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Plant Products

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Valley of California. The imported varieties usually have their shells dyed red or are dipped in salt to mask a mottled unsightly appearance. The new California varieties have a smooth sand-colored appearance and do not require dyeing. Recent domestic plantings are now nearly 31,000 acres, and production in 1979 is expected to exceed 12 million lb.[39]

Processing of tree nuts can be illustrated by the flow sheet for almond processing (Figure 5). There are some variations with other nuts necessitated by differences in hull, composition of the nut, etc. For most nuts, harvesting is done mechanically by machines which shake the trees to make the nuts fall on the ground. They are swept up and taken to dehullers where they may be both dehulled and fumigated to protect from insects prior to transport to the processor. At the processing plant, they are stored for one to several months before processing, and this storage must be done at low moisture levels (water activity, a_w <0.7) to prevent mold spoilage and possible formation of mycotoxins.[39] A drying step is sometimes necessary to achieve this moisture level. Walnuts have a high linoleic acid content and are subject to oxidative rancidity; hence, they are usually stored at a temperature range of 34 to 40°F. Other nuts can remain at ambient temperatures for long periods if the kernels are not physically damaged. Nuts for processing are removed from storage, bleached, and sold in-shell or shelled. Shelled nuts are subjected to combinations of physical, electronic and visual sorting to remove insect-damaged and moldy kernels. They are the sold in a variety of whole, sliced, or diced packs. Tables 18 and 19 present data on recent production of tree nuts and the value of the crop. Significant portions of both the almond and walnut crops are exported, principally to Japan and the EEC countries.

PICKLING*

Introduction

Pickled foods are those to which salt and/or vinegar are added as a primary means of preservation. Vegetables are pickled commercially in the U.S. by two general processes: (1) brining, and (2) direct acidification, with or without a mild heat process (pasteurization), and various combinations of these two processes. Refrigeration is used to extend the shelf life of certain products.

In sodium chloride brining, fresh fruits and vegetables are placed in a salt solution or dry salt is mixed in with the cut or whole vegetables. The brined vegetables undergo a microbial fermentation involving lactic acid bacteria, yeasts, and other microorganisms, depending upon the concentration of salt. Salt directs the course of the fermentation and prevents softening of the vegetables. The combination of salt and acid (produced by lactic acid bacteria) preserves the vegetables during storage up to a year or more. Brining was used before recorded history as a principal means of preserving fruits and vegetables. Today, brining of these commodities serves two primary purposes: (1) a means of preservation which yields a final product of desired qualities, and (2) a means of extending the processing season (it may be impossible or economically impractical to further process the entire crop of some commodities during the harvest season). Cucumbers, olives, and cabbage constitute the largest volume of fruits and vegetables brined in sodium chloride in the U.S.; but peppers, cauliflower, onions, citron, carrots, beans, and other commodities are also brined.

In contrast to sodium chloride brining, fruits such as cherries, citrus, pineapple, and berries may be preserved by brining in a calcium bisulfite solution. Little, if any, microbial fermentation occurs in this method of brining, due to the high concentration

* Contributed by Henry P. Fleming, USDA, Raleigh, NC and W. R. Moore, Jr., Pickle Packers International, St. Charles, IL.

of sulfur dioxide. The object is to bleach the fruit to an even, light-straw color prior to subsequent dyeing and to firm the tissue.

Direct acidification of fresh or brined fruits and vegetables is an important means of commercial pickling today, and may be accomplished by pasteurization, the addition of preservatives, refrigeration, or a combination of these treatments.

Statistics

Production statistics for pickling cucumbers, cabbage for sauerkraut, and olives and cherries for brining are given in Tables 20 through 23, respectively. Pickling cucumbers occupied the largest acreage (123,990 acres) and dollar value (*circa* $79 million) at the farm level of fruits and vegetables grown in the U.S. in 1977 for pickling (Table 20). Cabbage for sauerkraut was grown on 10,380 acres at a farm value of *circa* $7 million (Table 21). U.S. production of olives in Table 22 includes those held in brine for final processing as a black-ripe olives which are canned and retorted, as well as those that are brined and subsequently sold as pickled olives (listed as "Other" in Table 22). U.S. production of pickled olives primarily includes Spanish-type green olives, and constitutes a minor portion of the total brined olives consumed in this country. Sizable quantities of Spanish-type green olives, Greek-style ripe olives, and lesser amounts of other brined olives are imported each year (Table 22).

Although the total acreage of U.S. farmland devoted to pickling cucumbers has increased only slightly since 1930, total production has increased over 3 times, and the total yearly farm value has increased nearly 14 times. Per capita consumption has increased from 1.8 lb in 1930 to 8 lb in 1977 (Table 24). The 1976 U.S. retail sales of pickles, relishes, peppers, olives, and onions amounted to *circa* $625 million, with cucumber pickles accounting for over half of the total (Table 25). The percentage of movement of various types of pickles is given in Table 26. Sauerkraut production has increased slightly since 1930, but the per capita consumption has decreased (Table 24).

