

Commercial Brine Preservation of Vegetables^{1, 2}

By JOHN L. ETCHELLS

*Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration,
U. S. Department of Agriculture, Raleigh, N. C.*

and

IVAN D. JONES

Department of Horticulture, N. C. Agricultural Experiment Station, Raleigh, N. C.

Introduction

UNDER war-time restrictions with regard to metals, rubber, and other essentials, food processors are indeed faced with problems that tax their American ingenuity. Furthermore, the increasing demands that are being made for processed foodstuffs by the armed forces and by our allies over and above our usual civilian needs, add to an already acute problem. Thus, it would appear obvious that no possible phase of food preservation should escape closest scrutiny by those in any way connected with the food industry.

During ordinary times we usually think of canning, freezing, and drying as the major commercial methods of preserving fruits and vegetables for future table use. However, one of our oldest methods of food preservation—by the use of salt—should be included in the above group by virtue of the fact that millions of bushels of farm produce, such as cucumbers, onions, peppers, green tomatoes, and cauliflower, are annually preserved in brine by commercial pickling concerns. The average consumer probably has never seen any of the above products at the brine-preserved salt-stock stage, but he is rather familiar with the desalted, processed articles, such as various types of cucumber pickle or mixed pickle containing cucumbers, onions, peppers, and cauliflower.

Thus, the commercial pickling industry in this country attests to the practical nature of this method of preservation. Also, the fact that brined material may be kept for a period of several years prior to manufacturing into pickle products, is further proof that this basic procedure is sound. However, certain losses in nutritive constituents occur during the fermentation process which is brought about by micro-organisms associated with brining of vegetable material. In this connection it has been demonstrated that irrespective of the brine strength used (upwards of 90-percent saturation) certain types of salt-tolerant micro-organisms are able to grow, utilizing for their food nutri-

tive materials (principally sugars) which have diffused from the vegetable material into the brine. Since brined material is usually stored in high-salt content brines (60-80° sal.³, 15.8 to 21.1 percent salt), it logically follows that in the desalting operation there would be additional losses in soluble nutritive materials⁴. Such losses would be in keeping with the amount of salt removed. These are probably the main contributing reasons why commercial brine preservation of vegetables for table use has received only limited attention and has never figured in competition with other methods of preservation.

Notwithstanding the acknowledged losses attending the usual methods of brine preservation as described, it must be pointed out that, even with materials desalted from strong brines, appreciable amounts of nutritives can remain; principally proteins, starches, and minerals, which must be considered valuable adjuncts to the diet. To what extent improved or modified salting methods may minimize the losses occurring during brine preservation remains to be seen. However, from current work underway it appears that there are some extremely promising possibilities. Furthermore, as a method of emergency preservation requiring a minimum of labor and critical materials, and offering the possibility of storing large quantities of material in bulk until future processing and distribution may be brought about, brine preservation justly deserves adequate consideration in our war program.⁵

This paper represents a generalized report of a study on the brine preservation of certain vegetables. Only the principal phases of this investigation are considered at this time. In addition, brief recommendations are attached for the routine brining of the particular vegetables investigated.

³ Salometer reading, indicating per cent saturation with respect to salt.

⁴ These losses can be reduced in brined vegetable material by utilizing the material directly, without desalting, in soup mixtures. Here the salt content of the vegetables would go to seasoning the soup.

⁵ It is interesting to note that in Germany during World War I, due to shortage of tin and lack of freezing facilities at that time, thousands of tons of vegetables were preserved in brine for civilian use. In fact, the popularity of brined green snap beans was such that this product was commercially put up for several years after the war. This information was kindly supplied by Mr. Max Lehmann, Northwest Packing Co., Portland, Oregon, who was in Germany at the time.

¹ Presented at the annual meeting of the National Pickle Packers' Association, Chicago, Ill., January 19-20, 1943.

² Agricultural Chemical Research Division contribution No. 106. Approved for publication as paper No. 162 of the Journal Series of the N. C. Agricultural Experiment Station.

Table 1

Schedule of regular salting treatments used for green beans, lima beans and green peas.

