	Very good; light golden yellow	Very good	Very good	do	Group 2.

White varieties: Country Gentleman	do	Excellent; very attractive	Excellent	do	Very good; fine flavor	Do.
	On cob	Fair to good; many clear grains	Very good; uniform color	do	Very good	
Country Gentleman Hybrid 19 × 9.	Cream style	Very good; flat ivory white	Very good; light ivory yellow	Excellent	Excellent; very fine flavor	Do.
	On cob	Fair; many clear grains	Fair; dull ivory yellow	do	Excellent	
Country Gentleman Hybrid 19 × 24.	Cream style	Excellent; ivory white	Excellent; good clear white	Very good	do	Do.
	Whole grain	do	do	do	Very good	
	On cob	Fair; many clear grains	Very good; faint yellow tint	do	do	
Delicious	Cream style	Very good; attractive white	Very good; ricelike white	Excellent	Good to very good	Do.
Early Crosby [1]	do	Very good	Very good	Good	Very good	Do.
	On cob	do	do	do	do	
Early Fordhook [1]	Cream style	Fair to good	Fair	do	Fair	Group 4.
	On cob	Poor	do	do	do	
Howling Mob	Cream style	Very good; somewhat dull white	Excellent, uniform white	do	Good	Group 2.
	Whole grain	Very good; rather dull white	Fair; somewhat darkened	Good; pericarps prominent.	do	
	On cob	Good; dull white; too large	Fair; dull ivory white	Good	Poor	
Long Island Beauty	Cream style	Very good to excellent	Excellent	Excellent	Excellent; high quality	Do.
	Whole grain	do	Good; somewhat browned	Very good	Very good; flavor a little lacking.	
Mammoth White Cory. [1]	Cream style	Fair; ivory white	Good; dull ivory white	Fair	Poor; little flavor	Group 4.
Money Maker	do	Very good	Very good	Excellent	Excellent	Grou 1.
	Whole grain	Very good; slightly water-soaked appearance.	do	do	do	
	On cob	Excellent; fine ivory white	do	do	Excellent; very outstanding	
Narrow Grain Evergreen (Maine Style Evergreen).	Cream style	Very good	do	do	Excellent; very fine	Do.
	On cob	Excellent; slightly water-soaked appearance.	Excellent; good white	do	do	
Narrow Grain Hybrid, Asgrow.	Cream style	Very good; attractive white	Very good; slightly browned	Very good	Good	Group 3.
	On cob	Very good	Good; slight browning	Good	do	
Redgreen	Cream style	do	Excellent	Very good	Excellent	Group 2.
	Whole grain	do	Fair to good; darkened	Good; pericarps prominent.	Good	
	On cob	do	Excellent; ivory white	Very good	do	
Stowell Evergreen	Cream style	Very good; dull ivory white	Very good	Excellent	Excellent; outstanding	Group 1.
	Whole grain	do	do	do	do	
	On cob	do	do	do	do	
Stowell Evergreen Hybrid 14 × 5, Asgrow.	Cream style	Excellent; attractive white	Very good; slight ivory tint	do	Excellent; high quality	Do.
	On cob	Excellent; uniform color	Fair; somewhat browned	Very good	Very good	
Top Cross Country Gentleman.	Cream style	Very good	Good; slight browning	Good	do	Group 3.
	On cob	Poor; water-soaked appearance	Poor; brownish white	Fair; pericarps rather prominent.	Fair; lacking in flavor	
White Sunrise	Cream style	Good; somewhat darkened	Good; browned	Fair	Fair	Group 4.
	On cob	do	do	do	do	

[1] The 6 yellow and 3 white varieties designated were so poorly adapted to the climatic conditions or so lacking in vegetative vigor or resistance to disease, or both, that they produced very small yields of usable ears from repeated plantings of 1/20- or 1/10-acre each. This limited the amount of work that could be done with them. The results reported for these varieties obviously may not apply to them when grown in districts where they are better adapted or where diseases are less prevalent.

The detailed examinations showed that a variety yielding an excellent product when packed in one form might have a fairly serious defect when packed in another form. In a good many varieties irregularity in size or shape of ear, furrowing between rows, and like defects of form made the ears unsuitable for freezing on the cob but did not detract from their value for packing in other forms. Lightening of yellow color toward the inner ends of the grains detracted somewhat from the appearance of some of the whole-grain corn but was not apparent in cream-style corn or corn on the cob. These and other details that could not be stated in the table are included in the notes on the various groups together with data on the vegetative vigor and disease resistance of the varieties as shown in the culture plots.

An outstandingly important fact brought out by the comparative study is the very small differences in palatability and flavor of a considerable number of varieties, including both yellow and white types, when products of uniform and identical degree of maturity were compared. A fairly large group of varieties were entirely indistinguishable from one another in palatability and flavor and were necessarily given like rank as being equally good for freezing insofar as these factors are concerned. This is in accord with the results of Culpepper and Magoon (*19*), who found only very slight differences in quality between canned products of material of uniform known age from 15 varieties of corn.

In table 5 each of the varieties is placed in one of five groups or ranks with respect to its suitability for freezing, the varieties placed in the first group having highest excellence and the succeeding groups following in order of decreasing merit.

GROUP 1. EXCELLENT.—This group is made up of 6 yellow varieties, Bantam Evergreen (Golden Evergreen), Bantam Evergreen Hybrid (a cross of two inbred lines, Asgrow 24 and Purdue 39), Golden Bantam, Improved 10–14-Rowed Golden Bantam, Top Cross Bantam, Asgrow, and Top Cross Whipple Yellow (both introduced without specific statement as pedigree), and 4 white varieties, Money Maker, Narrow Grain Evergreen (Maine Style Evergreen), Stowell Evergreen, and Stowell Evergreen Hybrid 14 × 5 (a cross of two inbred lines, Asgrow 14 and Asgrow 5). These 10 varieties ranked so closely together on all factors graded, and particularly on palatability and fullness and desirability of flavor, that no subdivision of the group in order of excellence could be made. The varieties are not equally well adapted to all types of pack; Stowell Evergreen, Stowell Evergreen Hybrid 14 × 5, Asgrow, and Improved 10–14-Rowed Golden Bantam are too large for packing as corn on the cob.