Processing

Cucumber pickles

"Pickles", unless otherwise specified, generally means cucumber pickles to the U.S. consumer, and this connotation is implicit in the U.S. Standards for Grades of Pickles.[32] Essentially all of the pickling cucumbers grown in the U.S. are processed, while the longer, thicker-skinned, slicer-type cucumbers are used for the fresh market. Most pickling cucumbers are commercially processed into three general groups of products: (1) pickles made from brine-stock cucumbers, (2) fresh-pack pickles, and (3) refrigerated pickles (Flow Chart 5). Lesser quantities are preserved by specialized brining methods to produce half-sour and "genuine" dills[22,31] for distribution to delicatessens and other special grades. Prior to *circa* 1938 preservation of cucumber pickles was accomplished by the brine-stock method.[34] The fresh-pack process was introduced in 1938 as a result of studies by Etchells and co-workers,[35-39] and accounted for increased consumption of pickles (Table 24). It is estimated that over 40% of the pickling cucumber crop was processed by the fresh-pack process by the 1960s. Refrigerated pickles[33] began to increase in popularity in the late 1960s, accounting for another sizable increase in consumption. Today it is estimated that refrigerated pickles account for 14 to 15% of the cucumber crop, and brine-stock and fresh-pack cucumbers account for *circa* 43% each.[40]

Descriptions for these three methods of processing are given in Flow Chart 1. In brining, proper salting is critical to encouraging a desirable fermentation with the desired chemical changes (Table 27). A controlled fermentation method[41] has been described (Flow Chart 5, Table 8) which offers a means of eliminating many of the spoilage problems. Purging dissolved CO_2 from brines with N_2 to prevent bloater damage (hollow cucumbers),[41-44] which was part of the overall process, is widely used by the pickle industry. At present, the entire controlled fermentation process is in limited use by a few companies. After brine fermentation, the brine stock is desalted by washing to obtain the desired NaCl level and then processed into genuine dills, sweets, sours, relishes, and mixed pickles.[32,45] Some of these products are pasteurized, while others, to which vinegar, sugar, and preservatives are added, may or may not be heated. The preservation-prediction chart of Bell et al.[46] is widely used by commercial firms to formulate preservative cover liquors for shelf-stable sweet pickles which do not require heating.

Fresh-pack pickles (Flow Chart 5) are preserved by packing fresh cucumbers with a properly acidified cover liquor, followed by pasteurization. Pasteurization is accomplished by heating the packed cucumbers in multi-sectioned, steam pasteurizers until the center of the cucumbers reaches 165°F and holding at that temperature for 15 min.[36,38,47] This process has been widely used by commercial packers for years; although heating times and temperatures vary among packers and among products.

Refrigerated pickles (Flow Chart 5) are preserved by a mild acidification (pH <4.6) and refrigeration (34 to 40°F) and the use of preservatives, primarily sodium benzoate.[33] The cucumbers are not heat-processed before or after packing. The product is crisp, crunchy, and retains more of a fresh flavor, which accounts for its increasing popularity.

Sauerkraut

Sauerkraut is prepared by the natural fermentation of cut and salted cabbage, the final product containing a minimum of 1.0% acid, calculated as lactic, and 1.3 to 2.5% salt.[48] Recent interest has arisen in milder flavored sauerkraut, which is produced by hot-filling the sauerkraut after only 0.8 to 0.9% lactic acid is produced. The general salting procedure and microbial and chemical changes for the production of sauerkraut are summarized in Table 27. Sauerkraut is packed primarily in cans, bags, or glass for consumer use by general procedures given in Flow Chart 6. Canned kraut, containing the original or diluted fermentation liquor, is heated to 165°F in stainless steel vats,[49] or, more recently, to 185 to 190°F by steam injection into a thermal screw[50] and then packed into cans. After steam exhaustion, the cans are closed and cooled. Sauerkraut juice is canned.

Packaging of sauerkraut in plastic bags is gaining in popularity; over 42 million lb (*circa* 14% of the total kraut marketed) of bagged kraut were produced in the U.S. in 1977.[51] Preservation of bagged kraut is due to chemical additives (benzoic acid, sorbic acid, and potassium bisulfite).[51] Small quantities of kraut *circa* 9% of the total) are packed in glass, which may be preserved by heating or by use of preservatives.[50]

Olives

Olives for brining in the U.S. are produced primarily in California. Methods of brining olives for various products are summarized in Flow Chart 7 and Table 27. California-style black-ripe olives constitute the largest portion of olives produced for direct food use (Table 22). Brining is a means for temporarily storing the olives until they can be further processed into black-ripe olives. The olives undergo a microbial fermentation (Table 27) if stored in sodium chloride brine, but this fermentation is relative only to preservation of the olives while they are stored in brine. About half of the California olives for black-ripe processing are now held in a salt-free solution (Table 27) in an effort to reduce salt wastes; microbial growth is prohibited by the preservative solution. Salt-free storage is especially suitable for large varieties (e.g., Sevillano and Ascolano), which are very susceptible to shrivelling in salt solutions, but brining is still an important method of storing the smaller varieties (Manzanillo and Mission) of olives.[52] When needed for processing, the olives are darkened and debittered by treating them with sodium hydroxide and air.[53] California-style green-ripe olives are treated similarly, except air is excluded to prevent the darkening effect (Flow Chart 7). Only freshly picked olives are used in this process, as stored fruit does not produce the typical green-ripe color or flavor.[54] In black-ripe and green-ripe olives, the final product is canned and retorted having a pH of 7.0 to 7.5, and therefore it is not considered as a pickled olive. These types of ripe olives are unique to this country.

