

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN 461

OCTOBER 1950

**Causes and Prevention
of Failures in Home Canning**

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Thousands of jars of food are canned annually in the homes of the United States. Complaints of failures have indicated the need for better understanding of the fundamental principles of food preservation, home-canning techniques, and causes of spoilage. These studies were undertaken to supply some of the answers.

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CAUSES AND PREVENTION OF FAILURES IN HOME CANNING¹

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INTRODUCTION

Many people do not realize the importance and the scope of home canning in the United States. This method of food preservation is something that has been more or less taken for granted. It has been assumed that home canning was just another chore for the farm and rural housewife. Actually, many families pack hundreds of jars of fruits, vegetables, meats, and other products every year, to say nothing of the few dozen jars canned by many urban families. Since the beginning of World War II the amount of food canned annually in the homes of the United States has increased from about two billion jars before the war to an estimated four to five billion jars in 1943. Since then there has been some reduction in the annual pack of home-canned foods, owing to various economic and other reasons. It has been indicated that during the war years approximately one-half of the canned foods available to civilians was canned at home or in community canneries.

During the years when home canning was at a record high peak it was only natural that a number of complaints of failures should have come to the attention of those who were concerned with the home food preservation program. The nature of many of these complaints, which were relatively few in number considering the volume of home canning being done, served to show the need for better information on home-canning techniques as well as the need for education on the fundamental principles of food preservation and causes and diagnosis of spoilage.

This problem was discussed in some detail at a National Home Canning Conference held in Chicago in January 1943 by the Department of Agriculture. In an effort to diagnose the causes of the failures and spoilage encountered and as a means of teaching home canners how to avoid spoilage, so-called "spoilage clinics" were held in some regions of the country. Such "spoilage clinics" served a very useful purpose as an aid to persons concerned with the teaching and directing of home canning, such as home demonstration agents, community leaders, and public utilities company personnel, as well as to groups of home canners themselves.

An understanding and appreciation of the various factors that may contribute to home-canning failures are necessary if we are to attempt to diagnose the causes of food spoilage and advise home canners how these pitfalls may be avoided. In the following discussion some of the factors found to be important as causative spoilage agents are outlined.

¹ Acknowledgment is due the Hazel-Atlas Glass Company, Wheeling, West Virginia, for its support and cooperation in carrying on some of the research reported herein.

Research on home canning has been carried . . . Agricultural Experiment Station for a number of years. A research grant from the Hazel-Atlas Glass Company and cooperative work with the Bureau of Human Nutrition and Home Economics have aided in this work. The results have contributed materially to a better understanding of some of the problems encountered by home canners.

CAUSES AND TYPES OF SPOILAGE OF HOME-CANNED FOODS

Factors which may contribute to the spoilage of canned foods may be classed under three general headings — biological, chemical, and physical — of which the biological are by far the most important.

Biological Causes of Spoilage

Enzymes

So far as canned foods themselves are concerned, enzymes² naturally present in the raw material are relatively unimportant as spoilage agents because they are readily destroyed by heat during the canning process. Enzymes might contribute to discoloration or off-flavors in certain canned fruits if they were not destroyed during the preparation and processing operations. However, the heating encountered in recommended canning procedures is sufficient to inactivate them. It should be pointed out, however, that enzymes may contribute to the deterioration of raw material allowed to stand around for prolonged periods of time prior to being canned.

Bacteria, Molds, and Yeasts

Most canned foods are subject to spoilage by bacteria, molds, and yeasts. These microorganisms may exert their action on foods sometime in the interval between harvesting and processing or may develop in containers that did not seal during canning and processing, developed leaks after processing, or were underprocessed.

Molds are of low heat resistance and generally require small amounts of oxygen for growth. They are able to grow at relatively high acidity and may cause spoilage in semiacid and acid canned food when sufficient oxygen is present in the containers. Yeasts are also readily destroyed at temperatures below the boiling point of water. They ferment sugars to form alcohol and carbon dioxide. Many yeasts may grow in the absence of air.

Food may be divided into groups which are most susceptible to each type of spoilage. Cameron and Esty (1940) described such a classification based upon the acidity (pH value) of the product, as follows:

1. Low acid, pH 5.0 and higher: Includes peas, beans, corn, asparagus, marine products, meat, milk, etc. Subject to spoilage by all three groups of thermophiles and by mesophilic anaerobes including putrefactive anaerobes and *Clostridium botulinum*.

² Any of a class of naturally occurring complex organic substances that accelerate changes in animal or plant tissues; e.g., oxidases cause apples to turn brown when the cut surface is exposed to the air.

2. **Medium acid, pH 5.0 - 4.5:** Includes meat and vegetable mixtures, spaghetti, soups, and sauces whose ingredients produce a partially acid product subject to spoilage by the same organisms as Group 1. The thermophilic anaerobes (not producing hydrogen sulfide) which may cause flat sours are of increased importance in this group.

3. **Acid, pH 4.5 - 3.7:** Includes tomatoes, pears, figs, pineapple, nectarines, and other fruits subject to spoilage by nonsporeforming aciduric types of bacteria, butyric anaerobes of the *Clostridium pasteurianum* and Winogradsky type, and thermophilic anaerobes.

4. **High acid, pH 3.7 and below:** Includes sauerkraut, pickles, berries, citrus juices, grapefruit, and rhubarb.

To the above four groups a fifth may be added:

5. **High solids and high acid content:** Includes jams, jellies, syrups, catsup, and other concentrates.

The above classification of foods is made chiefly on a basis of acidity. Naturally these groups overlap to some extent, but each has its peculiar spoilage problem. Based upon this classification the important types of spoilage microorganisms may be grouped with the particular food groups in question.

Low and Medium Acid Foods: Spoilage of low and medium acid foods may be caused either by understerilization or by leakage of the container after it has been processed. Spoilage organisms developing in the preservation of this class of foods may be outlined as follows:

- a. Nonsporeforming bacteria — readily killed on heating.
- b. Aerobic sporeforming bacteria — require oxygen for growth.
- c. Mesophilic anaerobic sporeforming bacteria — grow in the absence of free oxygen. Putrefactive anaerobes are in this group.
- d. Thermophilic or heat-loving bacteria — grow at relatively high temperatures.

Of these groups of organisms the first two are of minor importance. Anaerobic sporeforming bacteria and thermophiles are the most important organisms encountered in the preservation of low and medium acid foods by canning. Of the former, perhaps the best known is *Cl. botulinum*. The prevalence of very heat-resistant organisms in many products makes it necessary to use a process of greater severity than is necessary from the public health standpoint.

The putrefactive anaerobes form very heat-resistant spores and often cause putrefactive types of spoilage in peas, corn, and other products, characterized by gas formation in the container and the production of a foul odor. If the container is a can it will swell, and the ends will bulge out. A glass jar will show gas bubbles inside and leakage. If the acidity of the product is near the acid limit for growth of the organism, only little growth may take place.

Thermophiles or heat-tolerant bacteria may be divided into three groups according to the type of spoilage which they produce. Although they have different physiological characteristics, all these groups have the common property of growth at high temperatures and of formation of heat-resistant spores. The

principal groups of these organisms have been described by Bigelow and Cameron (1932) as follows:

- a. "Flat Sour" Thermophiles (facultative and obligate anaerobes), such as *Bacillus stearothermophilus*. — Spoilage caused by these organisms is characterized by the production of acid without gas and is commonly referred to as "Flat Sour" spoilage.
- b. Acid and Gas-Producing Thermophilic Anaerobes. — These cause spoilage characterized by the swelling of cans or by gas bubbles and leakage in glass containers. The food may have a butyric acidlike odor.
- c. Hydrogen-Sulfide-Producing Anaerobes, such as *Clostridium nigrificans*. This organism causes spoilage characterized by a hydrogen sulfide (rotten egg) odor and blackening of the product. This organism occurs only infrequently and has been found in both peas and corn.

With low and medium acid foods, processing temperatures above that of boiling water, such as 240° or 250°F. obtained in a pressure canner with live steam under pressure, are necessary to sterilize the product properly and prevent spoilage.

Acid Foods: Foodstuffs of high acid content are readily sterilized at temperatures of 212°F. (boiling water) and lower because sporeforming bacteria cease to be a serious factor as causative agents of spoilage in the presence of acid. Many of these products are so acid that their own acidity serves as an adequate preservative. The important groups of microorganisms to be considered in the preservation of high acid foods are yeasts, molds, and certain nonsporeforming aciduric organisms, particularly *Lactobacilli* types of bacteria. Bacterial spoilage in acid foods is of primary importance in tomatoes and tomato products. The approximate acid growth limit for yeasts is pH 3.0 and for molds pH 2.0. The growth limit for the aciduric types of bacteria is usually from pH 4.0 to 3.0.

Bacillus thermoacidurans (Berry 1933) has been cited as a cause of a flat-sour type of spoilage of commercially canned tomato juice. Proper plant sanitation and adequate processing procedures have been effective in controlling such spoilage. Available information indicates that this organism is of minor importance as a spoilage agent in home-canned tomato juice.

Such acid products as sweet and sour pickles are sometimes packed without any heat treatment because the acidity of the product itself is adequate to prevent spoilage.

In dill pickles and similar products a growth of *Mycoderma* or scum yeast sometimes develops on the surface of the brine in the container. The relatively low acidity of these products permits the growth of such organisms if oxygen is present. If the *Mycoderma* continues to grow, it will eventually decrease the acidity of the brine to the point where bacteriological spoilage can take place. Similar cases have been reported where mold has grown and decreased the acidity of tomatoes and certain fruits to the point where *Cl. botulinum* or putrefactive anaerobes may grow.

With acid and high acid products, spoilage is prevented by processing or pasteurizing at temperatures of 212°F. (boiling water) or below, by the acidity of the product itself, and by the elimination of oxygen from within the containers.

High Solids and High Acid Foods Content: The important spoilage agents for foods of high solids and high acid content are yeasts and molds, and in rare instances bacteria. In conjunction with the pasteurizing action of high filling temperatures, the keeping qualities of these foods are governed by the osmotic pressure exerted by the product, its acidity, and salt concentration. The magnitude of the role played by each of these agents varies according to the product.