GROUP 2. VERY GOOD.—All the 13 varieties placed in group 2 were very good corns, fully equal in all respects to any commercial products that could be secured for comparison with them. The differences in grade and quality between the corns of the first group and those of this group are very slight; some are equal to those of the first group in appearance, but somewhat below them in flavor; others are equal in flavor but are a little less pleasing in general appearance and color, but none are much inferior to the first group in both appearance and table quality. The group is made up of 5 yellow varieties, Golden Cross Bantam (an introduction from the U. S. Department of Agriculture and Purdue University Agricultural Experiment Station),

Golden Sunrise, Kingscrost Golden Bantam, Top Cross Spanish Gold (introduced without statement of pedigree), Whipple Early Yellow; and 8 white varieties, Country Gentleman, Country Gentleman Hybrid 19 × 9 (a cross of inbred lines Asgrow 19 and Asgrow 9), Country Gentleman 19 × 24 (a cross of inbred lines Asgrow 19 and Asgrow 24), Delicious, Early Crosby, Howling Mob, Long Island Beauty, and Redgreen.

An attempt by the judges to arrange these varieties in order of excellence resulted in failure and general acknowledgment that all were practically indistinguishable in quality. Some of the varieties are not suitable for packing in all forms. Long Island Beauty and Howling Mob have ears too large for packing on the cob. In Country Gentleman and both its hybrids, the appearance of straight-packed whole ears in the frozen condition was marred by the presence of many grains having a clear, water-soaked appearance that entirely disappeared on thawing and cooking, and the cooked ears were decidedly attractive in color and appearance. In ears packed in brine, or in packs cut from the cob, this condition was not observed.

Two varieties of this group, Early Crosby and Golden Sunrise, made excellent products, but the plants suffered so severely from bacterial wilt that yields were very low under conditions in which most other varieties produced good ones. Plantings of these two varieties should be restricted to districts where they have been found to be reasonably productive and disease-free.

Group 3. Fair To Good.—The varieties of this group rank distinctly below those of the second group both in appearance and quality, although all the material was acceptable in appearance, palatable, free from any foreign or off flavor, and decidedly superior to canned corn of any variety in its freshness and appeal. The six varieties placed in the group consist of four yellow corns, Burbank World Wonder, Gold Coin, Golden Giant, Sweet Orange; and two white ones, Narrow Grain Hybrid (Asgrow) and Top Cross Country Gentleman (stated by the introducer to be a cross of western-grown open-pollinated Country Gentleman and Inbred 440). Three of these varieties, Burbank World Wonder, Golden Giant, and Gold Coin, were so lacking in vegetative vigor and suffered so severely from bacterial wilt that only a small percentage of the plants produced usable ears.

Group 4. Poor and Unpromising.—This group consisted of the yellow variety Golden Crosby, with three white varieties, Early Fordhook, Mammoth White Cory, and White Sunrise. None of them gave a product of more than mediocre appearance and quality, and only one, White Sunrise, possessed sufficient vigor and freedom from bacterial wilt to produce a fair crop.

Group 5. Definitely Unsuitable.—This group consists of two very early dwarf yellow varieties, Golden Gem (Nugget) and Golden Sunshine, originating in North Dakota. None of the early dwarf varieties are very successfully grown in the latitude of Washington, but these were the weakest and least vigorous of the early varieties tested and suffered most severely from bacterial wilt. The plantings were so nearly barren that the material available was scarcely sufficient for an adequate test. The samples packed were rather light yellow in color, fair to good in texture, and without distinctive flavor or quality. The results with these and other early dwarf varieties are in some part due to the character of the seasonal conditions

under which they were grown and, therefore, should not prejudice the reader against them for use in latitudes to which they are adapted.

It may be pointed out that repetition of this work with the same list of varieties in other sections of the country would undoubtedly result in some shifting of varieties from group to group, according to whether they were better or less adapted to the various sets of growing conditions. At the same time it may be doubted whether any wholesale rearrangement of groups would occur under any conditions that permitted normal development of the crop. Insofar as the varieties here used have been tested elsewhere, there seems to be fairly good agreement on the quality of their frozen or canned products, which would seem to indicate that the general ranking of varieties with respect to quality may hold fairly well over rather wide areas. The results of Culpepper and Magoon (*20*, *21*, *45*, *46*), who found that growth under rather widely differing climatic conditions as well as root pruning and other mutilations of the plant affected yields rather than chemical composition and quality of the grain, point to the same conclusion.

RELATION OF STAGE OF MATURITY TO QUALITY OF MATERIAL

The lots of sweet corn employed in the studies of effect of stage of maturity on quality were of various known ages ranging from 14 to 26 or 27 days from date of silking. The studies of Culpepper and Magoon (*19*, *20*) have shown that these ages represent the upper and lower limits within which sweet corn is of acceptable table or canning quality. During a period of 10 to 12 days the grains pass from a condition in which they are sweet and tender, but somewhat watery in consistency and deficient in flavor, onward through prime canning condition to a condition in which progressive toughening of pericarps, increase in starchiness and heaviness in consistency, and decrease in fullness and sweetness of flavor have carried the grain past usable stage. Culpepper and Magoon emphasized the necessity for harvesting corn for canning at a stage varying not more than 2 to 3 days on either side of 20 days from appearance of silks in order to obtain optimum quality in the canned product.

It is clearly evident from the results of this study that even closer grading for stage of maturity is a necessity for the production of a frozen corn of highest possible quality. Freezing produces no reduction in apparent starchiness or improvement in consistency comparable with the changes brought about in canned corn by the heat of processing, so that overmaturity in the frozen product is more apparent than in a portion of the same material that has been canned. It is consequently necessary to lower the age limit of corn for freezing somewhat below that of corn that may be successfully used in canning. In order to secure highest possible quality in the frozen product, sweet corn should be harvested in the first half of the period over which canners would use it for making cream-style pack. The upper limit is 20 to 22 days from date of silking for most of the varieties here studied and is that at which the grains still exude milk on pressure but are beginning to develop perceptible doughiness. In all the lots of various ages, the finest flavor and the best consistency were obtained in cream-style corns ranging between 16 and 22 days from date of silking. In whole-grain corns and entire ears, the upper limit in

age was 2 to 3 days lower; consistency and texture were less satisfactory and flavor less full and pleasing in lots made from corn more than 20 days of age. Consequently, the limit in age for corn to be frozen as whole grain or corn on the cob should not exceed 20 days under mean temperature conditions such as those of Washington, D. C., during July and August, when the bulk of the material here used was harvested. The rate at which corn will develop from silking onward to canning maturity will differ with the mean temperatures prevailing during the period, and in any given locality it will be somewhat slower in spring and in late summer than in midseason, as the studies of Magoon and Culpepper (*45*), Appleman and Eaton (*7*), and Appleman (*6*) have shown. It is a relatively simple matter to determine the rate of development of the ear for any given locality and for any desired portion of the season by the employment of the method of tagging ears at the time of appearance of the silk and following the subsequent development by frequent sampling.