Treatment No.:	Description
1	Initial brine strength 20° sal. (5% salt) for the first week, raised 10° sal. (2.5% salt) per week up to 60° sal. (15% salt).
2	Initial brine strength 40° sal. (10.6% salt) for the first week, raised 5° sal. (1.3% salt) per week up to 60° sal.
3	Initial brine strength 60° sal. and maintained at that concentration.

Report of Present Work

INVESTIGATIONAL work on brine preservation of vegetables has been underway for the past nine months as a joint research project of the Bureau of Agricultural and Industrial Chemistry of the U. S. Department of Agriculture and the North Carolina Agricultural Experiment Station. For the past several years this group has carried out extensive studies in connection with commercial brine preservation of cucumbers and the experience gained in this work is now being applied to other vegetable materials. To date, consideration has been given to the following vegetables: Green snap beans, green peas, lima beans, yellow wax beans, carrots, and certain leafy vegetables.

In carrying out the current brining program we have attempted to give consideration to the following points: (1) The study of "regular" or accepted salting procedures such as are used for cucumbers; (2) the development of modified salting methods better adapted to the vegetables involved in these studies, so as to minimize losses of nutrients; (3) vitamin retention with respect to carotene (pro-vitamin A) and vitamin C during curing and storage; (4) the chemical and bacteriological changes in the brine during curing and storage; (5) the physical changes with respect to color, texture, and general appearance during curing and storage; (6) methods most satisfactory for desalting brined vegetables prior to cooking; (7) color retention of the cooked product; and (8) edibility and methods of preparation of the desalted, preserved material.

Use of Regular Salting Treatments

THE large-scale brining has been restricted to green beans, lima beans, and peas (unshelled and uncut in all cases).

The program involved the use of three different initial brine concentrations (See Table I). Duplicate 60-pound lots of each vegetable were brined in 20-gallon open-headed kegs which were maintained under out-of-doors conditions. Eighteen lots were put down in May 1942. The approximate average brine temperature during curing was 80-90° F., and the range of the brine temperature from the time they were put down to the present has been from about 95° F. (highest) to 10° F. (lowest).

After approximately eight to nine months' storage in brine all lots of the above vegetable material are in excellent condition as judged by their color, texture, and freedom from spoilage.



Examination of various lots of brined material after approximately ten months' storage in brine.

It should be emphasized that the vegetables were salted whole; that is, the green beans were not cut; nor were the peas or limas removed from their pods. This would be a distinct advantage in areas where labor, time, or equipment at harvest did not permit the cutting or shelling operation.

Samples of the desalted cooked material exhibited a marked improvement in color as compared with the brined product prior to processing, returning more nearly to the color of the fresh material. This was particularly true of the limas and peas. The flavor was satisfactory for brine-stock vegetables.

Vegetables preserved in this way may be cooked with tomatoes or corn, or used in purees and soups. Lima beans may be baked with molasses similarly to navy-beans.

Use of "Low Salt" Acidified Treatments

DURING July, freshly harvested, mountain grown, green snap beans were put down in 60- to 70-pound lots, covered with a rather low-salt brine (17° sal. or 4.4% salt by weight), and no further salt was added. This treatment was designed to be sufficiently low in salt so that desalting prior to cooking might be eliminated.

Using this basic brining program, three variations in the treatment were introduced. Each treatment was carried out in duplicate 20-gallon kegs which were tightly headed at the start of the experiment. A hole in the head remained unbunged for the first ten days. By heading up the kegs shortly after being brined, exposure to sunlight and air, dilution by rain, and growth of surface microorganisms were avoided.

In the first treatment each keg received 60 pounds of beans which were blanched two minutes, plus 600 cc. of 116 grain vinegar and sufficient 17° brine to fill. In the second treatment all conditions were similar to those of the first treatment with the exceptions that the beans were not blanched. The third treatment was similar to the second except that the brine was acidified by adding 180 cc. of 50-percent edible lactic at the start rather than by adding vinegar.