Because of the high sugar content of most of these products, bacterial spoilage is not usually considered. Surface mold growth sometimes develops if conditions are favorable. Such conditions may arise if moisture collects on the surface of the product to form a solution of lower dissolved solids content and if sufficient oxygen is present to support growth.

Spoilage Due to Leakage

Even though it is given an adequate processing, a container of food that leaks because of a fault in the container itself or the closure, faulty application of closure, or mechanical damage in handling is subject to spoilage. This type of spoilage is caused by microorganisms which enter the container after it has been processed. Under these conditions it is evident that there are any number of different organisms that might cause spoilage. Frequently such spoilage is caused by microorganisms of low heat resistance which could not have survived the process. Here again instances have been reported when a mold had grown on an acid food to the point where its acidity was reduced low enough for bacteria to grow.

Incipient Spoilage of Raw Material

If the raw material is not properly handled and stored prior to being canned, spoilage may set in. Factors contributing to this incipient spoilage are warm storage temperatures and rough handling or bruising of the product. It is important from the standpoint of the effect of adverse conditions on flavor and nutritive value that home-canned vegetables be transferred as rapidly as possible from garden to jar.

Underprocessing

If the jars or cans of food are not processed sufficiently to destroy spoilage organisms which may be present, spoilage may occur. The development of spoilage from this cause may take place within a few days or not until several months have elapsed, depending upon storage temperature, nature of organism and product involved, and factors that are as yet little understood. Underprocessing in low-acid products, such as vegetables and meats, is particularly dangerous because of the potential danger of botulism.

It is well known that extremely heat-resistant sporeforming spoilage organisms are found in the soil and that their spores serve as a potential spoilage agent in home canning. Process times ranging from six to eighteen or twenty-four hours in a boiling water bath might be required to destroy these organisms. The only practical and proper way to process low-acid foods containing such spores is in a pressure canner or retort at temperatures of 240° to 250°F. in live steam.

Sources of Spoilage Organisms

For practical purposes it may be considered that the raw material itself and soil adhering to it are the major sources of spoilage bacteria in home canning.

In studies on the prevalence of *Cl. botulinum* in soils, Meyer and co-workers (1922) found that its distribution was widespread and that it might be encountered

anywhere in the United States. A study by Tanner and Dack (1922) in Illinois and a recent investigation by Parry (1946) in New York State confirm this opinion.

Studies in Massachusetts (Dubord and Esselen, 1945) indicated that potential spoilage bacteria, such as sporeforming anaerobes and thermophiles, are usually present in relatively small numbers except in occasional samples and that their number may vary widely. It was concluded that, because of the wide variation in the bacterial content of the soil and of vegetables grown in it, heat-resistant bacteria may be present at any time as a potential cause of spoilage unless process times which ensure their destruction are used. A recent survey of 25 Massachusetts soils showed no *Cl. botulinum* toxin when the soils were subcultured in suitable nutrient media. Although apparently not abundant in eastern soils, there is always the possibility that it may be present.

Improper Use of Processing Equipment and Containers

The improper use of processing equipment and containers can contribute to spoilage through underprocessing or faulty seals and leaky containers. The following factors, among others, must be considered in this respect:

1. Correct use of boiling water bath.
2. Correct use of pressure canner:
 - a. Pressure indicator must be accurate so that desired temperature can be maintained.
 - b. Pressure canner must be adequately vented.
3. A knowledge of the correct way to use the particular type of jar and closure is necessary in order to avoid difficulty.
4. With tin cans the sealer must be correctly adjusted to make a good seal.
5. Oven canning is not recommended and may lead to trouble.
6. Products should not be packed too tightly into the jars.

Faulty Containers and Closures

Faulty containers and closures may cause spoilage because the resulting incomplete seal permits spoilage organisms to gain entrance to the container and its contents after processing. The containers should be given a careful inspection prior to use.

Chemical Causes of Spoilage

Under the general heading of chemical causes of food spoilage and deterioration there are a number of factors to be considered.

Improper Handling of Raw Materials

If the raw material is allowed to stand around too long after harvest before being canned and processed, particularly at warm temperatures, there are several changes that may take place: loss of color and flavor, loss of nutritive value, deterioration in texture, and development of off-flavors due to microbial or enzymic action.

Oxidation

In canned fruits, particularly, oxygen or air trapped within the container can be an important cause of surface darkening and possible off-flavors, as well as loss of ascorbic acid (vitamin C). When jars are used as containers in home

canning, the venting of the jars during processing is effective in driving out trapped air. When short-time boiling water bath processes are used for fruits, tomatoes, and tomato juice, partial seal closures, such as the bail-type jar partially sealed, three-piece glass lid, and zinc P/L Mason cap, give the best venting performance.

The addition of small amounts of ascorbic acid to home-canned fruits is an effective means of preventing or retarding surface darkening caused by oxidation (Powers and Fellers, 1945). About 100 to 125 milligrams of ascorbic acid per jar is effective for this purpose.

Metallic Contamination

Contamination of the product with metals, such as iron or copper, particularly from utensils or equipment, may result in a grayish or black discoloration.

Hard Water

If hard water is used in canning, the minerals in it may cause toughness in some vegetables and may also cause a sediment in the jar.

Salt

It is recommended that plain salt be used in canning. The iodine in iodized salt has been reported as occasionally causing a black or purplish discoloration in starchy products such as corn. The compounds added to some kinds of table salt to prevent it from caking in humid weather are said to be likely to cause toughness in some canned vegetables.

Maturity and Variety of Raw Materials

Overmature vegetables do not lend themselves to making a top-quality canned product. Vegetables and fruits for canning should be at the optimum stage of fresh eating quality. The frequent custom of canning left-over vegetables from the garden when they have passed the good eating stage is poor economy if good foods are desired.

The variety of the product in some cases may influence the quality. This is particularly true in beets, from the standpoint of color. Some of the garden varieties do not have a good deep red color after being canned. The Detroit Dark Red variety is generally accepted as being one of the best for canning.

Sediment

The presence of sediment in jars of home-canned foods may be due to the nature of the product itself, such as starch from mature peas or beans; yellow crystals in asparagus, green beans, greens and onions; tartrates in grape products; and struvite (harmless crystals resembling particles of glass) in crab meat. These factors must be considered in diagnosing complaints of home canners.

Warm Storage Temperature

Warm or hot storage temperatures (above 70°F.) cause deterioration in the quality (color, flavor, nutritive value) of canned foods. Generally speaking, quality loss in fruit products is proportional to the storage temperature; therefore, cool storage temperatures are recommended.

Enzymes

If canned fruits are not processed or heated sufficiently to inactivate or destroy enzymes, discoloration and flavor changes may result. If recommended processing procedures are used, this trouble should not occur.

Off-Flavor from Jar Rings

Jar rings of poor quality may impart an off-flavor to home-canned foods. Such difficulty was experienced during the war owing to changes that had to be made in the composition of jar rings. In the future, little trouble from this cause should be expected because considerable effort has been expended in improving the quality of jar rings.

Hydrogen Swells

Hydrogen swells result when cans bulge because of the evolution of hydrogen following internal corrosion of the can. This condition is usually associated with acid foods, particularly some of the fruits. It depends upon a number of factors including efficiency of the exhaust, volume of headspace, storage temperature, and nature of the product, tin plate and inside enamel coatings. Occasionally, hydrogen springers are encountered in long-stored canned peas, snap beans, asparagus, and pumpkin.

Rancidity

Off-flavors due to the development of rancidity in fats or oils may contribute to the deterioration of quality in foods containing fat. The fat or oil may react with the rubber ring or sealing compound of the closure, particularly during long storage periods. The rubber seal may swell and soften.

Physical Causes of Spoilage**Faulty Operation of Processing Equipment**

This is particularly important in case of pressure canners and may lead to several causes of trouble, depending upon conditions — such as loss of liquid from jars or buckling in tin cans.

Loss of Liquid from Jars During Processing

Home canners frequently complain of an excessive loss of liquid from jars during processing, particularly in the case of products processed in a pressure canner. There are several factors which can contribute to this loss of liquid.

1. Type of jar closure (full or partial seal). It has been found that jars that are partially sealed during processing have a greater tendency to vent and lose liquid than do those that are fully sealed.
2. Fluctuation of pressure in pressure canner during processing.
3. Rate of cooling pressure canner at end of process.
4. Product and method of packing. Some products such as corn, shell beans, and others may absorb a considerable amount of water during processing with the result that the finished jars have a low liquid level. Products such as greens, if not adequately blanched before processing, may shrink and lower the liquid level in the processed jar.

Freezing

Freezing may soften the texture of canned foods but it does not harm them unless the frozen product expands sufficiently to break the seal or container.

Light

Recent investigations have shown that normal exposure to light could be expected to have little or no effect on the quality of most home-canned foods.

Rough Handling

This cause of trouble is quite obvious. Rough handling or abuse of the container after processing may lead to spoilage if the container itself or the seal is broken and leakage results. Rough handling may also dent tin cans and thus reduce or entirely neutralize the vacuum, or even produce "springers."

MICROBIOLOGICAL ASPECTS OF HOME CANNING

Survey of Factors Responsible for Spoilage of Home-Canned Foods

In 1942 a survey of home-canned foods in Massachusetts was made to obtain information about the efficiency and safety of home canning and to learn more about the nature and causes of spoilage (Tischer and Esselen, 1945). Certain aspects of this subject have been studied by previous workers. Normington (1919) investigated cold-packed peas in an effort to find the reason for the high spoilage rate of home-canned foods as compared with commercially canned products. It was concluded that home-canned peas were spoiled by resistant sporeforming organisms not killed by the temperatures maintained in processing. The use of a pressure canner in conjunction with lengthened process times was recommended. Biester, Weighley, and Knapp (1921) studied the effect of storage temperature on the keeping quality of home-canned vegetables packed by the one-period, cold-pack method. They concluded that process times adequate for one section of the country may not be so for another section and stated that process times may not be considered apart from storage conditions. Sunderlin, Levine, and Nelson (1928) examined jars of spoiled home-canned foods on a basis of appearance, vacuum, odor, pH value, titratable acidity, amino nitrogen, and ammonia. They also made microscopic examinations of the sediment and bacterial counts in plates and dextrose tubes. No group of tests appeared to be sufficient to detect all cases of spoilage, but physical evidences were reported higher than either chemical or bacteriological. Of the tests used, change in odor was the most consistent indication of spoilage.