EFFECTS OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING ON QUALITY

EFFECT OF VARYING THE LENGTH OF THE SCALDING PERIOD.—The length of the scalding period with all material used in the varietal comparisons was uniformly 4 minutes in actually boiling water. In one experiment a large lot of Stowell Evergreen corn 21 days of age from silking and in optimum condition for table use was subdivided into four portions that were scalded in a large volume of boiling water for 4, 5, 6, and 7 minutes, respectively, and packed as corn on the cob in brine in 10-pint paper containers. All four lots were of excellent texture and color; those scalded for 4 minutes had a very slight "cobby" flavor but were otherwise very good; those scalded for 5, 6, and 7 minutes were without cobby flavor and were pronounced excellent, the three lots being indistinguishable in palatability and quality. It seems probable that the 4-minute scalding period here used is the absolute minimum that can be used with safety with the larger eared varieties, and that a somewhat longer scalding period, at least 5 or possibly 6 minutes, should be employed with all varieties having medium to large ears.

EFFECT OF STORAGE FOR 6 MONTHS AT 15° F.—Portions of the pack of several varieties, prepared both in cream and whole-grain style and packed with and without brine in 1-pint containers and in No. 2 tin cans, were frozen and subsequently held for 6 months in the 15° F. room. These were carefully compared with portions of the same lots of raw material packed in identical forms but stored at 0° for 6 months. In the material packed in sealed tins, whether with or without brine, the lots held at the two temperatures were indistinguishable in color and texture, both while frozen and after being cooked. There was a slight but consistent loss in flavor in all lots held at 15°; although all were palatable, they were scored ½ to 1 point lower on flavor than corresponding lots held at the lower temperature. In the packs in paper containers, there were no differences in texture and only very slight differences in color in the two lots; the flavor of the material stored at 0° ranged from good to excellent, whereas that held at 15° was fair to poor in the brine packs and poor to inedible in the straight packs. The results show very conclusively that corn cannot be held for

extended periods at 15° without undergoing profound deterioration in flavor if packed in nonairtight containers, and less pronounced but plainly perceptible deterioration when packed in hermetically sealed containers.

EFFECT OF AIRTIGHT AND NONAIRTIGHT CONTAINERS.—There were no pronounced or significant differences between the products from the two types of package after storage at 0° F. In the cooked material, portions of the same original lots of material from the two types of containers were identical in color, consistency, palatability, and retention of varietal flavor. In the frozen condition, cream-style packs with or without brine and whole-grain packs in brine were identical in appearance in all types of containers; in the straight packs the corn in the nonairtight containers had a somewhat dulled appearance resulting from incipient drying, but regained its brightness and natural color on cooking.

PLAIN TIN COMPARED WITH ENAMEL-LINED CANS.—Color and flavor were equally well preserved in plain tins and those having corn-enamel or berry-enamel lining. Plain tin was not appreciably etched in the brine packs and no discoloration of can or contents was observed. Darkening may be expected if thawing and refreezing occurs. There appears to be no reason why plain tin containers should not be perfectly satisfactory for frozen corn if the public can be brought to consider frozen products in tin as perishable and to treat them accordingly.

DRY OR STRAIGHT PACKS COMPARED WITH BRINE PACKS.—As stated in the general discussion of dry and brine packs (p. 18), there was unanimous agreement of the judges that the brine packs of corn were slightly superior in several respects. Some of these, for example, the differences in appearance and color in the frozen condition, have been sufficiently discussed in the section to which reference has just been made. The difference in flavor may be discussed in some detail. There was apparently a slight superiority in flavor of the brine packs for all varieties and at all stages of maturity, which was attributed, after considerable study, to diffusion of the sweetened brine into the corn. This had apparently brought about a blending of the seasoning with the flavoring substances of the corn that could not be successfully imitated or equaled by addition of equivalent amounts of sugar and salt to the straight packs at the time of cooking. Some of the judges were of the opinion that in addition to this there was also a better preservation of the "fresh" flavor of the corn in the brine packs; others were undecided on this point. All were agreed upon the consistent superiority of the brine packs and in recommending the use of brine in cream-style and whole-grain corn as a means of securing the finest and the most delicate flavor.

COMPARISON OF WHOLE-GRAIN AND CREAM-STYLE PACKS.—Parallel packs in whole-grain and cream-style form were made from most of the varieties used in the work, and these were subjected to careful comparative study in an effort to determine any differences in effects of variety, stage of maturity, or methods of preparatory treatment on the quality of the two products. It was believed that the results with the whole-grain style of pack would be of especial interest; the very rapid annual increase in volume of canned corn packed in whole-grain style since 1934 and the present tendency to can both white and yellow varieties in this form indicate a receptive attitude on the part of consumers toward the whole-grain product (*3, 5, 12, 16*). It is

evident from the experience of canners [7] (*32*) that the standards for raw material for production of high-quality whole-grain corn differ somewhat from those in use in the production of cream-style corn. Since producers of frozen corn may desire to make both forms of product, an attempt was made to obtain all the information possible in regard to effects of varietal and maturity factors on the two products.

When cream-style and whole-grain packs made from corn of the same variety and stage of maturity were compared, certain differences were consistently found. The characteristic sweetness and flavor of the variety were always fuller and more pronounced in the cream-style sample. In the whole-grain corn, the pericarps or hulls were much more evident and seemed tougher; starchiness, when present, was much more apparent. These differences were obviously due to the fact that in cream-style corn, portions of the contents of the kernels are scraped out in preparation so that the flavoring substances present are immediately perceived on tasting the corn, whereas in whole-grain corn the pericarps must be crushed by the teeth and the contents forced out before the flavor is apparent. Consequently, a considerable part of the sweetness and flavor of the whole-grain corn fails to be perceived, and the consumer receives the impression that the whole-grain samples are several days older, hence less full and rich in flavor and somewhat tougher and more starchy than cream-style samples of identical age.