After about one and eight months, samples of the beans were processed simply by removing them from the salt brine, washing quickly, adding sufficient tap water to cover, and cooking. The resulting product possessed a fair bean odor and flavor, excellent texture, and an olive-green color. The salt content of the cooked beans was not undesirably high. A tasting panel composed of ten persons ate cooked samples of the beans served in several ways (including creamed, and southern style with ham hock) and, in general, judged them satisfactory for table consumption. Snap beans preserved in this way may also be used in soups and mixed vegetable dishes; cooked with navy beans, German Style; and cooked alone for those relishing an acid-flavored bean.

The work reported so far was carried out under what we might term large-scale conditions; hence it has been dealt with in considerable detail. The work which will now be described was carried out under laboratory condi-

Table 2
Salting treatments used for leafy vegetables
(kale, mustard greens, spinach and turnip
greens) and carrots

Treatment No.	Material	Description
1	Greens* Carrots**	Covered with 20° sal. brine (5% salt). Covered with 24° sal. brine (6.2% salt).
2	Greens Carrots	Brine plus sufficient vinegar to make the brine covering the material 0.3 to 0.4 per- cent acetic acid upon reaching equilibrium. Brine plus sufficient vinegar to make the brine covering the material 0.3 to 0.4 per- cent acetic acid upon reaching equilibrium.
3	Greens Carrots	Brine plus sufficient lactic acid to make the brine covering the material 0.3 to 0.4 percent lactic acid upon reaching equilibrium. Brine plus sufficient lactic acid to make the brine covering the material 0.3 to 0.4 percent lactic acid upon reaching equilibrium.
4	Greens Carrots	Same as No. 2 plus 0.005 to 0.01 gram of d-iso-ascorbic acid (designed to retard oxi- dation changes in the material). Brine plus mixture of vinegar and lactic acid.
5	Greens Carrots	Same as No. 2 but material blanched 1.5 to 2 minutes in boiling water. Same as No. 4 for carrots plus blanching of material plus d-iso-ascorbic acid as antioxidant.

*Packed in 1 quart jars; contents about one-half pound of fresh greens and 16-oz. of brine. Brine level brought to within one-quarter to one-half inch of the top and the jars partially sealed during the period of gas evolution. For subsequent storage, the brine level was raised to the top of the jar and the lids sealed tightly to avoid growth of surface organisms.

**Packed in 2 quart jars; contents about 2 pounds of whole carrots and 32-oz. of brine. Details concerning the handling of the brined lots the same as above.

NOTE: Attention is called to the fact that while asterisks appear only after Greens and Carrots in Treatment 1, the asterisks refer to Greens and Carrots in all treatments.

tions during the late fall and winter months and was designed chiefly to give valuable leads with regard to other vegetables suitable for large-scale operations. While the results might not be considered conclusive, we have usually found good agreement between such laboratory studies and subsequent larger-scale operations.

Leafy Vegetables

INVESTIGATIONS were undertaken during October 1942 on brine preservation of leafy vegetables under laboratory conditions (on a small scale, involving about one-half pound lots in one-quart jars). Four greens were

used, namely: Kale, mustard greens, spinach, and turnip greens. Each kind was subjected to five different treatments (See Table II) represented by covering with a 20° sal. brine (5% salt) unmodified or modified as indicated: (1) brine only; (2) brine plus vinegar; (3) brine plus lactic acid; (4) brine plus vinegar plus an anti-oxidant; and (5) blanched material plus brine plus vinegar. This made a total of twenty lots and all have been examined at regular intervals for changes in color, odor, brine turbidity, general appearance, and texture.

In general, after about four months' storage in brine, all greens, with the exception of some lots of spinach, were keeping well, possessed good texture, retained good to fair natural odor, and had a light green to yellowish color. In the case of the spinach lots, some were inferior and the brine-alone treatment in particular yielded a decidedly inferior product, of which the tissue was disintegrated and discolored. The only spinach lot comparable to the other greens in keeping quality appeared to be the lot which received vinegar plus antioxidant.

Greens preserved in this way may be covered with equal volume of water, cooked and served, or they may be used in soups, or in mixed vegetable dishes.