In the investigation of Tischer and Esselen (1945), samples of home-canned foods were collected with the aid of home demonstration agents of the Massachusetts Extension Service. About 300 samples of sound and spoiled foods were obtained from home canners in all parts of the State and brought to the laboratory for examination. Data concerning the source, canning technique, apparent condition of the sample, and other pertinent information were obtained from the home canners. Several heat-resistant putrefactive anaerobes were isolated from the spoiled samples, and their heat-resistance characteristics were determined. The results of this investigation were as follows:

Two hundred and ninety-three samples of sound and spoiled home-canned foods were examined in the laboratory by methods adapted from those used in the examination of commercially canned foods.

The samples were examined to determine (1) appearance of container, (2) appearance of food, (3) vacuum or pressure, (4) odor, (5) pH value, (6) bacteria observed with the microscope, and (7) presence of viable microorganisms.

In the laboratory examination of home-canned foods, bacteriological culture tests appeared to be the most reliable criterion of spoilage. More than half of the 146 samples submitted as sound contained viable microorganisms, indicating faulty canning technique and the possibility of spoilage. Ninety-

seven percent of the samples submitted as spoiled gave some evidence of spoilage.

The spores of four putrefactive anaerobes isolated from spoiled jars of asparagus, lima beans, and snap beans survived heating for 30 minutes at 110°C. (230°F) and 320 and 820 minutes at 100°C. (212°F.). In phosphate buffer their "F" and "z" values were only slightly below those of Cameron's putrefactive anaerobe No. 3679 and indicated a wide range of resistance among the four organisms.

As represented by this investigation, it would appear that about three-fourths of home-canning spoilage is due to understerilization and one-fourth to improper sealing. The boiling-water-bath method of processing is not adequate to destroy certain types of bacteria encountered in the home canning of low-acid vegetables. While a pressure canner correctly used is satisfactory for processing, understerilization may result if it is misused.

A survey of the spoilage actually encountered by home canners who submitted samples showed that approximately two percent spoilage was observed by 90 families who canned 22,544 jars of food in 1942. On this basis, the 293 families who submitted samples for laboratory examination canned 73,393 jars of food in 1942 and lost 1,438 jars through spoilage.

Vegetables as a Source of Spoilage Bacteria

The two types of bacteria of chief concern in home canning are sporeforming anaerobes and thermophiles. Anaerobes are organisms which grow in the absence of oxygen; and a jar or can of food provides a favorable environment for them. Thermophiles, or "heat-loving" bacteria, have an optimum temperature for growth at 122° to 140°F. (50° to 60°C.), but some facultative types will grow at room temperature.

Cameron (1938), and Townsend (1932) have discussed the importance of raw material as a source of spoilage bacteria in commercial canning. The latter author showed that the soil in certain areas was heavily seeded with thermophilic bacteria and that asparagus from such areas was difficult to sterilize. In commercial canning, equipment and other factors are frequently more important sources of contamination than the raw product.

Since some sources of contamination encountered in commercial canning are not present in home canning, it would appear that in home processing the raw material would be of greater importance as a source of spoilage bacteria.

Bushnell (1918), Bruett (1919), and Burke (1919) have indicated that blanching had no significant effect on the spores of heat-resistant bacteria, but Bruett reported that it does remove some spores because of its cleaning action. Smart (1937) summarized the work of previous investigators on the bacterial content of fresh vegetables, which indicated a wide variation between different lots. Heavy rainfall prior to the harvesting of many vegetables and ear-worm infestation in sweet corn caused high bacteria counts. Blanching caused a reduction of more than 90 percent in the number of bacteria on corn, green beans, and lima beans.

Dubord and Esselen (1945) carried on an investigation to determine the variation in the numbers of potential spoilage bacteria on fresh vegetables and the effects of washing, blanching, and holding in reducing their numbers. The study was concerned with spore forms rather than with vegetative forms of bacteria, as they are more heat resistant and are of major importance in home canning. As has been reported by other workers, a wide variation was found in the number and types of bacteria present on fresh vegetables.

The results of holding or storing fresh vegetables for a few hours or overnight were too varied for conclusive evaluation. In general the results obtained were similar to those of Cameron (1938) in that the numbers of sporeforming bacteria did not tend to increase, and in many cases decreased. However, when other factors such as quality and nutritive value are also considered, the desirability of canning vegetables as soon as possible after harvest should be stressed. When canning must be delayed, the vegetables should be stored at a low temperature.

The above investigation indicated that potential home-canning spoilage bacteria such as sporeforming anaerobes and thermophiles tend to be present in relatively small numbers on fresh vegetables, except in occasional samples, and that their number varies widely. Washing and blanching prior to canning effectively reduce the bacterial content of vegetables.

The incidence of putrefactive anaerobes encountered was low and may account for the fact that in some sections of the country the boiling-water-bath method of processing has been used successfully by many people. However, it was concluded that because of the wide variation in the bacterial content of the soil and of vegetables grown in it, the heat-resistant bacteria may be present at any time as a potential cause of spoilage unless process times which insure their destruction are used.

Botulism

Botulism has been defined as an acute toxemia caused by the ingestion of a potent toxin produced by an anaerobic sporeforming bacterium, *Cl. botulinum*, widely distributed in nature. Unlike many types of food-poisoning bacteria, the organism responsible for botulism produces its toxin in the food during the process of food spoilage. When the food is eaten, it is the toxin and not the bacteria that causes the poisoning. This organism produces spores which are much more resistant to heat than other kinds of food-poisoning bacteria, and it is difficult to destroy them in canning unless the foods are processed in a pressure canner at a high temperature. The botulinum bacillus differs from many kinds of bacteria in that it may grow in food without producing any obvious signs of spoilage. Thus, jars of canned foods containing its toxin do not necessarily show evidence of spoilage which would warn the housewife that the food was unfit to eat.

In a recent survey of available information on botulism and home canning, Esselen (1945) summarized some of the important points as follows:

Its spectacular nature and high mortality give botulism a place out of proportion to its frequency as a cause of death.

Almost without exception botulism outbreaks are caused by carelessness and the use of faulty canning techniques. Water-bath processing and open-kettle canning are responsible for many outbreaks.

Home-canned string beans, corn, greens, asparagus, and beets are foods that have been largely responsible for botulism outbreaks in this country. Many factors, some unknown, probably contribute to the low incidence of botulism from home-canned foods.

Botulinum organisms are widely distributed in nature and are not confined to certain geographical areas.

The presence of decayed plant material favors the growth and development of the botulinum organism, and for this reason the recommendation that only fresh sound products be used in home canning assumes an increased importance.

Botulinum toxin, if present in home-canned foods, may be destroyed by boiling the product for 10 to 20 minutes, depending upon the nature of the product.

Low-acid and medium-acid foods canned without a pressure canner or in a pressure canner incorrectly used *should never be tasted before they are boiled*.

Never taste any canned foods having a disagreeable odor or showing evidence of spoilage.

The addition of an acid, such as vinegar, to home-canned foods that contain botulinum toxin may increase the potency of the toxin. This may have a practical significance when such products as string beans are used for salads without being heated after the jar is opened.

Little is known regarding the effectiveness of botulinum antitoxin so far as human beings are concerned. Available evidence would indicate that it is effective if administered soon after consumption of the toxic foods.

Cl. botulinum can grow in many of the foods commonly canned at home. Frequently sufficient toxin to cause illness or death may be produced in canned foods before the appearance of the container or the food gives any warning of its dangerous nature.

The acidification of home-canned foods in order to reduce required process times is not generally recommended unless specific procedures are accurately followed.

A toxin may develop in home-canned foods even after long months of storage. It is recommended that home-canned foods be stored at a low temperature in order to retard or prevent the growth of viable organisms which might be present in the jar.

In some instances other spoilage bacteria may grow in jars of under-processed food and inhibit or retard growth and toxin formation by *Cl. botulinum*. In many such cases the food would be obviously spoiled and would not be eaten.

Some spores of *Cl. botulinum* are very heat resistant, and practical boiling-water-bath process times are inadequate to destroy them. Six to twelve or more hours in a boiling water bath would be necessary to give the same degree of sterilization as the recommended process times at 240°F. (116°C.).

Botulinum toxin may be produced in canned fruits and tomatoes if a mold growth develops which provides a favorable environment for the development of *Cl. botulinum*. Such products, when moldy, should not be eaten.

PRESSURE CANNERS

Equipment

For the safe processing of home-canned low-acid foods, such as vegetables, meats, poultry, and fish, temperatures of 240° to 250°F. must be used. The pressure canner, especially designed for this purpose, is essentially a pressure vessel which can be operated safely at internal pressures up to 20 pounds. The lid must be locked or sealed by an appropriate device. In addition, the pressure canner should be equipped with an accurate pressure indicator, a safety valve, and a petcock or valve which can be opened and closed to permit venting.

A number of different kinds of pressure canners are in use and on the market, but they all operate on the same fundamental principle and are designed to perform the same function. The various parts of the pressure canner may be outlined as follows:

Kettle — made of cast or sheet aluminum, porcelain-enameled steel, tinned steel, or stainless steel.

Lid — with some type of pressure indicator, petcock or vent, safety valve, and closure.

Closure — thumb nut type; screw band lock closure; slide closure with lugs; or flexible steel top.

Pressure or Temperature Indicator —

- a. Pressure gauge with dial face and scale divided into pounds of pressure with pointer to indicate pressure inside canner.
- b. Slide-type pressure gauge.
- c. Weight-type indicator.
- d. Thermometer — for accuracy in processing it is recommended that pressure canners be equipped with an accurate thermometer in addition to the pressure indicator.

Petcock or Vent and Safety Valve — these may be separate or combined.

- a. Petcock to exhaust or vent air and steam at beginning of processing period.
- b. Safety valve to blow off excess steam when pressure inside the canner is too high for safety.
- c. Combination petcock and safety valve.
- d. Combination vent and pressure indicator. On some of the more recent types of pressure canners, the weight-type pressure indicator and the stem on which it rests also serve as the petcock or vent.
- e. Safety plug or fuse designed to release pressure in case the safety valve fails to work.