The flow sheet for processing of Spanish-style green olives is given in Flow Chart 7; the composition of the brine solution and microbial and chemical changes are given in Table 27. It is essential that all of the fermentable sugars are removed during fermentation, as the olives are usually not heat processed after packing. Refermentation in the jar is not acceptable, since it results in cloudy brine, sediment, and gas pressure. Therefore, it may be necessary to referment stuffed olives to remove fermentable sugars from the pimiento or other material before final packing.

Neither Sicilian-style green olives nor Greek-style ripe olives are debittered before brining (Flow Chart 7); the final products are bitter. Sicilian-style olives are produced primarily from the green, relatively large Sevillano variety of olives and the Greek-style from naturally ripe olives. In California, Greek-style olives are given a brief exposure to lye *circa* 1/16-inch penetration) followed by aeration to provide a uniformly dark color;[52] whereas, the imported olives are usually not lye-treated. Greek-style olives may be dry salted or stored in brine.[55,56]

Cherries

Between 40 and 45% of the total sweet cherry crop is brined in calcium bisulfite for remanufacture into maraschino and candied cherries.[57] Various procedures are used to formulate the bisulfite brine (Table 27) in order to bleach and firm the cherries. The general process for further processing is outlined in Flow Chart 8. Harvested cherries may be transported to the processing plant before brining, although the recent trend is to brine the cherries in the field in barrels upon mechanical harvesting.[57] The brined cherries are then transported to the plant in plastic-lined tote bins and tank trucks and brines adjusted, as needed, for storage in large wooden or fiberglass tanks. Although the cherries are bleached, firmed, and ready for further processing within 4 to 6 weeks,[57] they may be stored for a year or longer if desired.[58] After leaching out sulfur dioxide from the calcium bisulfite brine, blemished cherries may be treated with a secondary bleach using sodium chlorite in order to obtain uniformly bleached fruit.[59] The cherries may be further processed at that time, or they may be returned to calcium bisulfite storage. Maraschino cherries are finished at *circa* 45% sugar and are preserved by pasteurization (185°F center temperature) or the addition of preservatives (sodium benzoate, potassium sorbate); candied cherries are finished at 72 to 74% sugar.[57]

Special Considerations

Advantages of Pickling as a Process

Pickling offers a low-energy means of preserving vegetables. The addition of acid, sugar, and preservatives may obviate the need for heat processing of brine-fermented products altogether.[34,46] Furthermore, certain brine-fermented products such as Spanish-style green olives, Greek-style ripe olives, and hamburger dill cucumber slices, may be preserved without heating or without the addition of sugar or large amounts of acid. Such products are shelf-stable, when hermetically sealed, because no fermentable sugars remain for fermentation, and the pH is sufficiently low to prevent growth of spoilage bacteria.

Even in pasteurized, fresh pickled vegetables, the heat process (e.g., 165°F internal product temperature for 15 min. for fresh cucumber pickles) is considerably less than for low-acid products which must be retorted. The low pH of pickled vegetables (pH 4.6 or lower) requires that they be thermally processed only to an extent that is sufficient to destroy vegetative cells of microorganisms of public health and spoilage significance; certain preservatives may be used to inhibit microorganisms of nonhealth significance in lieu of heat processing.[60] Thus, it is not necessary to thermally inactivate heat resistant bacterial spores as is required in low acid foods (pH >4.6).

Pickling also offers a means for greater retention of nutrients and quality factors of vegetables which may be labile to heat processing.

Spoilage Problems

Brined vegetables may be beset with numerous spoilage problems, but fortunately, research has uncovered the causes and corrective or preventive measures for most of these problems (Table 28). Serious spoilage problems can result as a consequence of exposure of the brine surface to air, since vegetables are commonly brined in open tanks. Yeasts, molds, fungi, and other aerobic microorganisms can grow on the surface of the vegetable brines, elaborate softening enzymes, and result in softening of the brined product. In extreme cases, brine acidity may be lowered sufficiently by oxidative microorganisms and offensive flavors and odors. Exposure of brine surfaces to sunlight greatly retards surface growth on cucumber brines,[61] and the use of plastic covers prevents growth on sauerkraut.[49] The recent introduction of anaerobic storage tanks into the California olive industry is a major improvement in the storage of brined olives.[52,67] The principle of anaerobic storage of brined vegetables could have wide application in the future.

Spoilage problems with pasteurized pickles are mainly associated with under- or overprocessing. Underprocessing can result in microbial spoilage, while overprocessing can reduce the texture, crispness, and other quality factors.[40,47,63-67,68] Extended storage of the finished product can result in important losses in texture and other qualities, especially at higher storage temperatures.[69,70]

Spoilage problems occur with brined cherries (Table 28) but apparently not to the extent of many vegetables brined in sodium chloride. Although there was a serious outbreak of softening of brined cherries in the 1957 season, this problem has not been serious since.[58] The high level of calcium chloride apparently protects cherry pectin from enzymatic breakdown.

Waste Treatment

Like most food processing plants, pickle plants create sizable quantities of organic wastes which must be treated to reduce the BOD prior to discharge into municipal disposal systems or into natural waterways. However, large quantities of sodium chloride from vegetable brining operations create a special problem in that the salt is not biodegradable, and the high levels of salt generated can adversely influence biodegradation of organic materials also generated under normal operations. Brine compositions of various brined vegetables are given in Table 27.