Preservation of Carrots

FRESH carrots have been put down using treatments similar to those described for leafy vegetables (See Table II and note exceptions). Approximately two-pound lots of carrots in two-quart jars were used and the ratio of carrots to brine was about 1:1. The following five treatments involving the use of 24° sal. brine (6.2% salt), unmodified or modified as indicated, were used: (1) brine only; (2) brine plus vinegar; (3) brine plus lactic acid; (4) brine plus a mixture of vinegar and lactic acid; (5) blanched carrots plus vinegar and lactic acid plus anti-oxidant. All lots were stored under laboratory conditions and were examined at intervals.

The preserved carrots, after about 2½ months, are in excellent condition as judged by color, texture, and general appearance. There has been no evidence of spoilage in any lot. The preserved material has a rich golden-orange color and good carrot odor. The carrot tissue is firm and crisp. The blanched lot is more tender than the unblanched material. All lots underwent active acid fermentation.

Dry Salt-Compression Treatment of Blanched Green Beans

BLANCHED, fresh green beans have been dry-salted at four different concentrations, 2.5, 5, 10 and 15 percent salt by weight. No brine was added, but brine was formed by the action of the salt in withdrawing water from the vegetable material. This treatment was carried out in an effort to increase the amount of salted material that can be packed into a given container, as well as to reduce losses of flavor, aroma, color, and nutritive constituents common to usual brining methods. Lots were held in storage at both room temperature (70° F.) and refrigerator temperature (35.6° F.). The latter temperature was expected to favor retention of color, flavor, and aroma and



Lima Beans (Fordhook Variety) after approximately ten months' storage in brine.

reduce loss of nutrients by arresting fermentation. Considerable interest has been shown in this approach, since some food concerns prefer to utilize an unfermented product and have available cold storage facilities that could be used for holding the salted material in bulk.

The fresh beans were blanched for three to three and one-half minutes in flowing steam and promptly cooled. They were cut into about one-inch lengths, packed into glass cylinders (two pounds in each) and dry salt was added while packing. Weights were applied at the rate of about five pounds per pound of beans and allowed to stand until the brine formed and rose over the top of the beans. After about 24 to 48 hours the beans from the cylinders were repacked into jars for more convenient handling and storage. Two sets of jars were filled with beans prepared at each salt concentration (2.5, 5, 10 and 15 per cent of salt by weight), one set for storage at room temperature and the other for storage at refrigerator temperature. Beans were canned at the same time for future comparisons.

The results in general, after about two months' storage, are most promising. It appears that, by this application of dry salting, a marked retention of flavor and aroma has been obtained as compared to beans salted by other methods. Also, about a hundred-percent increase in the amount of beans that can be put in a given container has been obtained as compared to other salting methods used.

It was noted that all the refrigerated lots retained their bright-green blanched color for about one month. After that time there was a gradual change to a lighter color, beginning with the lot containing 2.5 percent of salt, and by the end of two months all lots excepting that containing the highest percentage of salt looked alike (olive green). The lot containing 15 percent of salt still retained the major portion of its original green color. Beans stored at room temperature lost their bright green color much sooner than those that were refrigerated, the change to an olive green color being apparent in the lots containing 2.5 and 5 percent of salt within about three days, in the

lot containing 10 percent of salt after about eight days, and in the lot containing 15 percent of salt after about two or three weeks.

Bacteriological tests at the end of two months demonstrated that active acid fermentation in the refrigerated beans had been arrested for that length of time in the lots containing 10 and 15 percent of salt. However, active acid fermentation took place in the lots containing 2.5 and 5 percent of salt after about 21 and 45 days, respectively, and a gaseous fermentation by the *Aerobacter* group of bacteria occurred in the lot containing 2.5 percent of salt within seven days. In the case of beans stored at room temperature, active fermentation started in the lots containing 2.5, 5 and 10 percent of salt within one to three days. There was no evidence of an acid fermentation in the lot containing 15 percent of salt, although there was a vigorous, gaseous yeast fermentation which started after about two months.

Beans preserved by the dry salt-compression treatment may be cooked with water in the ordinary way, cooked with vegetable mixtures, or used for soups.

Vitamin Retention

NO mention has been made thus far of vitamin retention in the various whole vegetables salted by different treatments. The results have not been completed but a partial report based on preliminary observations can be made.