For these reasons, the samples of whole-grain corn that were judged to be of highest quality for their respective varieties were uniformly 2 to 4 days younger than those of the same varieties in cream-style form that were considered to be of highest quality. It may be said that corn when in optimum condition for packing in cream style is already too old for making a high-grade whole-grain pack. In order to secure highest quality, canners have found it absolutely essential to harvest corn intended for packing as whole grain from 3 to 5 days earlier than when packing cream style (*3, 5, 12, 16, 32*), and producers of frozen pack may profitably be guided by the canners' experience. Reasons have already been given (p. 54) for the statement that the range in stage of maturity that can be successfully used for freezing is somewhat narrower than that used for canning.

FREEZING OF CORN ON THE COB.—Successful freezing of an unnamed variety of corn on the cob was reported by Joslyn and Cruess in 1929 (*35*), and Diehl and Berry (*23, 24*) have reported results of work begun by Diehl in the same year. Most of the workers who have reported experimental work on the freezing of corn on the cob (*1, 4, 27, 28, 29, 30, 59*) have confined their work to one or a few varieties, and these have been the small-eared yellow corns such as Golden Bantam, Golden Sunshine, and their hybrids.

Corn frozen on the cob differs from other frozen foods, from which all nonedible material is removed prior to packing, as somewhat more than half the weight of the ear consists of cob. This necessarily makes corn so frozen more expensive than other types of frozen corn, and this will necessitate that it have exceptional attractiveness and high table quality if it is to compete in the markets with frozen cut corns. Consequently, 12 yellow and 14 white corns, presenting

[7] COVER, RALPH. WHOLE-GRAIN CORN. 54 pp. 1935. Baltimore. [Mimeographed.]

a rather wide range in size of ear and type and quality of grain, were frozen on the cob in an attempt to ascertain the factors that are of importance in determining quality in corn so frozen.

The chief difficulty encountered by earlier workers who have frozen corn on the cob has been "cobbiness," or the presence of an abnormal odor and flavor generally attributed to the absorption by the grain of substances derived from the cob. This condition has also been so generally present in corn canned on the cob in brine that an entirely new technique has been devised to prevent it (*2, 31*). Cobbiness has been rather frequently observed in this laboratory in past years in packs of frozen corn on the cob, both in experimental packs prepared by the authors and others and in commercial products. Diehl and Berry (*23, 24*) found that cobby flavor was very pronounced in Golden Bantam corn frozen without scalding, but that it was progressively less evident in lots scalded for periods increasing by ½-minute intervals up to 3 minutes, at which point the corn became normal in flavor. It would appear highly probable that abnormal odor and flavor in unscalded or insufficiently scalded corn are due to the same causes that are responsible for the development of abnormal flavors and odors in other unscalded frozen vegetables.

In both years of the present work, a scalding period of 4 minutes was used as a routine procedure with all corn regardless of size of ears. Corn on the cob was packed with and without brine, some of the straight packs having individual wraps about the ears. Cobby flavor occurred in some of the packs, but was very irregularly distributed, without much reference to size of ear or to variety. Its occurrence led to a modification of the scalding technique in the second year. The scalding time, except for certain special lots, was held at 4 minutes, but the size of the scalding tank and that of the heating unit were increased, with the result that the average mean temperature of the water during scalding became 206° F., an increase of 6° over the previous year. This modification greatly reduced the frequency of occurrence of abnormal odor and flavor but did not entirely eliminate it, as it was observed in some portions of the pack, but always in less pronounced degree than in the preceding year.

Abnormal flavor was practically never observed in ear corn packed in brine. Its occurrence in straight packs was very irregularly distributed through the packs. Although it is evident from the results that the scalding period used was too short for entire safety to the pack, it is also apparent from the irregular occurrence of abnormal flavor through the packs of both years that some other factor or factors played a part in producing it. Slow freezing suggests itself as the most probable cause, since the containers employed had heavy walls and considerable thickness in all dimensions. The fact that the preliminary freezing was done in a room at 15° F. rather than at 0° may also have been a contributing factor. The relative importance of these factors in producing the results cannot be determined, but the results warrant the conclusion that the scalding period for corn to be packed on the cob should be 5 to 6 minutes under conditions that maintain actual boiling of the water for the greater portion of the period, that the containers should be of a shape such as to facilitate heat transfer from the package, and that freezing should be promptly done at a temperature of 0°.

Under the conditions stated, ears of any variety of corn, white or yellow, may be frozen with as satisfactory preservation of quality and flavor as is possible to secure with the same variety packed as whole-grain or cream-style corn. This was accomplished in the present packs. No lowering of quality between corn on the cob and cut corns was observed in any variety, although size and shape of ear made many of the varieties unsuitable for packing. As with whole-grain corn, the corn used for freezing on the cob must be harvested 3 or 4 days earlier than that used for freezing cream style. All that has been said as to reasons for this recommendation in the case of whole-grain corn applies with equal or greater force here. Thorough chilling should immediately follow scalding and should be sufficiently prolonged to reduce the temperature at the centers of the ears to that of the water supply. If brine packs are made, the brine added should be made up with cold water and kept at a low temperature by means of cooling coils or other effective means until used. These precautions will greatly reduce the time required to reach freezing temperature in the freezing room.

In the present work, corn on the cob packed in brine was consistently superior to the corresponding straight packs in retention of full, characteristic flavor, freshness, and natural appearance. Such packing in the types of containers here used is impracticable because of the large volume and weight of brine necessary; this difficulty could be avoided by the use of containers designed to accommodate a definite number of ears with a minimum of space to be filled with brine.

If for sanitary or aesthetic reasons it is desired to wrap ears individually in waxed paper, cellophane, or similar covering, as was done with some lots in these experiments, the ears should be wrapped, frozen individually, and packed into the containers after freezing.

