[Reprinted from 1943 PROCEEDINGS OF INSTITUTE OF FOOD TECHNOLOGISTS, Pages 176-182]

BRINE PRESERVATION OF VEGETABLES [1]

J. L. ETCHELLS, I. D. JONES, AND M. A. HOFFMAN

Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture, Raleigh, North Carolina

Department of Horticulture, North Carolina Agricultural Experiment Station, Raleigh, North Carolina

INTRODUCTION

Today, increasing demands are being made for processed foodstuffs by our allies, the armed forces, and reoccupied areas. These are in addition to our usual civilian requirements. In order to fulfill such a large order in the face of war-time restrictions, no possible phase of food preservation can be overlooked by the food processor and food technologist. In view of such circumstances, it is logical that some attention be given to the commercial brine preservation of vegetable material for table use. Ordinarily, this method is thought of in the light of commercial pickling, where the final product reaches the consumer as the familiar cucumber pickle, or mixed pickle containing onions, peppers, cauliflower, or other vegetables. Hence, brine preservation is not usually considered in the same category with canning, freezing, and drying as a means of processing vegetable material for future use. Nevertheless, the fact that millions of bushels of vegetables are preserved annually in brine by commercial picklers offers tangible proof that as a method of preservation it is sound and practical. It remains for the food technologist to explore fully the possibilities of this method for the purpose of aiding in alleviating the emergency in food processing. In particular, it is important that procedures be devised which will minimize losses in nutritive constituents and in color, flavor, and aroma during the brine-curing and storage processes and also in the desalting operation usually employed in preparing brined vegetables for table use.

METHODS OF SALT PRESERVATION

In general, there are but two essential methods of preservation of vegetables involving the use of salt. By one method, dry or solid salt is added directly to the vegetable material. As a result of the action of the salt on the vegetable tissue, water is withdrawn which dissolves the salt and thereby forms brine. By the second method, the fresh vegetable material is covered with brine. Additional salt must then be added to maintain the original brine concentration due to the water content of the vegetables.

With either method the same fundamental changes take place in the vegetable tissue and in the brine. If a small amount of solid salt or a brine of low salt content is used, an active fermentation results, with the formation of a decided amount of acid. The preserving effect of the brine is obtained by the combined action of salt and of the acid produced by the fermentation. If a large amount of solid salt or strong brine is used, little or no acid is produced by the fermentation which takes place. In this case the preserving effect of the brine results mainly from the action of the salt.

---

[1] Agri. Chem. Res. Div. Contribution No. 119. Approved for publication as Paper No. 166 of the Journal Series of the North Carolina Agricultural Experiment Station.

Dry Salting. Dry salting, using a small amount of salt (2½ to 5 percent by weight), is usually employed for vegetables that are readily cut or shredded, that are high in water, and that contain enough readily fermentable sugar to support a vigorous fermentation—cabbage, lettuce, and turnips are typical examples of vegetables that are salted in this manner. Certain vegetables are best preserved when a large amount of salt (20 percent by weight) is used. Corn, lima beans, and green peas are examples of vegetables considered to be in this group.

Brining. Brining is generally used for preserving bulky or whole vegetables and those that may be low in water content. Also, brining may be used to advantage where the effect of shrinkage on the shape and structure of the vegetables, caused by the use of dry salt, would be unduly severe. For some vegetables a weak brine plus a small amount of vinegar is used. The addition of vinegar to the brine aids in bringing about a desirable fermentation and averts possible spoilage.

MICROBIAL AND CHEMICAL CHANGES

In the brine-preservation of vegetables, the salt exerts a selective action on the naturally occurring organisms to promote a desirable fermentation. Salt-tolerant organisms use as their nutritive material the soluble constituents that diffuse into the brine as the result of the action of salt on the vegetable tissue. These organisms bring about the production of various compounds, principally lactic acid, but also acetic acid, alcohols, and considerable amounts of gas.

During the past several years the investigations (1, 3) on commercial cucumber fermentations have shown a number of interesting relationships in regard to the influence of the salt content of the brine on the predominating microorganisms and the principal compounds formed. The work now in progress, on vegetables other than cucumbers, strongly indicates that these basic fermentation changes are, in general, similar in nature but may vary in magnitude, depending upon the vegetable being preserved.