Numerous efforts have been made to reclaim and reuse vegetable brines. A key problem to reuse of brine is the possible presence of softening enzymes and other components which could affect product quality. Examples of brine recovery systems examined include brine evaporation and incineration of the organic matter,[71,72] flocculation of brine organics by raising the pH to 10 or 11 followed by readjustment to pH 7 or lower,[73-75] and brine pasteurization.[74,75] The latter two methods are used to some extent in the brining of pickling cucumbers, although neither has received widespread use. Some cucumber briners simply reuse spent brine after ascertaining that the brine does not contain softening enzymes.

Another approach to reducing the level of waste salt in cucumber brining is to use a controlled fermentation procedure[41,76] and proper brine tank management which allows use of relatively low amounts of salt during storage (e.g., cucumbers can be stored at 7 to 10% salt if softening enzymes are excluded, rather than up to 16% salt as is now practiced by some briners.[77] A salt-free storage system has been developed for olives to be used for black-ripe processing[78] (Table 27) with elimination of salt disposal for this particular product. A similar salt-free solution has been tested for cucumbers,[79] but this procedure is not used commercially, probably because evidence indicates that cucumbers are likely to soften in such a solution.[80] The salt-free method is not used for Spanish-style green olives.

Sauerkraut wastes do not contain as high salt levels as do those from cucumbers and olives (Table 27); thus, salt waste does not present as serious a problem with sauerkraut. Efforts have been made, however, to convert the organic wastes from sauerkraut processing into a yeast by-product.[81]

Procedures have been developed for reclamation of used cherry brines involving filtration and treatment with activated carbon,[82] but the procedure is not yet in commercial use due to economic considerations.[58] Disposal of calcium bisulfite brine may be facilitated by brine neutralization with resultant precipitation of calcium sulfite.[83]

FABRICATED (OR ENGINEERED) FOODS FROM HORTICULTURAL CROPS*

The extent to which horticultural crops are used in fabricated foods is dependent upon the definition that is used for the term "fabricated foods". If the definition is limited to those foods that are made from basic ingredients, such as starches, fats, proteins, sugars, and the like, then horticultural crops are seldom used as the source of such ingredients. A noted exception would be potatoes, where flours, starches, granules, and flakes are frequently used in fabricated products, especially snacks. In some cases, horticultural crops, such as beets and carrots, may be used as a source of natural color in these fabricated foods.

Inglett[104] defines fabricated foods as "foods that have been designed, engineered, or formulated from various ingredients, including additives; — " and Bird[105] defines them as "foods that have been taken apart and put together in a new form." Even with these definitions, one must determine how broadly to use the word "ingredients". The term "taken apart" could mean merely cutting, and the word ingredient could mean a whole fruit or vegetable item. Therefore, under the broadest interpretation, horticultural crops are widely used in the fabricated food industry.

To develop a more realistic perspective on horticultural crops and fabricated foods, the fabricated foods should be categorized. These categories might be as follows. The first category contains foods formed and formulated from basic components such as proteins, starches, sugars, fats pectins, gums, and the like. Several examples of food items in this category would be meat analogs from vegetable protein, starch-based snack foods, and candies. As previously stated, horticultural crops are not used widely in such foods, but notable exceptions are potato starches and flours that are frequently used in snacks and the pectins from citrus that are used in candies.

A second category of fabricated foods are those that are primarily made from basic ingredients but contain some small quantities of natural products. Examples of these items include starch-based snack foods with onion or garlic powders added as natural flavorants. Chili powders are frequently used for similar purposes. Fruit powders and flakes may also be used in cereal-based formulated breakfast foods.

A third category of formulated foods is those comprised of "whole" or nearly

* Contributed by Charles C. Huxsoll, USDA, Albany, CA.

Table 25
SALES OF PICKLES AND RELISHES[a]

Item	1976
Pickles	322.0
Relishes	52.0
Peppers	63.5
Ripe olives	68.2
Spanish olives	101.1
Appetizer relish and onions	19.0
Total pickles and relishes	625.8

[a] Sales, millions of dollars.

From *Supermarket News*, June 13, 1977. With permission.

Table 26
MOVEMENT OF PICKLES ON THE GROCERY SHELF

Category	Share of total unit movement (%)
Pickles	56.24
Dill	31.30
Sour	0.73
Sweet	19.32
All other	4.89
Pickle specialties and relishes	43.76
Pimientos and peppers	22.97
Relishes	16.63
All other	4.16

From Anon., *Pickle Merchandisers 1978—79 Fact Book*, Pickle Packers International, Inc., St. Charles, Illinois, as extracted from Chain Store Age/supermarkets edition. With permission.