GENERAL RESULTS OF VARIETAL COMPARISONS

For practical purposes, consideration of varieties to be grown for freezing may be confined to the varieties placed in the first and second groups, except in districts in which varieties here placed in lower ranks have proved productive and disease resistant and have shown satisfactory quality. The first- and second-rank groups contain 23 varieties, 10 yellow and 13 white, which under the conditions of this test showed satisfactory productiveness and disease resistance, together with a quality of grain that made them satisfactory when frozen. Although divided into 2 groups, the differences upon which the division was based were very small and for the most part would have escaped any but the most critical inspection. Insofar as texture, flavor, and acceptability of the product are concerned, they may be considered as one group. For packing as corn on the cob, choice is necessarily restricted to varieties having ears of desirable size and shape, but the number of varieties having such ears is fairly large.

For emphasis, attention is called to the large number of varieties of comparatively recent introduction that were found to be of very high quality. The number of these in the first- and second-rank groups considerably exceeds that of the older, generally known and cultivated varieties. Should these newer introductions prove, on further testing in other districts, to have the high quality of grain and the desirable field characters shown in this test, it seems probable that

many of the older varieties will ultimately be replaced. One of these recent introductions, Golden Cross Bantam, has proved so far superior to older sorts in tests over a wide area that at present it is by far the leading yellow variety in acreage grown for canning.

It is obvious that sweet corn is especially well adapted to preservation by freezing. This is shown by the fact that in the present work practically all varieties of desirable character and good quality in the fresh material were preserved with no loss of quality by very simple although carefully controlled methods. The varieties in the lower ranks were so placed because of lack of high quality in the fresh material and not because of the breaking down of desirable quality under freezing treatment.

Succotash

The successful retention of desirable quality and flavor in sweet corn and lima beans by freezing suggested to the authors that suitable combinations of the two in the form of succotash might be preserved in the same way. Such a product would appear to have some possibilities if of satisfactory quality, in view of the wide popularity of succotash made directly from fresh materials in their season. Insofar as the authors can ascertain, no one has heretofore attempted either experimental or commercial production of a frozen succotash.

The work here reported was preliminary in character in the sense that its purpose was primarily to determine whether it was possible to produce a frozen succotash of satisfactory appearance and table quality, rather than to make an extensive or complete study of a large list of varietal materials. The work done was consequently confined to preparation of combinations of a few standard varieties of beans with a small number of sweet corns known to have satisfactory quality when frozen. The varieties of both were so chosen as to furnish indications whether frozen succotash had sufficient possibilities to warrant detailed studies of other varieties and of a wider range of combinations.

VARIETIES OF CORN AND BEANS EMPLOYED

The beans employed in the work were old and widely cultivated varieties or selections from such varieties. They included four dwarf or bush lima beans, Burpee Improved, Wood Prolific, Henderson Bush, and Fordhook, the last named a thick-seeded or potato type, one large-seeded pole variety, King of the Garden, and one dwarf variety of green snap bean, Asgrow Stringless Green Pod. The corns used included Golden Cross Bantam, Stowell Evergreen, Stowell Evergreen Hybrid 14 × 5, Long Island Beauty, an exceptionally vigorous variety having very large ears of good quality, and two comparatively recent introductions of high quality, Redgreen and Narrow Grain Hybrid. All the varieties of both corn and beans were being studied concurrently with respect to their suitability for freezing, and identical lots of separately packed materials were available for comparison with the various combinations.

DETAILS OF PREPARATION AND PACKING

The details of harvesting and preparation of materials for use in succotash were identical with those employed with corn and beans intended for packing separately. All of the corn used was prepared in cream style and was at the optimum stage of development for such use. The beans used of the large-seeded varieties were certain size grades obtained by screening large lots over standard screens; brine flotation was employed for the small-seeded varieties to eliminate overmature beans. The scalding periods for beans of the large-seeded types were 4, 3, and 2 minutes for the largest, the intermediate, and the smallest sizes, respectively, and 3 minutes for the small-seeded types such as Henderson Bush. The scalding period for all corn used was uniformly 4 minutes.

In packing it was found impossible to make up a uniform mixture of corn and beans in bulk because of their different specific gravities and consequent tendency to separate. They were kept in separate receptacles and mixed in the individual containers by measuring in the desired quantity of each and stirring. In all material prepared for use in the comparisons the proportions used were 2 parts corn to 1 of beans; but a few duplicate packs containing equal parts corn and beans were also made. Both straight and brine packs were made in 1- and 5-pint paper containers. A 2-percent salt solution was employed in the brine packs as a routine procedure, but duplicate packs of a part of the material were made in which a sweetened brine containing 2 percent of salt and 6½ percent of sugar was used. Portions of all lots were canned in No. 2 cans by a standard procedure and stored for comparison with the frozen material.

The methods of freezing, period of storage, and the methods of preparing, examining, and scoring the products after storage were those used with other frozen materials included in the study.

RESULTS WITH VARIOUS MIXTURES

The summary of results presented in table 6, with notes on the various combinations that follow, represents the concensus of opinion of the judges as to the quality of the material as prepared for the table as well as to its appearance and consumer appeal. The range of difference in quality between the various combinations was very small, but there was no question in any case as to the entire acceptability of the material.

TABLE 6.—*Results of examination of succotashes consisting of various corn and bean combinations*

Varieties used			Appearance and color in frozen condition	Characters in cooked condition		
Beans		Corn		Appearance and color	Texture	Flavor
Variety	Size or degree of maturity [1]					
Wood Prolific	14/32	Golden Cross Bantam	Attractive green and yellow	Very good, but beans whitened.	Very good	Fair to good.
Fordhook	20/32	do	Excellent; beans deep green	Very good	Excellent	Excellent.
Burpee Improved	24/32	Stowell Evergreen	Fair; beans slightly yellowed	Fair to good	Good	Good.
	22/32		Good	Good	Excellent	Excellent.
	20/32		do	do	do	Do.
King of the Garden	26/32, 24/32, and 22/32 mixed, equal parts.	Long Island Beauty	Very good	Good, beans browned	do	Very good.
Henderson Bush		Narrow Grain Hybrid	Fair; beans pale, corn waterlogged	Fair to good	do	Excellent.
Do		Stowell Evergreen Hybrid 14×5.[2]	Good; beans pale	Very good	do	Do.
Asgrow Stringless Green Pod.	Young beans	Redgreen	Excellent; beans deep green	Excellent	Very good	Fair; corn predominates.
	Intermediate		Very good	Fair, beans browned	Fair	Fair to very good.
	Full grown, shelled		Poor; beans purplish brown	Fair to poor; color as when raw.	do	Fair to good.