For this reason, the following description of the bacteriological and chemical changes will be based principally on the work previously reported (1, 3) for cucumbers. In general, the predominating organisms found in vegetable fermentations to date (in 5, 10, and 15 percent salt brines [2]) are (1) the acid-forming bacteria, (2) the *Aerobacter* group, and (3) the yeasts.[3] The first group is responsible for the developed brine acidity while the latter two bring about chiefly gaseous fermentations.

Acid-forming Bacteria. The influence of salt is most clearly demonstrated with respect to the acid-forming bacteria. There is a direct correlation between the population of these organisms and the brine concentration used. The highest populations occur in the weak (5 percent salt) brines and correspondingly lower populations at increasing brine concentrations. Also, the acid fermentation starts earlier in the weaker brines. In strong brines (15 percent or above) little or no growth of these organisms occurs.

---

[2] In these three brining treatments the first two (5 and 10 percent) are raised gradually to 15 percent while the 15 percent treatment is maintained at that concentration.

[3] Current work in progress on dry-salted peas and snap beans has indicated that active fermentation, under certain conditions, may occur by non-acid-tolerant *coccus* forms. The exact role these organisms play in the fermentation proper has not been fully established at this time; however, it has been demonstrated that they are rather sensitive to small amounts of organic acids but not to salt (20 percent) or refrigerated storage temperature (about 35 deg. F.).

The Aerobacter Group. General observations have revealed that fermentations by the *Aerobacter* group may occur in brines over a wide salt concentration range. Fermentation by these organisms has been encountered in salted lettuce and snap beans where the salt content was as low as 2½ percent and in brined onions where the concentration was as high as 23 percent salt. As a rule, the fermentation period is limited, in the case of weak brines, to the first 48 hours. Here, the rapid onset of the subsequent acid fermentation reduces and finally eliminates the *Aerobacter* group, since they are unable to withstand the increasing acid content of the brine. At salt concentrations above those tolerated by the acid-forming bacteria (15-percent brines and above) vigorous fermentation by the *Aerobacter* group may occur. This fermentation starts after about two to three weeks and lasts about 10 days, resulting in large quantities of carbon dioxide and hydrogen being evolved. The same condition may be encountered in 10-percent brines, which, although not inhibitive for the acid-formers, may have had a delayed or restricted acid fermentation, thus allowing sufficient time for an *Aerobacter* fermentation to get under way.

Yeasts. As in the case of the *Aerobacter* group, the salt concentration of the brine has little or no effect on yeast populations, once fermentation is under way. Typical yeast fermentation has been found in brines ranging from 5 to 23 percent salt. However, the salt content of the brine does govern the time the yeast fermentation begins and the duration of that fermentation. Fermentation at lower salt concentrations (5 percent) starts sooner than at high concentrations (15 percent) and is usually of shorter duration.

PRESENT INVESTIGATIONS

Investigational work on brine preservation of vegetables has been under way for the past year as a joint research project of the Bureau of Agricultural and Industrial Chemistry of the United States Department of Agriculture and the North Carolina Agricultural Experiment Station. 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. A report of this work has recently been published (2). However, a general summary of the methods employed and principal results obtained will be given at this time.

In these studies a number of different brining and salting procedures were investigated. Certain of these were brining treatments which are followed commercially by cucumber pickle packers; others were treatments investigated previously in the experimental brining of cucumbers, and still others were procedures devised specifically for the preservation of the given vegetable receiving treatment. These procedures fall into the two groups previously mentioned, namely, those in which brines of different salt content were used and those in which dry or solid salt was added directly to the vegetable material.

NON-ACIDIFIED BRINE TREATMENTS

In the brining of cucumbers, the fresh produce is covered with brine of given salt content and concentration of the brine is gradually raised by the addition of salt until the desired brine strength is attained. The cucumbers are then held in brine storage until ready for use. The brined material so preserved must be desalted prior to use as an edible product.

This general procedure has been investigated for the preservation of green beans, peas, and lima beans. Sixty-pound lots of each vegetable were placed in unsheltered open-headed kegs and covered with brines, initially 5, 10, and 15 percent with respect to salt content. The 5 and 10 percent brines were gradually increased to 15 percent, and storage was carried out at this latter concentration. The average brine temperature during curing was 80 deg. to 90 deg. F. The brine temperature during storage ranged from 95 deg. F. (high) to 10 deg. F. (low). Attention is called to the fact that these vegetables were salted whole; that is, the green beans were not cut, and the peas and lima beans were not removed from their pods. This method of handling would be most advantageous in areas where labor, time, or equipment did not permit the cutting or shelling operations.