With respect to the green beans, lima beans, and green peas, salted according to the 20°, 40° and 60° sal. treatment and held under outside storage conditions, the following observations have been noted: After about a four-months storage period, the best retention of carotene⁶ (pro-vitamin A) was obtained with green peas. About one-half of the initial carotene content of the material remained. There was considerably less retention (in all lots) in the case of lima beans and green beans as compared to peas.

The salting treatment used did not appear to materially affect carotene retention in the case of peas. However, the use of brines of initially lower salt content (20° and 40° sal.) seemed to favor better retention in the case of green beans, after one month's storage, as compared to the 60° sal. initial brine. At the end of four months' storage, however, this relationship appeared to be absent. Vitamin C losses were practically complete in all cases.

The "low-salt" acidified lots of green beans (17° sal. brine) after eight months showed much better carotene retention than did the lots salted according to the 20°, 40° and 60° sal. schedules just discussed. In fact, the low-salt, acidified lots showed about 90- to 95-percent retention. The blanched lots showed slightly lower carotene retention than did the unblanched lots. Also, there was from 10- to 15-percent retention of vitamin C.⁷ It must be

⁶ Chemical analysis was made for carotene on initial fresh vegetable material (whole), as well as on the material during curing and storage. Carotene is transformed in the body to vitamin A.

⁷ Vitamin C is water soluble. Accordingly this vitamin diffuses from the vegetable into the brine, thereby reducing the concentration in the brined vegetable to about half of its original concentration. Also, this vitamin is easily oxidized, which accounts in part for its destruction in lots of material salted and stored in open-headed kegs (20°, 40° and 60° sal. schedules).

Table 3

Routine salting and brining recommendations for vegetables included in this study.

Vegetable receiving treatment	Designation of treatment to be followed	Strength of brine to be used to cover vegetable	Salt to be added to maintain brine at desired concentration.*	Quantity of acid added to brine at the start**	Comments
Unshelled green peas and lima beans	Strong brine	60° Sal. or 15% by weight	15 lbs. per 100 lbs. of vegetables	None	Particularly adapted for pre-serving large quantities of fresh produce when time and facilities for handling are limited
Snap Beans	"Low Salt" acidified	17° Sal. or 4.4% by weight	None	8-oz.	Brined product may be prepared for table use without desalting
Snap Beans	Dry Salt	None	(5 lbs. of dry salt added per 100 lbs. of packed material)	None	Salted product may be prepared for table use without desalting
Leafy vegetables, Turnip greens, Mustard greens, Kale	"Low Salt" acidified	20° Sal. or 5% by weight	None	8-oz.	Washed and trimmed greens should be blanched by submerging for 5 minutes in boiling water
Carrots	Weak brine	24° Sal. or 6.2% salt by weight	None	None	Brined product possesses pickle-like flavor.

*Expressed as pounds of salt per 100 pounds of green vegetables; salt to be added on the cover or head of container after brining.

** Expressed as the quantity of household vinegar to be added to 1 gallon of brine.

pointed out that the kegs containing these lots were headed up (closed) after salting; hence the brine surface was not exposed to air as was the case with lots of green beans, lima beans, and green peas (at 20°, 40° and 60° sal. brine) in kegs which were false-headed and stored out of doors leaving the brine surface exposed during curing and storage.

Examination of the leafy vegetables for carotene content after about four months showed about 40- to 50-percent retention; from 3,000 to 5,000 International Units per 100 grams was the range for all brined greens except spinach which was not examined. Also, there was some vitamin C retention in the salted material.

The salted carrots were analyzed after about two months and showed little or no loss of carotene. The salted material contained about 10,000 International Units per 100 grams which was about the same as the initial content when salted. Determinations for vitamin C were not made since this vegetable is not a potent source of this vitamin.

The dry-salted compressed lots of blanched green beans, put up with 2.5, 5, 10 and 15 percent of salt by weight, were analyzed after about two months' storage at room and refrigerator temperatures. The preliminary results

showed similar values with respect to carotene and vitamin C retention by the beans irrespective of the amount of salt used or storage temperature employed. On the average, about 15 percent of the vitamin C and 60 percent of the carotene were retained⁸ in all lots of salted beans after about 2 months storage at either room or refrigerator temperature.