Table 27
GENERAL INFORMATION ON BRINING OF FRUITS AND VEGETABLES PRIOR TO FURTHER PROCESSING

Chemical additives to brine or holding solution	Type of microbial fermentation	Chemical changes during fermentation or storage
Pickling cucumbers (natural fermentation)		
During fermentation, the cucumbers are held in 5 to 8% NaCl; after fermentation, the NaCl content is increased 0.25 to 0.5% weekly by addition of dry salt until final holding strength of 8 to 16% NaCl,[61] For large cucumbers, the brine may be purged throughout fermentation with N_2 to remove CO_2.[41,42]	Primary fermentation is by lactic acid bacteria, but secondary fermentation by yeasts may occur, especially at higher brine strengths.[61]	Fresh cucumbers contain *ca.* 1.8 to 2.5% fermentable sugars as glucose and fructose,[84] Fermentation yields a final brine of *ca.* pH 3.2, *ca.* 0.8% titratable acid as lactic, small amounts of acetic acid, ethanol, CO_2, and other compounds also are formed. Fermentable sugars may remain after the lactic fermentation, especially at higher salt levels.[61]
Pickling cucumbers (controlled fermentation)		
The cucumbers are salted as in natural fermentations. Acetic acid or vinegar is added to lower cover brine to *ca.* pH 2.8. After 18 to 24 hr, the brine is buffered to *ca.* pH 4.6 with 0.5% NaOAc·3 H_2O[41] Alternatively, NaOH may be added to neutralize the brine to pH 4.6,[85] Pure cultures of lactic acid bacteria are then added. The brine is purged throughout the fermentation with N_2 to remove CO_2.[41]	A special salt- and acid-tolerant culture of the homofermentative lactic acid bacterium, *Lactobacillus plantarum*, is used as an inoculum at the rate of 10^9 cells/gal of brined cucumbers. A culture of *Pediococcus cerevisiae* also may be added.[41]	Fermentation yields a final brine of pH *ca.* 3.3 and *ca.* 1.2% titratable acid as lactic.[61] The absence of fermentable sugars is assured by addition of the acetate buffer, which allows the added culture to complete the fermentation.

Table 27 (continued) GENERAL INFORMATION ON BRINING OF FRUITS AND VEGETABLES PRIOR TO FURTHER PROCESSING

Chemical additives to brine or holding solution	Type of microbial fermentation	Chemical changes during fermentation or storage
	Sauerkraut	
Dry salt is distributed uniformly in shredded cabbage for a final concentration of 2 to 3%, preferably 2.25%, NaCl and held at this level during fermentation and storage.[49]	Primary fermentation by a sequence of hetero- and homofermentative lactic acid bacteria.[49]	Fresh cabbage contains 3 to 4.5% fermentable sugars consisting primarily of glucose, fructose and sucrose.[39,86] At 65°F, completely fermented sauerkraut contains 1.7 to 2.3% acid, as lactic; preferably, lactic and acetic acids are in a ratio of *ca.* 4:1 at 2.25 NaCl; ethanol *ca.* 0.25 a variable amount of CO_2, mannitol, dextrans, and other compounds are formed; the final pH is *ca.* 3.6.[49,87]
	California-style black-ripe olives	
Green olives are stored by two methods prior to processing for black-ripe olives 1. NaCl brine method — Olives are covered with 5 to 7.5% NaCl for small varieties of olives (Mission and Manzanillo) and with 2.5 to 5% NaCl for large, shrivel-susceptible varieties (Sevillano and Ascolano). The salt strength is increased gradually over a period of weeks to 7 to 10%. This was the primary method of holding prior to the 1970s.[53] 2. Salt-free method — Olives are covered with a solution of 0.67% lactic acid, 1% acetic acid, 0.3% sodium benzoate, and 0.3% potassium sorbate[78], or with modifications of this solution. Salt-free storage is now used primarily for Sevillano and Ascolano varieties which are more likely to shrivel in salt solutions.[52]	1. NaCl brine method — Not well studied, but get growth of lactic acid bacteria and yeasts,[53] 2. Salt-free method — No fermentation occurs.[78]	The main sugars in olives are glucose and fructose with lesser amounts of sucrose.[56] Average total sugars, fresh weight basis, for the five primary varieties grown in California are Ascolano, 5.54%; Barouni, 4.59%; Sevillano, 4.09%; Mission, 3.68%; and Manzanillo, 2.96%,[88] In NaCl holding solutions, acidities of 0.4 to 0.6%, as lactic, develop,[53] a level too low to account for complete fermentation of the sugars. Thus, fermentable sugar remains, but with little significance, as the olives are to be darkened and canned. In the salt-free method, the olives simply equilibrate with the solution.
	Greek-style, naturally ripe olives	
Tree-ripened olives are brined by two primary methods 1. Dry salt method — Alternate layers of dry salt and olives are added. The final NaCl content may be highly variable (e.g., 7.1 to 19.3%). 2. Brine method — the olives are maintained in a brine of *ca.* 10% NaCl.[56]	Variable, with a mixed flora of coliforms, yeasts and lactic acid bacteria in some cases,[55] to a complete lactic fermentation in other cases.[56]	The sugars may or may not be completely fermented (e.g., final contents of traces to 0.6%); the total acidity, as lactic, is usually less than 0.5% (range of 0.03 to 0.76%), and the final pH varies (3.9 to 7.1).[55]