Gasket — Some pressure canners have a rubber or composition gasket to complete the seal between the cover and kettle and to prevent leakage of steam.

Care of Pressure Canners

For successful canning it is important that pressure canners and their controls be maintained in good working order. If it is given proper care, a pressure canner will last for years.

Before canning and before placing the pressure canner in storage between canning seasons, make sure that it is clean. The kettle should be washed with hot soapy water, rinsed, and dried. The lid should not be immersed in water but rather should be wiped off with a soapy cloth and then a clean damp cloth and dried. Harsh scouring powders should not be used, and in aluminum canners strong soaps may be harmful. Stains may be removed from aluminum canners with a paste of whiting and vinegar. Use water instead of vinegar with whiting for cleaning enameled-steel pressure canners.

The openings to the petcock, safety valve, and pressure gauge should be checked to make sure they are clean. If these openings become dirty and clogged and remain so during canning, the pressure indicator may not register the correct pressure, the safety valve may fail to work if the pressure becomes too high, and the efficiency of the venting operation may be impaired. These openings may be cleaned with a toothpick or a small sharp-pointed tool. Petcock and safety valves should be cleaned frequently by drawing a string or narrow strip of cloth through them. It is recommended that the petcock and safety valve be removed occasionally and soaked in vinegar for a short time. Ball-and-socket type safety valves should be unscrewed and cleaned after each use.

The edges of the kettle and lid should be clean and, if necessary, should be scrubbed with whiting and water. Dried food, dirt, or scale from hard water on either edge may prevent a tight seal and allow steam to leak out.

Gaskets

In canners with a rubber gasket, the gasket should be kept clean and free from grease. Some types of gaskets may be turned upside down when they no longer give a perfect seal in the original position. Leakage between the kettle and the lid may be caused by shrinkage of the gasket. If this happens, the gasket should be stretched carefully between the fingers until it fits. If the gasket deteriorates or ages so that it will no longer make a tight seal, a new one should be ordered from the manufacturer of the pressure canner.

Pressure Indicators

Dial-type pressure gauges should be tested for accuracy at least once a year before each canning season. Your county home demonstration agent should be able to do this testing or to advise where it can be done. If the gauge must be sent to the manufacturer or the dealer from whom the canner was bought, it should be well packed as though it were a delicate piece of glass.

If your dial type gauge is one to four pounds off, allowance must be made for this inaccuracy, when processing at 10 pounds steam pressure, as follows:

If gauge is reported high —

- 1 pound high — process at 11 pounds
- 2 pounds high — process at 12 pounds
- 3 pounds high — process at 13 pounds
- 4 pounds high — process at 14 pounds

If gauge is reported low —

- 1 pound low — process at 9 pounds
- 2 pounds low — process at 8 pounds
- 3 pounds low — process at 7 pounds
- 4 pounds low — process at 6 pounds

If the pressure gauge is five or more pounds off, it should be discarded and replaced by a new tested gauge. New pressure gauges can usually be obtained from the manufacturer of the pressure canner at a cost of approximately two dollars.

A weight-type pressure indicator, if thoroughly clean, needs no adjustment.

Pressure Canner Operation

It is important to follow the manufacturer's directions in using a pressure canner. The general procedure for the correct operation of pressure canners may be outlined as follows:

1. Be sure the pressure canner is clean and its parts are in good working order.
2. Place one to two inches of boiling water in the pressure canner to avoid boiling dry. Place kettle over enough heat to raise pressure quickly.
3. Place hot filled jars on a rack or in a wire basket in the pressure canner. Be sure to leave room on all sides of each container so that the steam may circulate

freely. Do not let the jars touch or tip over. If the pressure canner is large enough to hold two tiers of jars, a wire rack should be used to separate the two layers.

4. Put the pressure canner lid on correctly and tighten securely so that no steam will escape except at the open petcock or vent. Arrows or other guides indicated on the kettle and lid should be matched. If the cover has thumb nuts, grasp opposite nuts and tighten part way. Then continue around the lid, gradually tightening each pair. Repeat until all nuts are tight. This method gives a more even seal and prevents the lid from being distorted. If the canner has a separate safety valve, be sure that it is correctly adjusted before beginning to process. If the canner has a dial-type pressure gauge, open the petcock; if it has a weight-type pressure indicator, remove weight so that the canner can be vented.

5. If the canner has separate safety valve, be sure that it is correctly adjusted before beginning to process. If the canner has a dial-type pressure gauge, open the petcock; if it has a weight-type pressure indicator, remove weight so that canner can be vented.

6. Turn the heat high (Figure 1 top). When a steady stream of steam begins to issue from the petcock or vent, start counting time (Figure 1 bottom). The canner should be vented in this manner for ten minutes in order to exhaust the air from within the pressure canner. This is of utmost importance. If the air is not eliminated from within the canner, it will be impossible to reach the desired processing temperature (240°F.) even though the pressure indicator registers an apparent 10 pounds steam pressure.

7. At the end of the venting period, close the petcock (Figure 2 top) or vent and let the pressure rise until the indicator registers the exact pressure desired. Adjust the heat to maintain the pressure as steady as possible.

8. Start counting the processing time from the moment the pressure reaches the correct amount for the product being canned (Figure 2 bottom). Count the time accurately. Keep an even pressure throughout the process. If the pressure is allowed to fluctuate, it may force liquid out of the jars. Never try to lower pressure by opening the petcock.

9. When the processing time is up, turn off the heat, slide the pressure canner to one side of the source of heat, and let it cool slowly until the pressure reaches zero. Then open the petcock or vent gradually. If the petcock is opened suddenly or before the pressure has dropped to zero, liquid will be pulled from the jars. If the petcock is not opened when the pressure reaches zero, a vacuum may be formed in the pressure canner and force liquid out of the jars.

10. After the pressure reaches zero and the petcock is opened, the pressure canner should be allowed to stand for five minutes before it is opened. In no case should the pressure canner be opened in less than 20 minutes after the end of the process.

11. If the product is packed in tin cans, it is not necessary to wait for the pressure to fall to zero. Open the petcock as soon as the processing time is up, but be sure to open it gradually to let the steam escape slowly.

12. When the pressure canner is opened, the back of the lid should be lifted so as to direct heat and any remaining steam away from the face and arms of the operator.

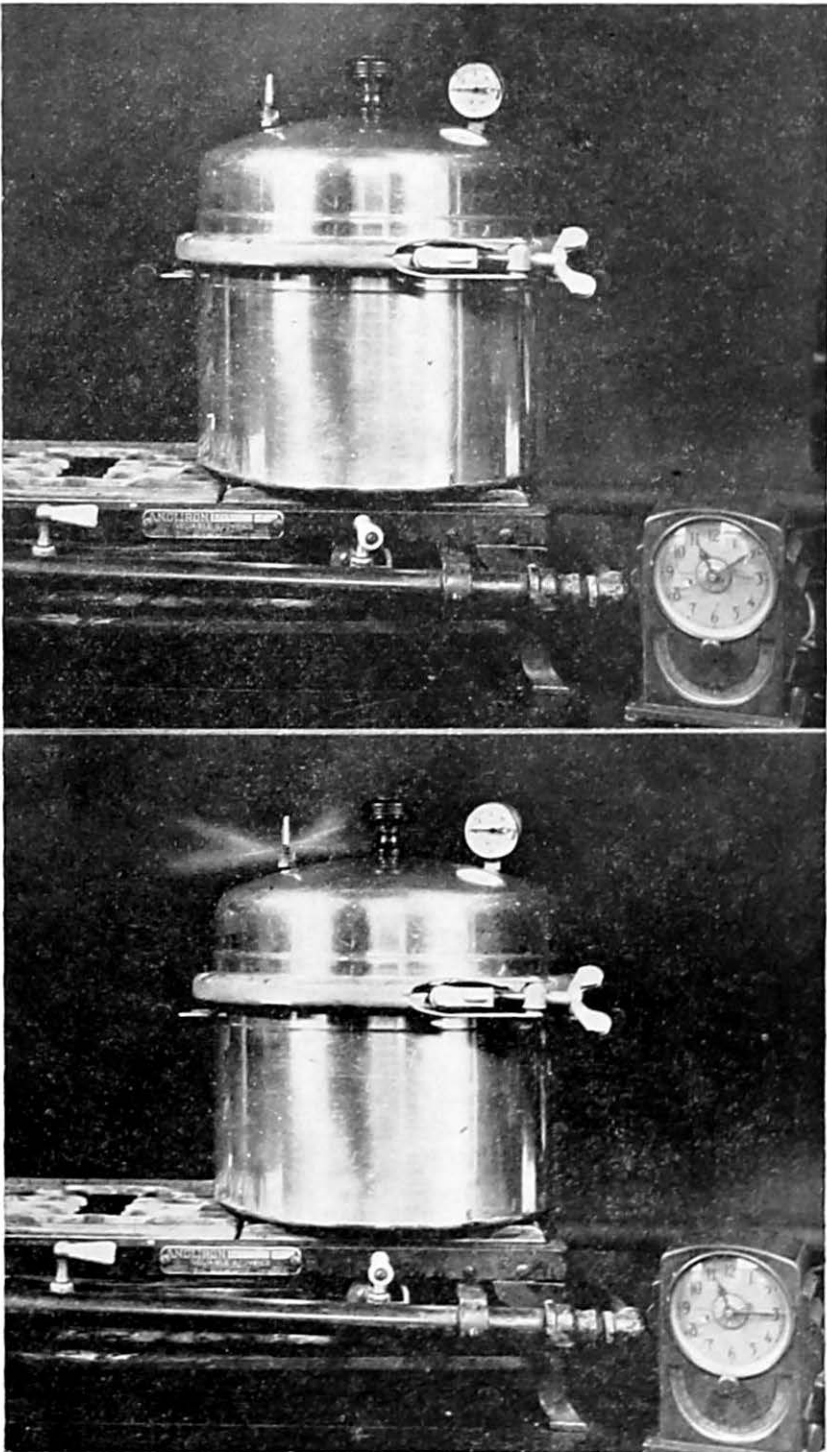


Figure 1.

Top: Pressure Canner Sealed and Heat Turned on High. Petcock Open.
Bottom: Steady Stream of Steam Issuing from Petcock. Start counting venting time (10 minutes).