[1] The screen sizes (in thirty-seconds of an inch) are those by which the beans were held, not those through which they passed.
[2] A cross of the 2 inbred lines Asgrow 14 and Asgrow 5.

Most of the judges considered that the succotashes in which yellow corn had been used were somewhat more attractive in appearance and would have a stronger appeal to a prospective purchaser, when viewed in the frozen condition, than those made with white corns. Golden Cross Bantam, the only yellow corn used, was employed in two combinations, with Fordhook and with Wood Prolific. It was generally agreed that the combination with Fordhook was slightly superior to the other in all respects. The color of the frozen product was very attractive, the rather deep green of the beans contrasting effectively with the light, bright yellow of the corn, and the colors were very well retained after cooking. The texture was excellent. The beans used were those held by the $^{20}/_{32}$-inch screen from a large lot held by screens ranging from twenty-six thirty-seconds to fourteen thirty-seconds of an inch in size.

The Golden Cross Bantam and Wood Prolific combination had a very good appearance while frozen, but the color of the beans blanched to greenish white after being cooked and many of the seed coats ruptured and permitted the cotyledons to escape. Texture was consequently not first class. The flavor was primarily that of the corn, the flavor of the beans being too mild to give proper balance to the blend. The succotash would have been improved by the use of a larger proportion of beans. Use of older beans would also have improved flavor, but at the expense of color. Only beans held by the $^{13}/_{32}$-inch screen had been used, because larger sizes of this variety became rather badly whitened on freezing and detracted from the appearance of the pack through their suggestion of overmaturity.

For the combinations of Burpee Improved lima beans with Stowell Evergreen corn, the beans were screened and three sizes selected and used separately. The largest size, those held by the $^{24}/_{32}$-inch screen, became somewhat yellowish green when frozen and bleached considerably when cooked, were slightly too firm in texture, lacked distinctive flavor, and were somewhat starchy, so that this sample was only fair in appearance and good but not outstanding in palatability and flavor. The two lots made with the beans held by the $^{22}/_{32}$- and $^{20}/_{32}$-inch screens were distinctly better in color both while frozen and after being cooked, as the beans retained a good green color that contrasted well with the ivory whiteness of the corn. Texture and flavor were excellent, and some of the judges found the blending of flavors in these combinations especially appealing and consequently considered them superior to any other of the combinations made with white corns.

In the combination made from King of the Garden lima beans and Long Island Beauty corn, the beans used were a mixture of equal parts of the three sizes held by the $^{26}/_{32}$-, $^{24}/_{32}$-, and $^{22}/_{32}$-inch screens. In the frozen condition the corn was an excellent white and the beans a very good green with a few slightly yellowed ones. The beans became slightly darkened when cooked but the appearance of the cooked product was good. Texture was excellent and the flavor, although not equal to that of the Golden Cross Bantam and Fordhook or of the Stowell Evergreen and Burpee Improved combinations, was well balanced and pleasing and was rated as very good.

Henderson Bush lima was used in two combinations, one with Narrow Grain Hybrid and the other with Stowell Evergreen Hybrid 14 × 5. The beans used were unscreened, but the overmature ones

had been removed by flotation in 6-percent brine. The appearance of the mixture with Narrow Grain Hybrid in the frozen state was only fair, for the beans were a rather pale green and the corn was dull white in the dry pack and semitransparent or waterlogged in appearance in the brine pack. After the material was cooked the straight pack was very good in appearance and the brine pack only fair, but both were excellent in consistency and flavor. A minority of the judges considered this the best of all the succotashes; others thought that the flavor, though pleasing, was too mild and lacking in distinctive character to be given highest rank. The combination of Henderson Bush lima with Stowell Evergreen Hybrid 14 × 5 was somewhat more attractive, both while frozen and after cooking. Although the beans were rather pale green, the corn was an excellent, slightly ivory-tinted white, and the contrast was very pleasing. Texture and flavor were excellent and were considered by some of the judges fully equal to that of the Henderson Bush and Narrow Grain Hybrid combination.

Some lots of succotash were prepared from a green snap bean, Asgrow Stringless Green Pod, in combination with Redgreen sweet corn. As very extensive use is made of succotashes consisting of corn and green snap beans in portions of the United States in which the lima bean is not generally grown, it was thought worth while to test the possibilities for preserving this type of product by freezing. Three lots of succotash were made, with beans of three stages of maturity. In lot 1, young beans in which the seeds were not more than one-fourth normal mature size were used; the pods were broken into lengths of approximately 1 inch and scalded for 2 minutes. In lot 2, the beans used had attained full length and had seeds ranging from one-fourth to three-fourths mature size; these were broken into 1-inch lengths and scalded for 3 minutes. The mixtures consisted of 2 parts of corn to 1 of beans. Lot 3 consisted of shelled beans that had nearly or quite reached full size but had not begun to dry; these were scalded for 3 minutes and the succotash from them was made of equal parts of corn and beans.

The lot made with the youngest beans was very attractive, both while frozen and when cooked, the deep green of the beans contrasting effectively with the ivory whiteness of the corn. Texture was excellent, but the flavor was essentially that of the corn, the beans being too mild in flavor to be much in evidence. In a mixture of equal parts of beans and corn, there was considerable improvement in the flavor, but the corn flavor still predominated. Lot 2 (made with beans of intermediate size) was attractive while frozen, but the beans became somewhat badly browned when cooked. Texture was fair and flavor fair to good. There was lack of agreement among the judges as to quality; those familiar with the product as made from fresh material considered it very good, whereas those to whom it was a new product considered it not equal in flavor or quality to either of the constituents as separately frozen and prepared for the table. A like difference of opinion developed as to the quality of lot 3, made from shelled beans and corn. The color of this material was unique but not attractive, the mottled purplish brown of the beans clashing rather than blending with the white of the corn. Texture was only fair, some of the beans being slightly starchy and too firm. Flavor was rated by several of the judges as fair, good, and very good. When the three lots of snap

bean and corn succotash are considered as a whole, the material did not make a very favorable impression upon those who had had no previous experience with such products; those familiar with it as made from fresh beans and corn regarded the samples as very good examples of such succotashes.