Table 27 (continued)
GENERAL INFORMATION ON BRINING OF FRUITS AND VEGETABLES PRIOR TO FURTHER PROCESSING

Chemical additives to brine or holding solution	Type of microbial fermentation	Chemical changes during fermentation or storage
	Spanish-style green olives	
After lye and washing treatments, the olives are brined and held at 4 to 7% NaCl during fermentation, which may require 6 months or longer.[53] Up to 65% of the fermentable sugars may be lost during lye treatment. Therefore, sugar may be added to supplement the natural sugars of the olive to assure sufficiency of fermentable sugar for the lactic acid fermentation.[53]	Primary fermentation by lactc acid bacteria,[53] but yeasts may result in a secondary fermentation or may predominate if the olives are not adequately lye treated.[99]	The completed fermentation will result in a brine of pH 3.8 or below, and 0.7 to 1.0% titratable acid (as lactic), provided adequate sugar was initially present.[53]
	Sicilian-style olives	
Green olives (Sevillano variety) are not lye treated but are brined in 7 to 8% NaCl.	Lactic acid ferementation similar to that in holding solutions (NaCl brine method) for California-style, black-ripe olives[53]	Similar to NaCl brine method for California-style, ripe olives.[53]
	Cherries	
Various methods are used to formulate a calcium bisulfite holding brine. Examples include: (1) addition of $Ca(OH)_2$ to water, followed by bubbling of SO_2, final pH 2.7; (2) addition of $CaCO_2$ to water, followed by bubbling of SO_2, final pH 2.0; and (3) addition of $NaHSO_3$ or $Na_2S_2O_5$ to water, followed by addition of HCl to pH 3.5. In the latter formulation, the brine will contain *ca.* 1% SO_2 and 0.85% $CaCl_2$.[57]	No microbial fermentation.	The brine reaches an equilibrium with the fruit in *ca.* 200 to 300 hr at *ca.* pH 3.5, a soluble solids refractive index of *ca.* 11 and an SO_2 content of *ca.* 4000 ppm. After 4 to 6 weeks, the cherries are bleached to a light straw color and are firm and ready for further processing.[57]

Table 28
SPOILAGE PROBLEMS IN THE PICKLING PROCESS

Spoilage defect	Causative agent(s)	Corrective measure(s)
	Cucumber pickles	
Gaseous deterioration (bloater formation) (hollow pickles)	CO_2 from the cucumber tissue[44] and organisms such as yeasts[61,89-91] and bacteria, including hetero-[92] and homofermentative[93] lactic acid bacteria.	Brine at lower brine strengths to encourage fermentation by lactic acid bacteria rather than by yeasts.[61] Purge CO_2 from brines during fermentation.[41,42,44]
Softening	Softening enzymes from fungi carried into the brining tank on the surface of the fruit and in the flowers of small fruit[94] and from other microbial sources, and the cucumbers themselves; and improper storage conditions, including temperature, time, pH, and salt level.[77]	Remove flowers from small fruit before brining, or drain tanks after *ca.* 37 hr to alternate enzyme level;[90] and/or maintain salt at a sufficient level to prevent action of the enzymes[96] and maintain adequate storage conditions.
Bleaching	Exposure of brine stock to sunlight and oxygen.	Minimize exposure of brine stock to sunlight and air.
Off flavors and odors	Growth of undesirable microorganisms during brine storage and/or processing and exposure of cucumbers or pickles to oxidizing agents.	Maintain a proper fermentation to favor growth of lactic acid bacteria and good sanitation and handling practices in the brine yard and in further processing.
	Sauerkraut	
Soft kraut	Insufficient salt and yeast and mold growth on kraut surface due to contact with air.[87]	Add proper amount of salt and distribute uniformly during tanking.[87] Exclude air from contact with surface of kraut by proper heading, using air-impermeable, plastic covers over the kraut surface.[87]
Pink kraut	Excess salt, resulting in growth of pink yeasts.[87] *Lactobacillus brevis* has been implicated to cause pink to brown off colors.[86]	Evenly distribute the proper amount of salt during tanking.[87]

Inferior or off flavor	Fermentation temperature too high, favoring homo- rather than heterofermentative lactic acid bacteria;[97] and growth of yeasts, molds and other undesirable microbes on the surface of the kraut due to contact of kraut surface with air.[87]	Ferment at 65°F or lower to favor growth of heterofermentative lactic acid bacteria,[49] and exclude air from contact with surface of kraut by proper heading, using air impermeable plastic covers over the kraut surface.[87]
	Olives	
Softening	Softening enzymes from mold and yeast growth on the brine surface, and bacterial softening due to too low salt or acidity during brine storage.[53,63]	Prevent microbial surface growth by exposure of surface to sunlight or by excluding or restricting air from the surface with specially designed tanks and covers, and fortify brine with salt and acid as needed.[53,62]
Fisheye spoilage (gas blisters under the skin)	Gas-forming bacteria proliferate, especially coliforms, and produce gas which separates the skin from the flesh when the brine contains less than 5% salt or a high pH (4.8—8.5); delayed growth by lactic acid bacteria allows coliforms to grow.[53,56]	Fortify brine with proper amount of salt and acid as needed and encourage growth by lactic acid bacteria by transfer of actively fermenting brine or by addition of pure culture lactic acid bacteria.[53,62]
Nailhead (small depression under skin)	Bacterial action caused by delay in placing olives in brine after harvest.[98]	Brine olives promptly after harvest.
Malodorous fermentations	Butyric or rancid odors are caused by butyric acid bacteria and "zapatera" spoilage is caused by other spoilage bacteria, which grow when the lactic acid bacteria fail to become established.[53]	Use proper lye and washing treatments and brine as recommended to encourage growth of lactic acid bacteria. Brine may be fortified with acid below pH 4.5 to prevent grow of undesirable bacteria.[63] A pure culture fermentation method for Spanish-style green olives is available,[99] which speeds the lactic fermentation and eliminates many spoilage problems; but it is not currently in wide commercial use in the U.S.