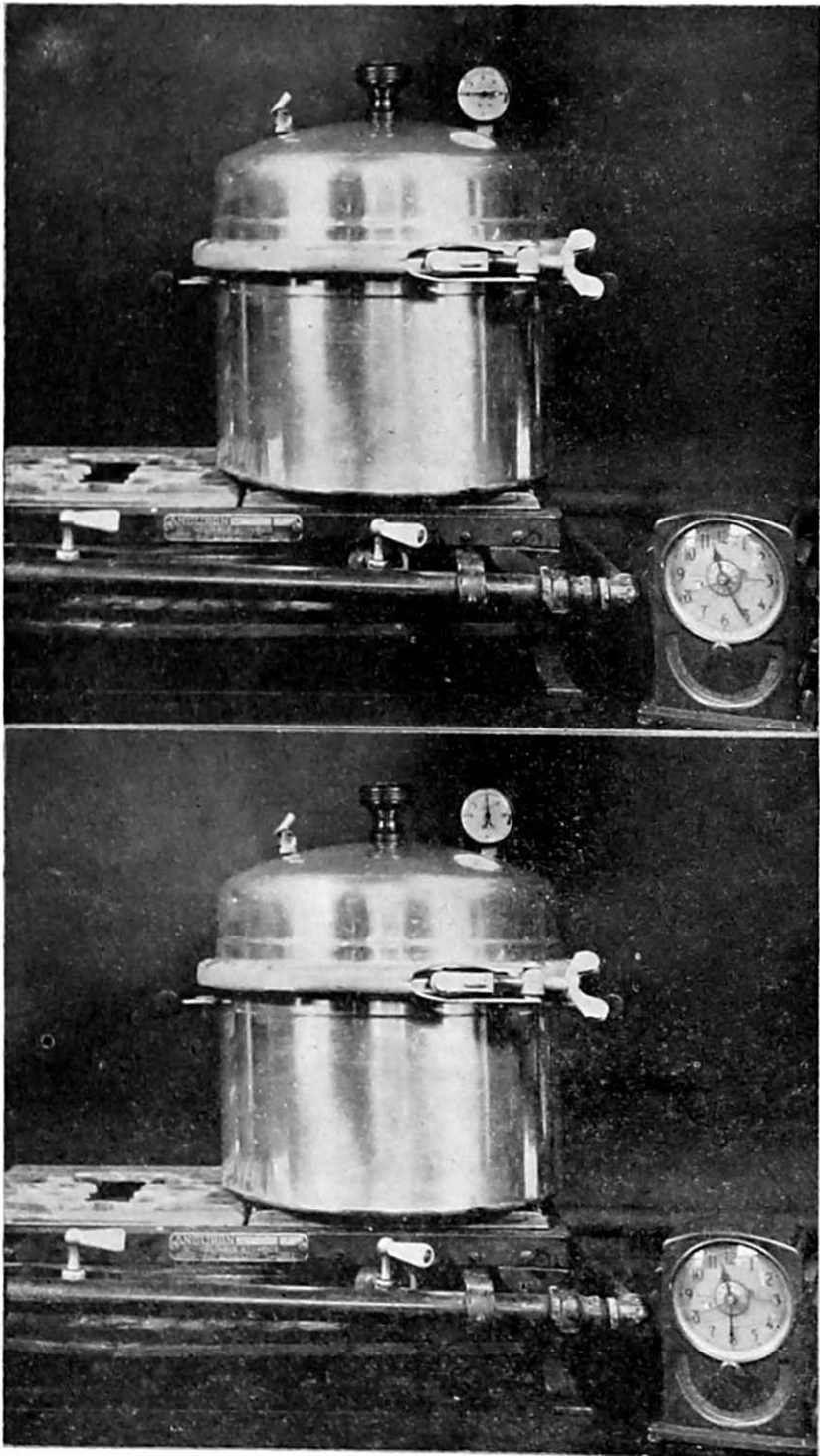


Figure 2

Top: After 10-minute vent, the petcock is closed to let steam pressure rise to desired pressure.

Bottom: Ten Pounds Steam Pressure. Start counting process time. Adjust heat to maintain steady pressure.

Storing Pressure Canners

Before being stored for any length of time, the pressure canner should be thoroughly cleaned and dried. Food or salt deposits left on canners may injure the surfaces of the canners, particularly those made of aluminum. The threads of the screw locks should be covered with a thin film of vaseline or salt-free oil to prevent rust. Crumpled newspapers placed inside the kettle will absorb moisture and odors. The lid should be wrapped in paper to keep dust out of the pressure indicator and valve openings and to protect the edges. The lid should then be placed in an inverted position on the kettle.

Venting Pressure Canners

In order to obtain the high temperature required for processing canned foods, it is very important that all the air be driven out of the pressure canner. A mixture of air and steam will create a pressure without a corresponding high temperature. The presence of air may also form "cold air pockets" in the canner so that the jars are not all processed at the apparent or indicated temperature. Recommended home-canning process times are based on the assumption that all the air has been driven out of the pressure canner before the start of the process. Thus, the correct use of the petcock or vent becomes one of the most important points in the operation of a pressure canner. Inadequate venting, with its resultant understerilization, can be an important cause of spoilage in home-canned foods.

In commercial canning, the importance of complete venting is well recognized and has been the subject of extensive research work.

Retorts (large size commercial pressure canners) are vented before the start of the process time and throughout the processing to make sure that the air has been removed.

Esselen (1944) investigated the venting characteristics of 11-quart and 25-quart size aluminum pressure canners. Various venting procedures were employed in order to determine the venting time necessary to drive the trapped air out of the pressure canner and to obtain a uniform temperature within the canner. The results of these studies are summarized in Table 1. Temperature measurements were made at four points within the canner: in the center and two inches below the top, in the center and half-way between the top and bottom, and on opposite sides half-way between the top and the bottom.

The coolest points in the incompletely vented pressure canner were found to be at the sides, and the highest temperatures were usually reached in the top of the canner. The data indicated that under these conditions some jars in the canner might be given an adequate process, whereas others would be under-processed.

It was pointed out that the process time required would have to be considerably increased if, because of insufficient venting, the actual processing temperature in a pressure canner was 235°F. when the reading on the pressure indicator was 240°F. In some cases the process time at 235°F. would amount to 140 per cent or more of the time required at 240°F. For example, a product that requires a process time of 30 minutes at 240°F. would have to be processed 42 minutes at 235°F. to receive the required degree of sterilization.

On the basis of the data obtained it was concluded that a venting time of at least 10 minutes is recommended for pressure canners of the size commonly used in home canning. When processing a full load of pint jars, particularly, it

would be desirable to allow the water to boil for 10 minutes in the canner just before sealing the top, in addition to the 10 minute venting time.

Fitzpatrick, McConnell and Esselen (1945) investigated the venting times required for community cannery-type retorts under various conditions. The following recommendations were made:

1. All No. 2 and No. 3 size retorts should be equipped with venting outlets of at least 3/8 to 1/2 inch diameter and preferably larger. The vents should be placed in the top of the retort with the steam inlet at the bottom.
2. The start of the venting time should be counted when a steady stream of steam issues from the vent.
3. The vent valve should be wide open during venting.
4. All retorts should be continuously vented throughout the process with the vent valve partially open.
5. No. 2 size self-heating retorts should be vented for at least 25 minutes.
6. No. 2 size steam retorts should be vented for at least 7 minutes.
7. No. 3 size steam retorts should be vented for at least 25 minutes at 0 pounds pressure or 10 minutes at 10 pounds pressure.

Gunness and Fellers (1948) have described a dependable portable gauge tester for home pressure canners. A number of these gauge testers constructed at the University of Massachusetts for use by County Extension workers have given satisfactory service over a period of several years.

TABLE 1—EFFECT OF DIFFERENT VENTING PROCEDURES ON THE TEMPERATURE VARIATION INSIDE PRESSURE CANNER DURING PROCESSING.
(From Esselen, 1944.)

Load	Venting Procedure	Range of Temperatures in Canner			
		At 10 Pounds Pressure*		At 15 Pounds Pressure*	
		Minimum	Maximum	Minimum	Maximum
Eleven-Quart Aluminum Pressure Canner					
Jars		°F.	°F.	°F.	°F.
3 quart	No venting	237	239	...	...
3 quart	Vented 4 minutes	240	240	250	250
4 quart	Vented 4 minutes	240	240	250	250
Twenty-five-Quart Aluminum Pressure Canner					
7 quart	No venting	235	240	246	250
7 quart	Vented 5 minutes	238	240	248 1/2	250
7 quart	Vented 7 minutes	239	240	249	250
7 quart	Vented 10 minutes	240	240	250	250
7 quart	Vented slowly and continuously	234	240	...	...
7 quart	Water boiled 5 minutes before closing; then vented 10 minutes	240	240	250	250
18 pint	Vented 12 minutes	233	240	243	250
18 pint	Vented 48 minutes	236	240	...	...
18 pint	Water boiled 5 minutes before closing; then vented 10 minutes	237	240	...	...
18 pint	Water boiled 10 minutes before closing; then vented 10 minutes	239	240	250	250
9 pint	Vented 5 minutes	237	240	...	...
9 pint	Vented 10 minutes	237	240	...	...
9 pint	Water boiled 5 minutes before closing; then vented 10 minutes	238 1/2	240	...	...
9 pint	Water boiled 10 minutes before closing; then vented 10 minutes	239	240	...	...
7 pint	Vented 10 minutes	238	240	...	...

*As indicated by standardized pressure gauge.

Canning in a Pressure Saucepan

Kraska and Kubista (1948) described a method for processing vegetables in a pressure saucepan. In this method a definite "cooling time" was observed before the jars were removed from the canner. This additional time was approximately equal to the difference in come-up time between the saucepan, which comes up to pressure relatively fast, and the large canner, which comes up more slowly. The added "cooling time" was said to equalize the sterilizing effectiveness of the two procedures. Only one type of saucepan was employed in these investigations.