BLENDING OF FLAVORS IN THE MIXTURES

The blending together of flavors was very good in all the mixtures with the exceptions already noted—the young snap beans with Red-green corn and the mixture of Wood Prolific and Golden Cross Bantam. In both these mixtures the defect was not a failure of the flavors of the corn and beans to blend together but an absence from the beans of sufficiently pronounced and distinctive flavor to make itself evident against the flavor of the corn. Use of a larger proportion of beans would have in some degree improved the balance of the mixture. In the other succotashes there was very satisfactory blending of flavors of the two components, no case of clashing or incompatability of flavors having been found.

COMPARISON WITH IDENTICAL MIXTURES FROM SEPARATELY FROZEN CORN AND BEANS

A number of succotashes were made up from separately packed and frozen material for comparison with the combinations made from other portions of the same lots of fresh corn and beans. All the succotashes made up just prior to cooking from separately frozen materials were indistinguishable in every respect from those mixed prior to freezing; texture, color, and flavor of each component being precisely that which it had when packed together. Consequently, succotashes may be prepared and frozen as such, or may be made up from separately packed corn and beans by mixing together the desired proportions at the time of cooking.

COMPARISON WITH IDENTICAL MATERIAL PRESERVED BY CANNING

Attempts to compare the frozen material with identical material canned by standard procedure led to considerable difficulty, because the products could not be judged by any common scale. Although most of the canned samples were considered good to very good, they were comparatively unprepossessing in appearance by reason of the dullness and opacity of color in the white corns and the disappearance of the green color and its replacement by brown in the beans. Texture was very good in all except the Stowell Evergreen and Burpee Improved mixture made with beans from the 26/32-inch screen, in which processing had rendered the firmness and starchiness of the beans more prominent and objectionable than in the corresponding frozen lots. Flavor ranged in the various lots from good to very good, but all had the typical canned flavor and were lacking in the fullness and freshness characteristic of all the frozen samples.

EFFECTS OF VARIOUS PREPARATORY TREATMENTS AND METHODS OF PACKING

There were very slight and unimportant differences in appearance between the straight and the brine packs while frozen, and the two were identical in texture and flavor when cooked. A number of packs

in 2-percent brine and 6½-percent sugar solution had been made in addition to that in the usual 2-percent brine. The judges were divided in opinion as to the advisability of using sweetened brine, the majority considering that it improved the product, but a minority dissented, feeling that if used at all the amount of sugar should not be greater than 3 or 4 percent. There were no differences in texture and quality between the identical lots packed in 1- and 5-pint containers, and differences in appearance were limited to the slightly greater drying and opacity generally observed in all larger containers packed straight.

SUMMARY

The rather general application to vegetables of freezing as a means of preservation makes it necessary to study the available varieties of each vegetable to determine those that are best suited for freezing. The present study of comparative suitability for freezing in groups of varieties of vegetables employed 18 varieties of peas, 14 of green beans, 8 of lima beans, and 35 of sweet corn. The varieties used were selected from those that are most widely grown in the eastern United States, and were primarily those regarded as having somewhat better than average quality as fresh vegetables in addition to a satisfactory degree of productiveness and disease resistance. They were, consequently, chiefly old, rather widely known varieties, with a smaller number of relatively recent introductions that seemed to have decided promise.

The work was begun in 1934 and repeated in 1935 with very closely accordant results for the two seasons. The raw materials were grown at the Arlington Experiment Farm, Arlington, Va., under direct supervision of the experimenters and with as uniform conditions of soil and cultural treatment as it was possible to obtain; hence they were all of known and comparable history.

Methods of harvesting, grading, preparing, and packing the various vegetables were standardized at the outset in order to secure uniformity in treatment of material to be subsequently compared. The details of preparation necessarily varied with the different products, but features receiving special stress in all cases were (1) prompt handling from harvesting onward, (2) rigid inspection and careful grading for stage of maturity, (3) scalding in a large volume of water for periods experimentally predetermined to yield best results for the particular product and stage of maturity, (4) immediate and thorough cooling in running water, (5) prompt packing and transfer to the freezing room, and (6) such distribution of containers in the freezing room that maximum contact of the air with their surfaces was assured.

As an integral part of the study of varietal adaptability, a detailed study was made of the effect of stage of development or degree of maturity of the material on appearance, flavor, and palatability and table quality of the product made from it. This was accomplished by harvesting at predetermined stages of development, by separating the various lots of material into a series of advancing sizes and stages of maturity, or by both methods, and by preparing and packing the material at each of these stages separately. Subsequent comparisons of such series permitted determination of the effects of stage of maturity on quality and appearance of the product and rather

accurate fixing of the upper and lower limits within which the material may be frozen with optimum texture, flavor, and quality as a food product.

Methods of preparatory treatment and packing are not standardized, and the degree to which the inherent quality of a vegetable may be affected by variations in these treatments is not fully known. For these reasons identical material was subjected to a number of somewhat different preparatory treatments. Duplicate packs were prepared with and without addition of brine. Various sizes of containers of both airtight and nonairtight types were used for both dry and brine packs. Comparisons of originally identical material subjected to these various treatments permitted determination of treatment and packing that gave best preservation of appearance and table quality for the different vegetables.

Preliminary freezing of the material in circulating air in a room held at 15° F., followed within a few days by transfer to a room held at 0°, was employed as a routine procedure throughout the work. Although entirely successful results were obtained under the exceptional conditions of these experiments, immediate freezing at a temperature of 0° is an absolute necessity for commercial freezing of vegetables.

In each of the vegetables studied, with the exception of corn, the group of varieties employed showed a rather wide range in appearance and table quality after identical preparatory and freezing treatment. Each group contained varieties that ranged in quality and appearance of product when ready to serve from excellent through good to mediocre or poor.