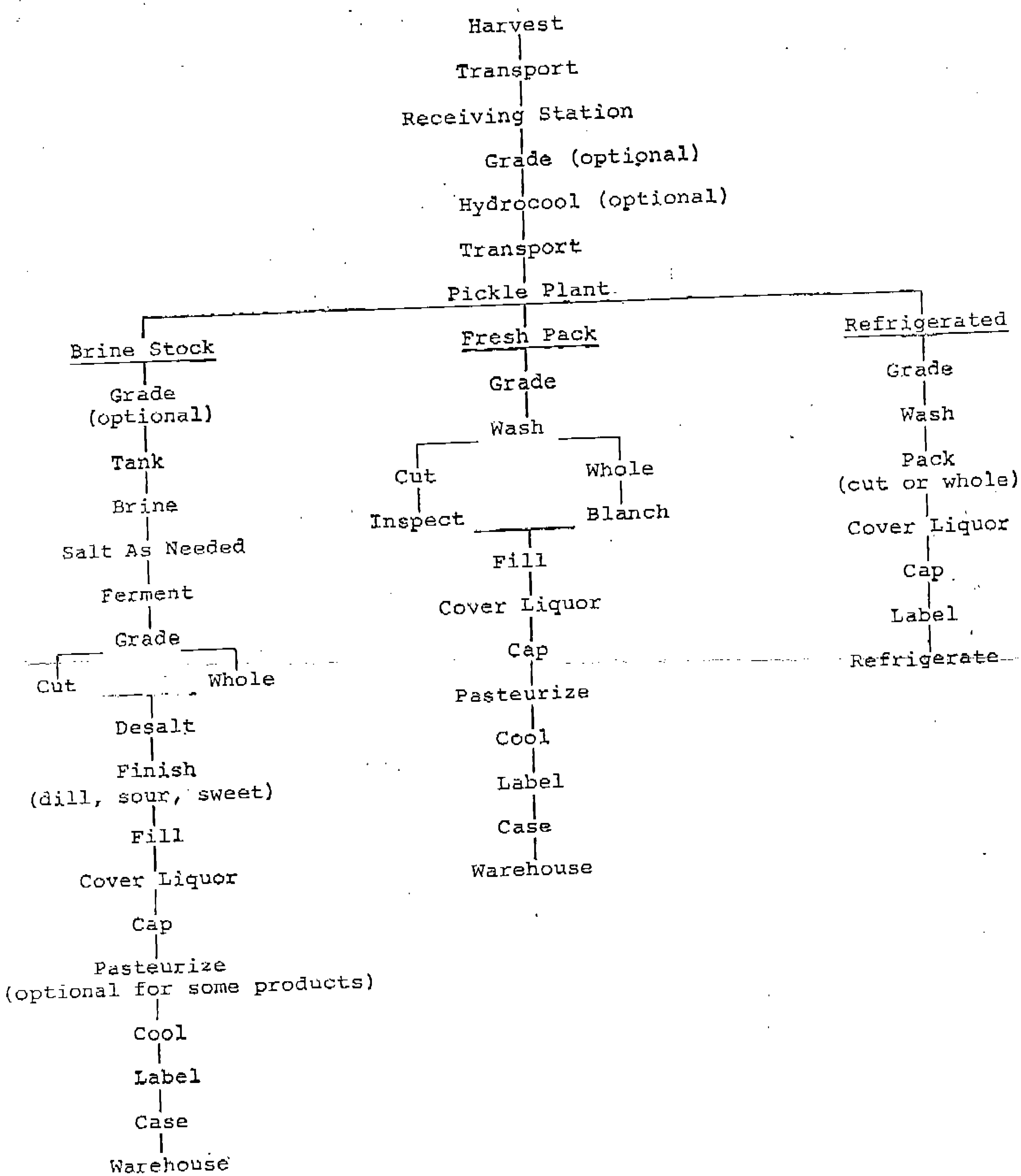


Fig. 1. Flow chart for cucumber pickle processing.