RESULTS

(1) After about 12 months' storage in brine, all lots of the above-mentioned vegetables were in excellent condition as judged by their color, texture, and freedom from spoilage.

(2) The treatments employing brines, initially 5- and 10-percent and gradually raised to 15-percent salt, were found to have no apparent advantage over the treatment where the vegetables were simply covered with 15-percent brine and sufficient salt added to maintain this concentration.

(3) Approximately one-half of the original carotene content of the green peas remained after four months' storage in brine. The retention was similar, irrespective of the 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 TREATMENT

This modified salting treatment eliminates the necessity for desalting the preserved produce at the time of preparation for table use. Brines of relatively low initial salt concentration were used and no more salt was added during the curing or storage processes. Sufficient amounts of vinegar or edible lactic acid were added to produce an initial brine acidity of from 0.3 to 0.4 percent calculated as lactic acid.

GREEN BEANS

Freshly harvested snap beans in 60- to 70-pound lots were covered with about a 4.5 percent brine which was acidified in the manner indicated above. The kegs were tightly headed at the start of the experiment. A small hole in the head remained unbunged for the first 10 days. Two varieties of beans were used, the Tendergreen and the Black Valentine Stringless. Both were harvested and brined at the same time.

RESULTS

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

(2) The lots (Tendergreen) that were blanched two minutes in boiling water prior to brining 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-salt brining" procedure. The beans were prepared for table use simply by washing, adding just sufficient water to cover, and cooking.

(4) Beans (both varieties) brined in this manner showed about 90- to 95-percent carotene retention. The blanched lots were slightly lower. About 10 to 15 percent of vitamin C was retained.

(5) The Black Valentine Stringless variety yielded an extremely tough brined product which remained tough even after prolonged cooking.

LEAFY VEGETABLES

Leafy vegetables such as kale, mustard greens, spinach, and turnip greens, in approximately one-half pound amounts, were put down under laboratory conditions according to the "low-salt" acidified brine treatment. All lots were stored at room temperature in partially sealed containers.

RESULTS

(1) After approximately four to five months' storage in brine all 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 they were spoiled.

(2) Approximately one-half the original carotene content was retained in the brine-preserved material. The amount retained was about 3,000 to 5,000 International Units per 100 grams.

CARROTS

Fresh carrots were preserved using a 6.2-percent brine and acidifying as previously indicated. Two pound lots of carrots in two-quart jars were cured and stored under laboratory conditions, in partially sealed containers.

RESULTS

(1) After about six months' storage, all lots were in excellent condition and possessed good flavor, aroma, and firm, crisp texture. The characteristic color of the carrot was retained.

(2) The lots that were blanched prior to brining were more tender than those that were unblanched although they were slightly lighter in color.

(3) There was little or no loss in carotene in any of the lots of brined carrots. The final values for carotene for the preserved product ranged from 12,000 to 15,000 International Units per 100 grams.

DRY SALT-COMPRESSION TREATMENT

The preservation of green beans was accomplished by the incorporation of different amounts of dry salt with the fresh produce. Brine was not added to these lots but was formed by the solution of the salt in the water withdrawn from the vegetable material as a result of the action of salt on the plant tissue. This general treatment of dry-salting 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 loss of flavor, aroma, color, and nutritive constituents which is caused by dilution and is common to the usual brining methods.

In this experiment the fresh green beans were blanched 3 to 3½ minutes in flowing steam and promptly cooled. They were then dry-salted at four different concentrations, 2.5, 5, 10, and 15 percent salt by weight. The salted material was compressed at the beginning of the curing period by the application of weights at the rate of five pounds per pound of beans in the containers. The compression was continued until the brine formed and rose over the mass of salted produce.

Lots of each treatment were held in storage at both room temperature (70 deg. F.) and refrigerator temperature (35.6 deg. F.). The latter temperature was expected to favor retention of color, flavor, and aroma and to reduce loss of nutrients by arresting fermentation. This approach is of considerable interest to some food concerns since they desire, if possible, to utilize a brined product that has not undergone fermentation.

The various lots of salted beans were stored in partially sealed jars at the temperatures indicated above.

RESULTS

(1) After approximately six months' storage, the dry-salted lots of beans, held at both room and refrigerator temperatures, were of good keeping quality and showed no evidence of spoilage.

(2) This method permitted about a 100 percent increase in the amount of beans packed in a given-sized container as compared with brining methods used for this product.