Taube and Sater (1948) investigated the effectiveness of six different types of pressure saucepans for canning vegetables. They found that the come-up, venting (one minute), and cooling times for pressure saucepans were much shorter than for pressure canners. This combination of factors required a longer time of processing at 240°F. in the saucepan than in the canner. They also pointed out a considerable variation in the heating, operating, and pressure control characteristics of the different canners studied. Such variables add to the difficulty of establishing standard process times for canning vegetables in pressure saucepans. Recommended saucepan process times were found to be 20 minutes longer than those previously established for processing pint jars in pressure canners. They specified that saucepans equipped with an accurate control or indicator of 10 pounds pressure (240°F.) may safely use the following processing periods for pint jars:

<i>Product</i>	<i>Minutes</i>	<i>Product</i>	<i>Minutes</i>
Asparagus _____	45	Peas _____	60
Lima beans _____	55	Cubed pumpkin _____	75
Snap beans _____	40	Strained pumpkin _____	80
Beets _____	45	Spinach _____	65
Carrots _____	40	Summer squash _____	50
Cream-style corn _____	105	Dry-pack sweet potatoes _____	85
Whole-kernel corn _____	75	Wet-pack sweet potatoes _____	75
Okra _____	45		

Fellers, Esselen and Cole (1950) indicated that, in general, pressure saucepans are not recommended for canning vegetables and meats because of their variable operating characteristics.

Boiling Water Bath

A boiling-water-bath canner consists of a covered vessel sufficiently large to accommodate the number of jars to be processed at one time. It should be fitted with a suitable metal, wood, or wire rack to keep the jars from touching the bottom. It must be deep enough to have one to two inches of water over the tops of the jars with extra space for boiling. If deep enough, a pressure canner may be used as a water bath. The cover should be set on without fastening, and the petcock should be wide open so that no pressure is built up.

In using a boiling water bath, the water should be boiling when the jars are placed in it. Because the jars will usually cool the water to below the boiling point, the start of the process should not be counted until the water again begins to boil. Failure to keep the water boiling throughout the process or to have the containers covered with water may result in underprocessing and subsequent spoilage. Boiling water may be added during the processing if needed to keep the containers covered.

Fruit and tomatoes may be processed in steam in a pressure canner according to the following method: the canner is vented 10 minutes and then operated in the usual manner except that the processing is done at 0 to 1 pound steam pressure. Recommended boiling-water-bath process times are used.

Oven Canning

The use of ovens of kitchen ranges for processing canned foods has been practiced to some extent for a number of years and has been a source of concern to technologists because adequate processing temperatures for low-acid foods are not obtained and because of other inherent sources of danger.

Haddock (1933) made a two years' study of oven canning in this laboratory. Some of her conclusions were as follows:

1. A large number of heat-controlled, insulated gas and electric ovens were tested and found to differ widely in their behavior.
2. The results of tests made on 20 ovens indicated great variations not only between different makes but between ovens of the same make. Under the same conditions the time required to raise the temperature of 9 filled pint jars from 112° to 212°F. ranged from 37 to 120 minutes.
3. Oven processing had a greater deteriorating effect upon rubber jar rings as measured by decreased elasticity than did processing in a boiling water bath or pressure canner.
4. Many common spoilage organisms were not destroyed in jars of food subjected to the recommended oven-processing times.
5. The processing times usually recommended for oven canning were far short of the time required to bring oven-canned foods to the temperatures of food processed in a boiling water bath.
6. Oven canning was not recommended as a safe method of food preservation.

In 1943 difficulties with oven canning reached serious proportions. This situation was accentuated by the improper use of the three-piece glass lid used extensively as a means of conserving critical materials in wartime.

When this type of closure is tightly sealed prior to processing, it provides such a good seal that the jar may not vent and a high internal pressure may be developed. Thus the improper use of this seal resulted in jar explosions, particularly in oven canning. A number of cases were reported in which ovens and stoves were wrecked and personal injuries sustained. In an attempt to eliminate this trouble, the Department of Agriculture pointed out the hazards of oven canning, and a positive stand against it was taken. According to the United States Department of Agriculture (1944) warning:

Oven canning is dangerous in more ways than one. Even though the oven temperature goes to 250°F. or higher, food in the jars stays at about boiling point (212°F.). For vegetables, that is not hot enough to make bacteria harmless.

Also, oven canning has caused serious accidents to persons and property. When jars seal during processing, steam builds up inside the jars and they may explode. The oven door may fly off . . . glass may fly out . . . you may be hit and seriously hurt by the flying pieces . . . and your kitchen wrecked.

HOME-CANNING JARS

Common Types

There are four common types of home-canning jars in general use today. They are usually available in four sizes: half-pint, pint, quart, and half-gallon. They differ mainly in the means of sealing that is employed, as illustrated in Figure 3.

1. The **Bail-Type Jar** has a glass lid which fits on a rubber ring and is held in place by a wire bail. (*Shoulder seal.*)

2. The **Two-Piece Metal Lid or Self-Sealing Jar** has a lacquered or enameled metal lid with an attached rubber sealing gasket. The lid is held in place by means of a metal screw band. (*Top seal.*)

3. The **Modified Mason or Three-Piece Glass Lid Jar** has a glass lid which accommodates a rubber ring in a recess around its periphery. The glass lid is held in place by a metal screw band. The seal is made by screwing down the metal band so that the rubber ring is compressed between the glass lid and the top of the jar. (*Top seal.*)

4. The **Mason Jar** has a zinc cap with a white glass lining. This type of jar is sealed by screwing the cap down tightly on a rubber ring placed between the edge of the metal cap and the shoulder of the jar. (*Shoulder seal.*)

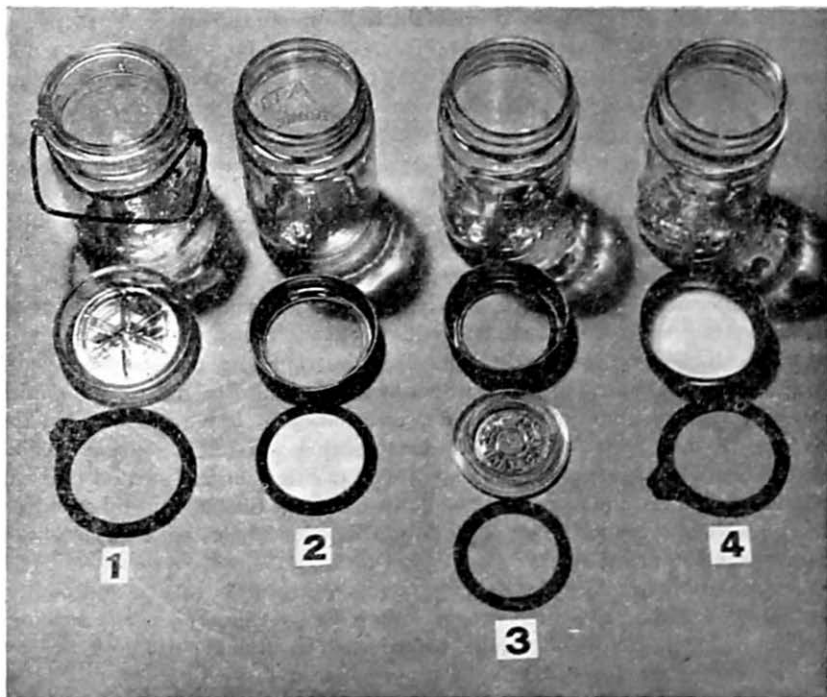


Figure 3. HOME-CANNING JARS.

(1) Bail-type; (2) Two-piece Metal Lid or Self-Sealing Jars; (3) Modified Mason or Three-piece Glass Lid Jar; (4) Mason Jar with Zinc P/L Cap.

Using Home-Canning Jars

Preparation of Jars and Caps

Examine jars and closures carefully to make sure that they are in good condition and will make an airtight seal. Discard all jars and lids with cracks, chips, an uneven sealing surface, or any defect that might prevent an even seal. The jars should be thoroughly washed in hot soapy water, rinsed in hot water, and drained just prior to use. Caps, lids, and rubber rings should be rinsed with hot water unless the manufacturer directs otherwise. Do not stretch rubber rings excessively.

Filling

When the jars are filled, care should be taken to leave sufficient headspace at the top to permit expansion of the food during processing. It is good practice to leave 1 inch headspace over the solid food and add sufficient syrup, brine, or hot water to leave $\frac{1}{2}$ to $\frac{1}{4}$ inch headspace above the liquid.

Clean Tops of Jars

A clean sealing surface on the jars is essential. With a hot, damp cloth wipe the threads and tops of jars free of all seeds, pulp, or food products.

Sealing

1. The Mason Jar — Adjust the wet rubber ring on the jar shoulder and screw the cap down firmly, then turn back $\frac{1}{4}$ inch. As soon as the jar is taken from the canner, screw the cap down tight to complete the seal.

2. The Modified Mason or Three-Piece Glass Lid Jar — Fit the wet rubber ring on the glass lid. Put lid on jar with the rubber side down. Screw metal band down firmly, then turn back almost a quarter turn, using thumb as a guide. As soon as jar is taken from the canner, screw the metal band down tight to complete the seal. When cool, or the next day, the metal bands should be removed, taking care not to break the seal.

3. The Two-Piece Metal Lid or Self-Sealing Jar — Place the metal lid on the top of the jar with the sealing gasket next to the glass. Tighten metal screw band firmly. This type of closure seals itself. Do not tighten bands after the jars are processed. When cool, or the next day, the metal band should be removed, taking care not to break the seal.

4. The Bail-Type Jar — For fruits, fruit juices, and tomatoes processed in a boiling water bath or a pressure canner at 212°F., and fish, meats, and poultry processed at 10 pounds pressure in a pressure canner, it is recommended that this type of jar be *partially sealed* in order to provide maximum venting. Adjust wet rubber ring on jar, place the glass lid in position on the jar and pull wire bail over the lid until it snaps into the notch on top of the lid; leave short wire in the *up* position. As soon as jar is removed from the canner, push the short wire down to complete the seal.

For low-acid vegetables and other products, except fish, meats, and poultry, that are processed at 10 pounds pressure in a pressure canner, it is recommended that the bail-type jar be fully sealed before it is placed in the canner in order to prevent an excessive loss of liquid during processing. Adjust the wet rubber ring on the jar, place the glass lid on the jar and pull the wire bail over the lid until it snaps into the notch on top of the lid. Push the short wire down to the sealed position. The jar is completely sealed when removed from the canner after processing.