In green snap beans, three varieties, Giant Stringless Green Pod, Mosaic-Resistant Stringless Green Refugee (Idaho Refugee), and Kentucky Wonder Pole, were distinctly superior in color and appearance in the frozen condition and in color, texture, palatability, freshness, and fullness of flavor when cooked, and are regarded as exceptionally promising material for freezing. Four varieties, Asgrow Stringless Green Pod, Burpee Stringless Green Pod, U. S. No. 1, and Round Pod Kidney Wax, were very nearly or quite equal to the first group in texture, flavor, and palatability when cooked, but were not so attractive either in the frozen condition or after being cooked, because of the loss of fresh color. The other seven varieties, Asgrow Stringless Valentine, Tendergreen, Konserva, Keeney Improved Kidney Wax, Tennessee Green Pod, Black Valentine, and Full Measure, were of distinctly poorer quality in respect to texture and flavor as well as in appearance and amount and quality of color retained, and consequently did not appear to be suitable or promising for freezing. Black Valentine and Full Measure were the least promising of the group.

The 18 varieties of peas studied fell into four groups with respect to degree of suitability for freezing. Thomas Laxton and Asgrow No. 40 were superior, all factors considered, to all the others. A second group made up of Dark Podded Telephone, Onward, Alderman, and Laxton Superb compared favorably with the first group in most respects but did not equal them in all; all of this group developed unsatisfactory color or texture at certain stages, which made exclusion of these sizes from the pack necessary to maintain high quality. A third group consisting of Green Admiral, American

Wonder, Market Surprise, Improved Stratagem, Improved Pilot, and Nott Excelsior have defects, chiefly of color but in some instances in other respects, which make them only fair to mediocre in quality for freezing. A fourth group, including Alaska, Champion of England, Dwarf Telephone, Laxtonian, Pedigree Extra Early, and Wisconsin Early Sweet, were so lacking in characters essential to satisfactory results in freezing that the products made from them were very poor and unsatisfactory in quality. The varieties differed greatly in the range of stages of development in which they had desirable quality for freezing. Thomas Laxton and Asgrow No. 40 had very good to excellent quality at all stages of development, hence appear to be exceptionally promising material for freezing. In most other varieties the smallest and the largest sizes that could be separated by screening had undesirable characteristics when frozen and only the intermediate stages had highest quality.

Of the eight varieties of lima beans employed, King of the Garden and Giant Podded, two pole varieties, and Dreer Bush, a potato type lima, were superior to the others. They retained a satisfactory degree of fresh, attractive green color, both in the frozen state and after being cooked, and had excellent texture and flavor at all stages of development up to full size. The other varieties required various amounts of grading, because in them the larger sizes of beans lose color, develop starchiness, and lose flavor. Fordhook has these defects in the larger sizes, but when these sizes are graded out the smaller sizes are equal in quality to those of the first group named. Henderson Bush has the serious defect that some seeds become white before reaching full size, and further, this variety is not equal in flavor at any stage to the varieties just named. Burpee Improved has fairly good color and appearance but is of rather low quality in palatability and flavor. Wood Prolific and New Philadelphia are mediocre in flavor, become badly bleached in freezing, and appear to have no promise as material for freezing. For the packing of so-called baby limas the younger stages of Giant Podded, King of the Garden, Fordhook, and Dreer Bush made products distinctly superior to Henderson Bush, Wood Prolific, or New Philadelphia. The larger sizes of the large-seeded varieties made a product quite distinct in character from the baby-lima pack, but also superior in palatability and quality to that made from Henderson Bush and related varieties.

Thirty-five varieties of sweet corn, 18 yellow and 17 white, were employed, and all were packed at a number of known and different stages of maturity, determined by tagging the ears on the day that silks appeared. All were packed in 2 styles, as cream-style and as whole-grain corn, and most of the varieties were also packed as corn on the cob. The differences in quality of the frozen product between varieties of sweet corn, harvested and packed at suitable and identical stages of development, were much smaller than those found between varieties in other vegetables. Sweet corn varieties generally appeared to retain whatever characteristic palatability and quality they possessed as fresh products to very nearly the same degree when they were prepared and frozen by the methods here used. Of the 35 varieties used, 10 were grouped together as having highest quality. These were Bantam Evergreen, Bantam Evergreen Hybrid, Golden Bantam, Improved 10–14-Rowed Golden Bantam, Top Cross Bantam, Top

Cross Whipple Yellow, Money Maker, Narrow Grain Evergreen, Stowell Evergreen, and Stowell Evergreen Hybrid 14 × 5. Thirteen others were grouped together as very good to excellent but not quite equal in every respect to the first group. These were Golden Cross Bantam, Golden Sunrise, Kingscrost Golden Bantam, Top Cross Spanish Gold, Whipple Early Yellow, Country Gentleman, Country Gentleman Hybrid 19 × 9, Country Gentleman Hybrid 19 × 24, Delicious, Early Crosby, Howling Mob, Long Island Beauty, and Redgreen. The varieties of a third group were distinctly below the last in appearance and quality although very acceptable; these were Burbank World Wonder, Gold Coin, Golden Giant, Sweet Orange, Narrow Grain Hybrid, and Top Cross Country Gentleman. The remaining varieties had rather mediocre appearance and quality and appeared to be without much promise for freezing when grown under the conditions obtaining in this work.

As a test of the possibilities for preserving ready-mixed succotashes by freezing, a number of lots of succotash were prepared, using six different varieties of corn, five varieties of lima beans, and one variety of snap bean in various combinations. The results show that the corn and beans in the various mixtures preserve their characteristic flavor and quality to the same degree as when frozen separately and that it is possible to prepare and preserve such mixtures by freezing with excellent results.

Comparison of parallel packs with and without brine showed somewhat better preservation of freshness and naturalness of color in brine packs of peas, lima beans, and sweet corn, when the two packs were examined in frozen condition. These differences disappeared in cooking and the two packs were then indistinguishable in appearance, color, and quality. Straight-packed green beans were somewhat superior in color to brine packs while frozen, the brine packs showing some loss of color and considerable splitting of pods. When cooked, the straight packs underwent greater fading and browning than did the brine packs, hence were less attractive as served.

In all the vegetables, the differences in appearance of material preserved in hermetically sealed and nonairtight containers were very slight, and there were no differences in preservation of flavor and quality over ordinary storage periods. When the storage period was extended to 18 months, retention of appearance and quality was decidedly better in hermetically sealed containers, but for normal periods of storage nonairtight containers are perfectly satisfactory.

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