(3) The beans stored at refrigerator temperature retained their bright green color for about one month. After that time there was a gradual change to a lighter color, beginning with the 2.5 percent dry-salted lot, so that by the end of two months all lots excepting the 15 percent lot, had an olive green color. The last retained most of its bright green color somewhat longer.

(4) Active acid fermentation in the refrigerated lots was arrested in the treatments receiving 10 and 15 percent dry salt up until the time this report was prepared (about six months after packing). However, an active acid fermentation took place in the 2.5 and 5 percent salted lots after about 21 and 45 days respectively. Also, a gaseous fermentation by the *Aerobacter* group of bacteria occurred in the lot containing 2.5 percent of salt within seven days. Furthermore, a fermentation was brought about by certain non-acid-tolerant *coccus* forms in the 10 percent salted lot during the storage period.

(5) In the beans stored at room temperature, active acid fermentation started in the lots containing 2.5, 5, and 10 percent salt within one to three days. After six months there was no evidence of an acid fermentation in the beans receiving 15 percent dry salt, although there was a vigorous gaseous yeast fermentation which started after about two months.

(6) The vitamin-retention studies after 2.5 months showed that about 60 percent of the carotene 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). After about five months' storage, the results were essentially the same for carotene retention, although little or no vitamin C remained.

DISCUSSION

In considering the over-all possibilities of brine preservation as an emergency method for storing foods, a number of interesting points come up for discussion. These not only concern the advantages and disadvantages of the method in general, but also must give consideration to the quality of the product which may be produced under the varying existing conditions attending emergency food preservation.

The experiments that have been conducted to date indicate that brine-preservation methods based on different degrees of refinement may be satisfactorily employed. With exceedingly limited facilities for the preparation of produce, many vegetables might be preserved merely by covering with brine of a suitable salt content. For example, unshelled peas and lima beans, and uncut green beans previously mentioned were preserved by covering with a 15 percent brine plus the addition of sufficient salt to maintain this concentration throughout the storage period. The material was stored in open containers and remained unsheltered at all times.

The application of this simple procedure may be of great value in the emergency preservation of certain vegetables in foreign areas reoccupied by Allied armies.

With better facilities available, such as blanching equipment, cold-storage space, and adequate labor, a much better final product can be obtained. The advantages of blanching vegetable material prior to preservation by freezing and dehydration have been well established. Likewise, the work to date on brine preservation, where blanched material was used, has demonstrated that a better product can be expected where blanching is practiced.

When vegetable material is brine-preserved, certain losses in soluble nutritive materials occur during the fermentation process caused by the salt-tolerant microorganisms. Further losses occur when the material is desalted. In the latter case the losses would be in proportion to the amount of salt removed.

By utilizing the brine-preserved material directly, as in soup mixtures, the losses accompanying desalting can be reduced. Here the salt content of the vegetable would go toward seasoning the soup.[4] This general procedure has been used for years by commercial concerns for brine-preserved okra. The same treatment can be readily adapted to other vegetable ingredients of soups such as corn, lima beans, and snap beans. In fact, it is probably one of the most advantageous methods of using brine preserved material on a commercial scale and is being given considerable attention by various food concerns.

The problem of reducing the losses in nutritive material brought about by the microorganisms associated with brine fermentations is difficult owing to the wide range of salt tolerance of certain types (yeasts, *cocci*, and *Aerobacter*). From the work done on the salted green beans, it appears possible that storage at refrigerator temperature (35 deg. F.) and at not less than 15 percent salt, will arrest the fermentation caused by the usual predominating organisms, namely the acid-forming bacteria, the *Aerobacter*, and the yeasts, for upwards of six months.

CONCLUSION

As a method of emergency preservation, requiring a minimum of labor and critical materials, and offering the possibility of storing large quantities of vegetable material in bulk until further processing can be brought about, brine preservation justly deserves adequate consideration in our war program.

REFERENCES

(1) ETCHELLS, JOHN L., AND JONES, IVAN D. Bacteriological changes in cucumber fermentation. Food Industries, 15, Feb., 54-56 (1943).

(2) ———, AND ———. Commercial brine preservation of vegetables. Fruit Products Journal 22, 242-246, 251, 253 (1943).

(3) JONES, IVAN D., AND ETCHELLS, JOHN L. Physical and chemical changes in cucumber fermentation. Food Industries 15, Jan., 62-64 (1943).

[4] Approximately one-half pound of preserved vegetable material at 15 percent salt could be used per gallon of soup liquid.