Removing Screw Bands

The day after canning or after the jars are cooled it is desirable to remove the metal screw bands from jars sealed with the two-piece metal lid and three-piece glass lid types of closures. Bands left on the jars may be difficult to remove when the jars are opened after storage. After removal from the jars the bands should be washed and stored in a dry place until they are needed again.

Internal Pressures Developed During Processing

When a home-canning jar is sealed and heated, a pressure is developed within it caused by the expansion and vapor pressure of the contents of the jars. The amount of pressure which may be developed within the container is influenced by the temperature of the contents at the time the jar is sealed, the amount of headspace, and the processing temperature. At a given processing temperature the amount of internal pressure developed varies inversely with the headspace volume and sealing temperature, that is, the use of a relatively large headspace and a high filling temperature reduces the pressure that may be developed. It may be calculated or demonstrated in practice that under extreme conditions very high internal pressures might develop in tightly sealed jars. However, home-canning jar closures are designed to vent at relatively low pressures, when correctly used, so that dangerously high pressures are not created within the container. The jars and closures, if partially sealed, vent at a low pressure. Fellers, Levine, and Maclinn (1937) pointed out that when the bail-type jars were partially sealed and processed in a boiling water bath, no appreciable pressure was built up (0.1 to 0.5 pounds per square inch). When fully sealed, the jars developed a maximum pressure between 6 and 7 pounds per square inch, before venting occurred. During processing in a pressure canner, internal pressures of approximately 10 pounds per square inch were developed in both the partially- and fully-sealed jars. Differences in headspace and in filling temperatures made very little difference in the pressure developed. The extent of pressure created in the jars was dependent on the pressure developed in the pressure canner, regardless of the type of seal.

With both the bail-type jar and the two-piece metal lid closure, if the jars are "fully sealed" the closures still vent at relatively low pressures and are perfectly safe and satisfactory in home canning. Such jars are not really tightly sealed so far as their venting pressures are concerned. However, with the Mason and modified Mason or three-piece glass lid jar it is essential that the closure be only partially sealed during processing. If the closure is fully sealed by screwing the metal band down tight, its venting pressure may be dangerously high when the usual canning methods are followed. During the recent war, considerable trouble and a number of accidents occurred when the three-piece glass lid jars were fully sealed prior to processing, particularly when they were processed in an oven (a processing method which is in itself dangerous and not recommended).

On the basis of a study of 1943 home-canning accidents, the National Safety Council (1944) made the following comments relative to the physical limitations and peculiarities of home-canning jars and closures:

Most of the difficulty experienced with home canning equipment has been with jar closures. Three principles are generally employed in sealing jars, although cap assemblies may vary as to material—metal or glass—or the device which fastens down the lid.

All caps have one common factor: they must vent during processing when steam pressure is created inside the jar. Pressure must be allowed to escape or one of two accidents may occur: the seal may break, with consequent chance of food spoilage, or the jar might explode. Therefore, if the cap does not vent automatically, then provision must be made to vent it manually. An additional safeguard advocated by some authorities is the exhausting of jars to allow air to escape just before actual processing is started.

Specific authoritative directions must be followed for each particular type of cap, regardless of what Mrs. Housewife did in past years with a similar cap, or what the neighbor accomplished last week with a product that "seemed" to be the same.

Tests have been conducted by some agencies to determine average internal pressure strength of regular glass canning jars of uniform manufacture. Results show that the average round jar will withstand 75 pounds per square inch or more. As the contour of the jar tends towards a square shape, its strength decreases proportionately, with the average square jar strength found to be 30 pounds per square inch or more, and square jars with round corners about 40 pounds per square inch or more. With a maximum of 15 pounds, generally recommended in pressure canners, standard canning jars normally are well within safe limits.

Although in recent years lighter-weight thinner-walled glass jars have been manufactured, improvements in the quality of the glass and manufacturing processes have made them nearly as strong as the old heavyweight jars.

Research by fruit jar manufacturers has determined that the glass of a regular jar is able to withstand thermal shock (sudden change from cold to hot, or vice versa) of about 70°.

An exception to the usual recommendation of partially sealing certain types of jars is the canning procedure in which the jars are exhausted and then fully sealed before processing. Faust (1945) recommends that jars of vegetables to be processed in a pressure canner be heated or exhausted for 10 to 15 minutes in boiling water and sealed tightly before closing the canner to prevent a loss of liquid from the jars during processing and cooling. In a recent study of this method of canning, using three-piece glass lid jars, Dawson, Gilpin, Toepfer, and Batchelder (1949) reported that from the standpoint of liquid retention and palatability of asparagus the most satisfactory method of canning is to exhaust and completely seal the jars before processing. Ascorbic acid retention was not significantly different in this method as compared to others. However, it was pointed out that the greater amount of work involved and the additional time required for exhausting are factors to be considered in the choice of a processing method.

IMPORTANCE AND FUNCTION OF VACUUM

Fellers, Levine, and Maclinn (1937) pointed out that a good partial vacuum in the sealed jar is of primary importance in home canning. Vacuum is generally expressed in "inches of mercury" and may be described as the absence of "normal pressure." Normal atmospheric pressure is that pressure due to the weight of the air enveloping the earth; at sea level this pressure is approximately 15 pounds per square inch.

If a jar is closed at room temperature, the air within exerts the same pressure outwards as the atmosphere without exerts on the container. If a part of the air in the jar is removed and the jar is then closed, the remaining air exerts less pressure outwards than the atmosphere exerts upon the outside of the jar, and

it is said that a "partial vacuum exists in the container." Atmospheric pressure at sea level is sufficient to support a column of mercury 29.92 inches high, having a cross-section of one square inch. If the air remaining in the "partial vacuum" supports a column of mercury to a height of 20 inches, then the difference between the heights of the columns, 10 inches, represents the "vacuum." This vacuum is what is meant whenever the word is used in general literature on canned foods.

A vacuum is produced in home-canning jars either by filling the food into the container hot or by heating the product in the jars or by both. The application of heat causes the internal gases and vapors to expand and escape by means of the jar "venting." Upon cooling, after the process, there is a contraction of the expanded gases, vapors, and solids; and a partial vacuum is formed within the container. Thus, the formation of a vacuum depends mainly on the venting of the jar and is enhanced by hot filling.

In addition to inhibiting the growth of certain types of spoilage microorganisms, if they should be present, the vacuum serves important functions in maintaining an effective seal on the jar and in preventing or retarding oxidative changes in color, flavor, and vitamin content of the product by the resultant absence of excessive amounts of air or oxygen.

Measurement of Vacuum by Water Displacement Method

The usual method of determining vacuums in canned foods is by piercing the top of the can or metal lid of the jar with a vacuum gauge provided with an appropriate fitment. Obviously, this method cannot be used for determining vacuums in jars sealed with glass lids. However, a water-displacement method, such as described by Maclinn and Fellers (1936), is quite satisfactory for determining the vacuum in any of the various types of home-canning jars. This method depends on displacement by water of a certain volume of the headspace, depending upon the vacuum (partial pressure) present in the jars.

The sealed jar, complete with its contents, is weighed after processing or storage. It is then immersed in water in an inverted position and the seal broken, permitting the headspace to fill with water in proportion to the vacuum in the headspace. With the jar still inverted, the water levels inside and outside the jar are made the same, the cap is replaced and resealed, and the jar is then removed from the water, wiped off, dried, and reweighed. The difference in weight between the first and second weighings indicates the amount of water that was sucked in. The lid is then removed and the jar completely filled with water, including the space under the lid, after which it is dried and weighed again. This weight minus the first weight gives the volume of headspace. The vacuum can be determined from the weight of the water sucked in and the volume of the headspace, as indicated in the following example:

a. Weight of jar and contents after processing	_____	980 grams
b. Weight after opening under water	_____	1030 grams
c. Gain in weight (b-a)	_____	50 grams (cc.)
d. Weight of jar completely full	_____	1050 grams
e. Original headspace volume (d-a)	_____	70 grams (cc.)
f. Vacuum b-a/d-a x 30	_____	21.4 inches

It is frequently assumed that, in order to obtain the benefit of the elimination or reduction of air in the headspace of the jar, all that is necessary is a high

vacuum. This assumption overlooks one very important point and that is the quantity of air remaining in the container. For a given vacuum, the amount of air left in the container will vary directly with the original amount of air or headspace in the jar. For example, assume that in a pint home-canning jar, for headspaces of $\frac{1}{4}$, $\frac{1}{2}$, and 1 inch the volume of air in the headspace is 20, 40, and 75 cc., 20 percent of which consists of oxygen, the element responsible for undesirable oxidative changes in foods. If the vacuum formed in the jar after processing and cooling is 20 inches, only 20/29.92 or 66.8 percent of the air in the headspace has been removed. If there was a $\frac{1}{2}$ inch (40 cc.) headspace at the start, this means that approximately 13.3 cc. of air or 2.6 cc. of oxygen remained in the jar after processing. This relationship between vacuum, headspace, and volume of residual air in the container is illustrated in Figure 4.

VENTING AND LOSS OF LIQUID FROM HOME-CANNING JARS

Home canners frequently complain of an excessive loss of liquid from jars during processing, particularly in products processed in a pressure canner. Factors which contribute to this loss of liquid have been investigated in this laboratory. Fellers, Levine, and Maclinn (1937) reported that fully sealing bail-type home-canning jars prior to processing was very effective in reducing liquid losses and improving the general appearance of the product. Fully sealing the jars, lowering the pressure slowly at the end of the process, and leaving a large headspace decreased the loss of liquid in pressure-processed jars.

Oxygen or air trapped in the container of home-canned foods, particularly fruits, can be an important cause of surface darkening, off-flavors, and loss in vitamin content. Through the venting of the closure on jars of home-canned food during processing, air trapped in the headspace or in the product may be released. The type of closure and the method of processing affect the efficiency of venting in removing air from the jars. Fellers, Levine, and Maclinn (1937) presented data which indicated that partially sealed bail-type jars processed up to 20 minutes in a boiling water bath had a considerably higher vacuum than fully sealed jars. When processed in a pressure canner at 10 pounds steam pressure, both the partially sealed and the fully sealed jars had good vacuums. The vacuums in the fully sealed containers were only slightly lower than those in the partially sealed containers.