Varietal suitability of vegetables to preservation by brining has not been investigated in detail in these studies. However, two varieties of green beans; namely, Tendergreen and Black Valentine Stringless were tested using the "low-salt" acidified brine (17° sal.) treatment. The Tendergreen variety yielded a satisfactory brined product as previously indicated in this report. The same treatment with the Black Valentine Stringless (harvested at the same time) produced an extremely tough bean which remained tough even after prolonged cooking.

Summary and Conclusions

REGULAR salting treatments (20°, 40°, and 60° sal. brines) for green beans, peas, and lima beans cured and stored in open, unsheltered containers.

1. Green beans, lima beans, and peas were satisfactorily

⁸ Based on concentrations present in the blanched material at the time salted.

preserved by covering with a 60° salometer brine and adding sufficient salt to maintain this concentration.

2. These products when desalted and cooked resembled similar canned vegetables in appearance. The texture and flavor were somewhat altered but were entirely satisfactory.

3. The vegetables were also satisfactorily preserved using 20° and 40° salometer brines which were gradually increased to 60° salometer for storage purposes. No advantage was realized by these modifications.

4. Approximately one-half the original carotene (pro-vitamin A) content of the green peas remained after four months' storage in brine. The retention was similar irrespective of salting treatment. In general, there was considerably less carotene retention in the preserved green beans and lima beans. Vitamin C losses were practically complete in all cases.

"Low-salt" acidified brine (17° sal.) treatment for green beans cured and stored in closed containers.

1. After approximately 10 months' storage in brine all lots were in good condition as judged by general appearance, flavor, and texture.

2. The lots that were blanched (two minutes in boiling water) prior to salting possessed better flavor and texture than the unblanched lots. Also, the blanched lots required considerably less cooking.

3. The necessity for desalting prior to cooking was eliminated by the "low-salting" procedure. The beans were prepared for table use simply by washing, adding just sufficient water to cover, and cooking.

4. The carotene (pro-vitamin A) content of the various lots preserved by the above method using closed containers was much higher than of green beans salted in open-headed, unsheltered containers.

"Low-salt" acidified brine (20° sal.) treatment for leafy vegetables (kale, mustard greens, spinach, and turnip greens) under laboratory conditions in closed containers.

1. After four to five months' storage in brine all the leafy vegetables, with the exception of spinach, were in good condition as judged by appearance, color, and texture.

In general, the spinach lots were inferior in texture and in some cases were spoiled.

2. Approximately one-half of the original carotene (pro-vitamin A) content of the leafy vegetables was retained in the brine-preserved material. The amount retained was approximately 3,000 to 5,000 International Units per 100 grams.

"Low-salt" acidified brine (24° sal.) treatment for carrots cured and stored in closed container.

1. After approximately two to three months' storage all lots were in excellent condition and possessed good flavor, aroma, and firm texture. The characteristic color of the carrots was retained.

2. There was little or no loss of carotene (pro-vitamin A) in any of the lots of brined carrots.

3. The blanched carrots that were brined were more tender than the unblanched lots similarly treated.

Dry salt-compression treatment for blanched green beans (2.5, 5, 10 and 15 percent salt by weight) cured and stored under laboratory conditions in closed containers.

1. This application of dry salting gave better flavor and aroma retention in beans so preserved than was obtained by other methods of salting this vegetable.

2. This method permitted about a 100-percent increase in the amount of beans packed in given-sized containers as compared with other methods used.

3. The lots stored at refrigerator temperature retained their bright green blanched color for about one month.

4. Active fermentation in the refrigerated lots was arrested in the treatments with 10 and 15 percent salted up to the time this report was written (two and one-half months after packing), while in the treatments 2.5 and 5 percent salt active fermentation took place at 21 and 45 days respectively.

5. The vitamin retention studies showed that about 60-percent of the carotene (pro-vitamin A) and 15-percent of the vitamin C was retained in all lots of beans irrespective of the quantity of salt employed or conditions of storage as to temperature (room or refrigerator).