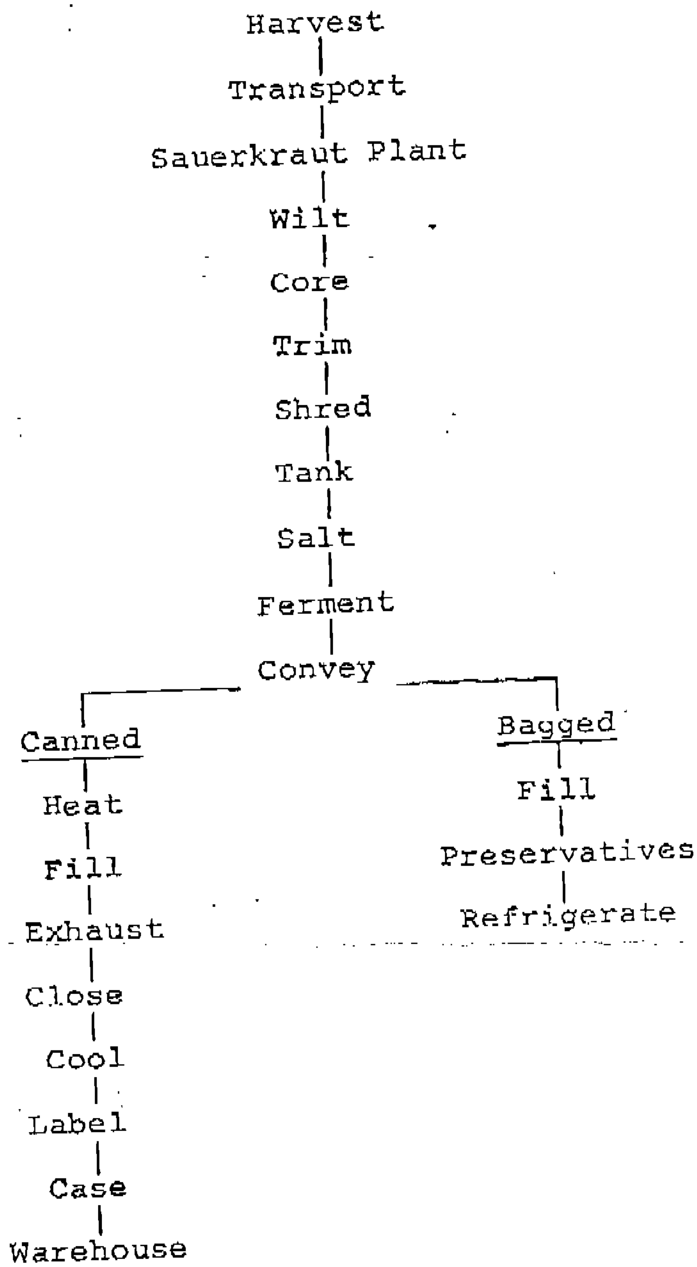
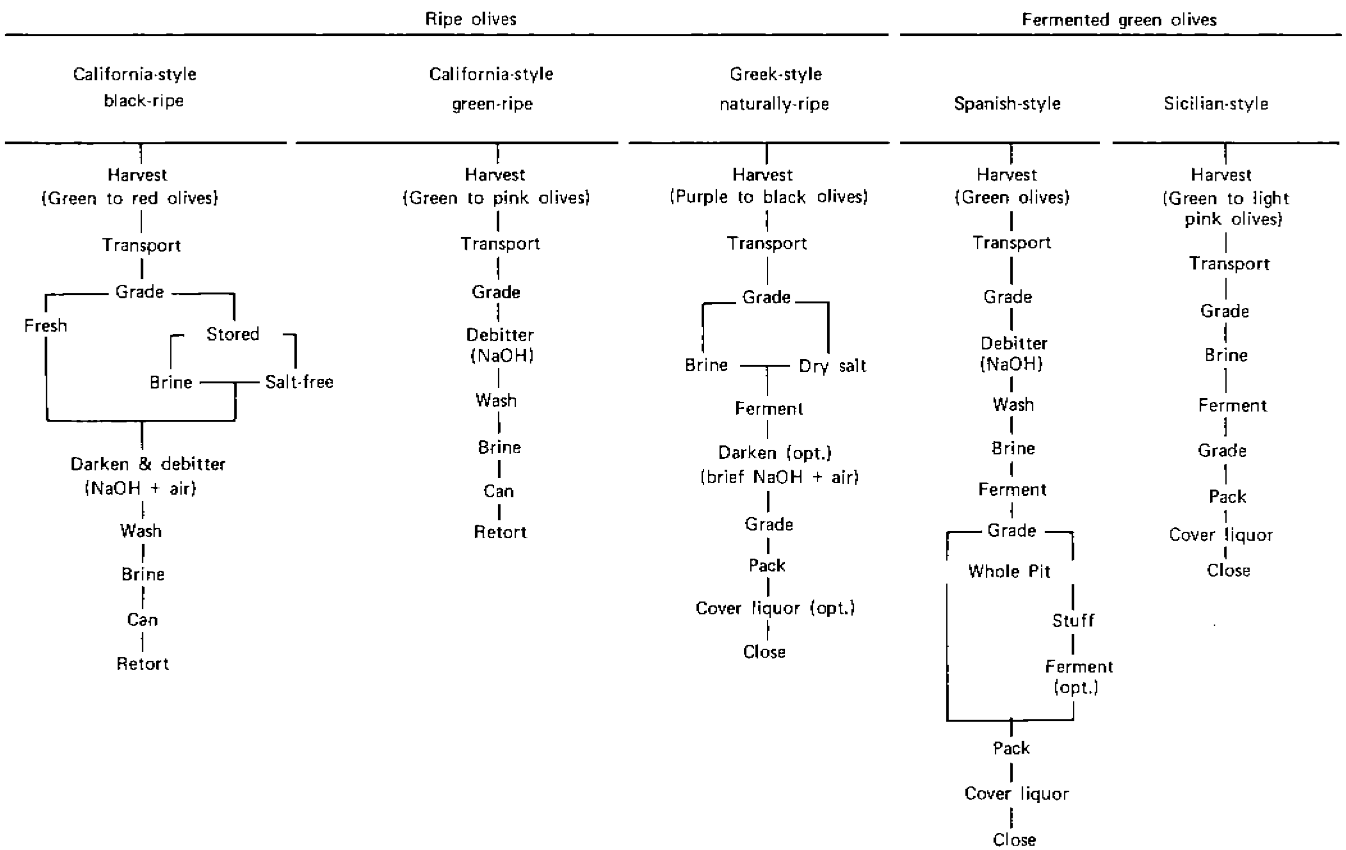


Fig. 3. Flow chart for sauerkraut processing.



Flow Sheet 7. Flow diagrams for olive processing