Effect of Pressure Canner Operation on Loss of Liquid

Esselen and Fellers (1948) investigated the effect of different processing procedures on venting and loss of liquid from home-canning jars. The types of pint jars and seals studied were: (1) Bail-type jar fully sealed prior to process; (2) Bail-type jar partially sealed; (3) Two-piece metal lid closure fully sealed; (4) Three-piece glass lid partially sealed prior to processing, the band being turned back one-half inch in one series of tests and one-quarter inch in another series; and (5) Zinc P/L Mason cap partially sealed prior to processing, the cap being turned back one-quarter inch. Tests conducted to demonstrate the effect of method of operating the pressure canner on the loss of liquid from the above kinds of jars and closures, using water as a test medium, are summarized in Table 2. The relative tightness of the jar seal during processing had a definite effect on the tendency of the jar to lose liquid during processing in a pressure

canner. Jars with a partial seal showed a greater loss of liquid than those that were fully sealed during processing. Faulty operation of a pressure canner, which permitted the pressure to fluctuate during processing, or too rapid cooling caused a greater loss of liquid also.

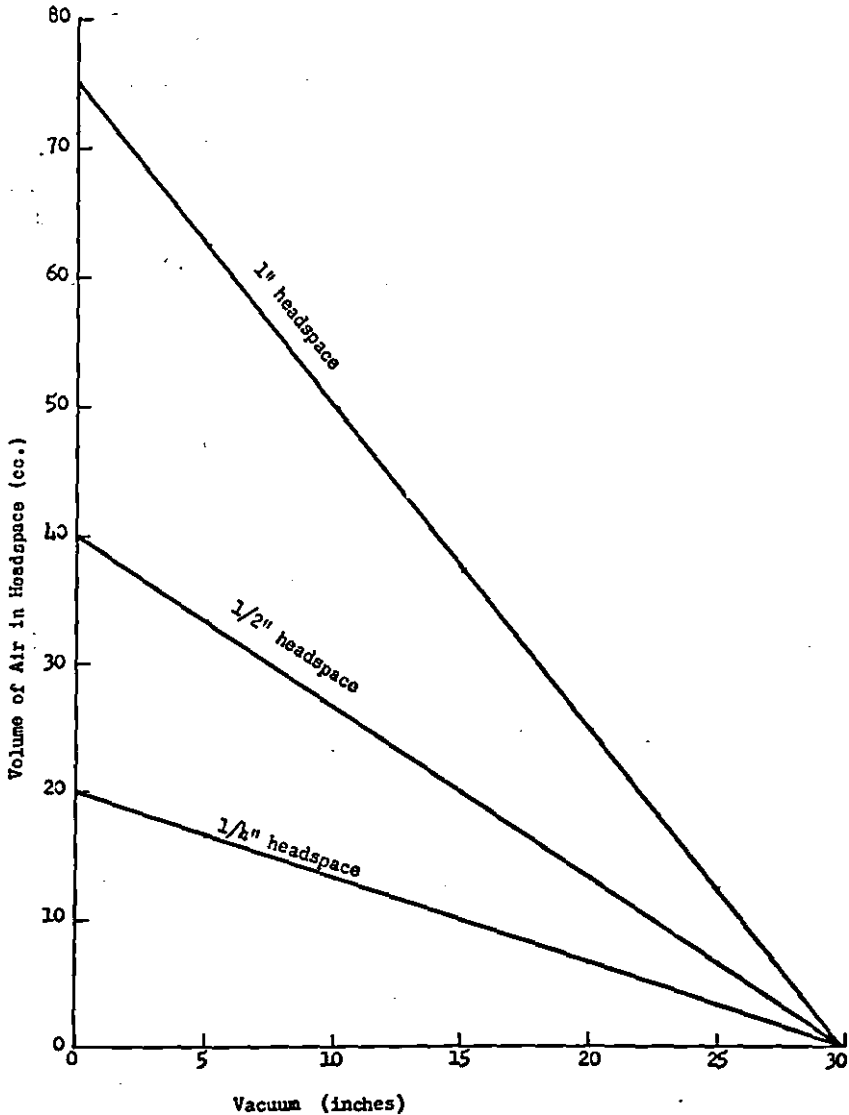


Figure 4. Relationship Between Vacuum, Headspace, and Volume of Air in Headspace of Pint Home-Canning Jar.

TABLE 2—EFFECT OF METHOD OF OPERATING PRESSURE CANNER AND TYPE OF JAR CLOSURE ON LOSS OF LIQUID FROM JARS DURING PROCESSING.
(From Esselen and Fellers, 1948.)

Method of Operating Pressure Canner	Type of Jar Closure and Volume of Liquid Lost					
	Bail Type		Two-piece Metal Lid, Full Seal	Three-piece Glass Lid,* Partial Seal	Three-piece Glass Lid,‡ Partial Seal	Zinc P/L Cap, Partial Seal
	Full Seal	Partial Seal				
	ml.	ml.	ml.	ml.	ml.	ml.
Pressure dropped rapidly after process.	7.2	22.3	3.4	2.6	35.4	26.6
Slow cool. Jars removed when pressure reached 0 pounds.	5.0	11.0	1.0	0.5	10.2	14.7
Slow cool. Jars removed 15 minutes after pres- sure reached 0 pounds.	4.5	7.9	0.5	0.0	7.6	15.2
Pressure fluctuated during processing, slow cool. .	8.8	12.5	2.2	4.2	20.0	18.6

*Metal band turned back $\frac{1}{4}$ inch to make partial seal.

‡Metal band turned back $\frac{1}{4}$ inch to make partial seal.

Effect of Processing Method on Venting Characteristics

Extensive tests were carried out by Esselen and Fellers (1948) on the effect of different processing methods, filling temperatures, and headspace volumes on the venting characteristics of home-canning jars. Pint jars were filled with (1) boiling water and (2) previously boiled water at 70°F. (21°C.), leaving headspaces of 25, 50 (approximately one-half inch), 75, and 100 cc. The jars were sealed, processed, and allowed to cool overnight. The volume of residual air in the jars was measured by the water displacement method (Maclinn and Fellers, 1936).

From 9 to 27 jars were processed in from one to three groups under each variable as indicated in Table 3 and the results represent averages of all the jars in each variable. Usual recommended home-canning procedures were followed in order to obtain information on the effect of the different factors under practical conditions. New closures, and new jars in the case of bail-type jars, were used in all tests. The total number of individual jars and closures tested amounted to approximately 6500. Table 3 summarizes the results obtained with jars filled with boiling water allowing a 50 cc. headspace. Typical effects of headspace volume and hot and cold filling are represented graphically in Figure 5. The results are reported in terms of volume of residual air rather than actual vacuum because the primary interest is the amount of air left in the jars which might be available to cause deterioration of the product during storage.

The authors summarized the results of this investigation as follows:

The data obtained in this study discuss the control of certain factors which have a direct bearing on the loss of liquid from home-canning jars during processing in a pressure canner. A loose or partial seal on the jar, fluctuation of the pressure during processing, and rapid cooling of the pres-

sure canner after processing are factors which contribute to a loss of liquid. Even with partially sealed jars good pressure canner operation can contribute markedly towards preventing an excessive loss of liquid.

To keep the loss of liquid at a minimum, the following procedure of operating the pressure canner is recommended: Maintain a constant even pressure during processing. At the end of the process time turn off the heat or slide pressure canner away from the source of heat on the stove. Allow natural cooling and do not open vent until zero pressure is reached. Open petcock or vent as soon as zero pressure is reached, then allow five minutes to elapse before opening the canner. In any event do not open canner less than 20 to 25 minutes after the heat is shut off at the end of the process period. If the canner cools more rapidly than this, it may be left on a warmer portion of the stove or on very low heat during part of the cooling period.

For fruits and other acid foods, which are usually given a short process in a boiling water bath, a partial seal on the jars permits a more effective exhaust of residual air. If a full seal is used, a hot fill and small headspace (one quarter inch) are effective in reducing the amount of residual air left in the jars after processing. With such products a loss of liquid from partially sealed jars does not present a serious problem.

On the other hand, with low acid foods that are processed in a pressure canner at 10 pounds steam pressure the use of a full seal to prevent an excessive loss of liquid will still provide satisfactory venting and permit most of the trapped air to be exhausted from the jars during processing.

Esselen and Woodward (1945) studied the effect of different kinds of containers on the retention of ascorbic acid in tomato juice. They indicated the effectiveness of venting as a means of exhausting trapped air from home-canning jars during processing. Bedford and McGregor (1948) pointed out the necessity of a good vacuum for the retention of ascorbic acid during storage of home-canned vegetables. Jars with low vacuum (2 to 5 inches), retained 4 to 32 percent of the reduced ascorbic acid, whereas jars with a good vacuum (12 or more inches) retained 50 percent or more. Clayton, Pressey, and Lees (1948) in an

TABLE 3—VENTING CHARACTERISTICS OF HOME-CANNING JAR CLOSURES UNDER DIFFERENT PROCESSING CONDITIONS.
(From Esselen and Fellers, 1948.)

Processing Method	Type of Closure and Volume of Residual Air in Headspace				
	Bail Type		Three-piece Glass Lid.	Two-piece Metal Lid.	Zinc P/L Cap, partial Seal
	Partial Seal	Full Seal	Partial Seal	Full Seal	
	cc.	cc.	cc.	cc.	cc.
Boiling water bath					
15 minutes	6.7	20.5	6.0	9.8	7.5
30 minutes	5.5	16.2	4.0	12.0	5.0
120 minutes	4.7	18.3	1.2	9.4	1.9
Pressure canner					
0-1 lb. steam, 15 min.	4.0	16.5	4.0	9.0	4.6
0-1 lb. steam 30 min.	6.2	15.5	2.0	8.0	2.8
5 lb. steam, 1 min.	5.0	11.2	3.0	10.5	2.6
5 lb. steam, 5 min.	1.2	13.4	2.3	9.2	4.1
10 lb. steam, 1 min.	2.2	5.0	0.8	11.0	3.7
10 lb. steam, 60 min.	1.0	2.2	1.2	3.2	5.2

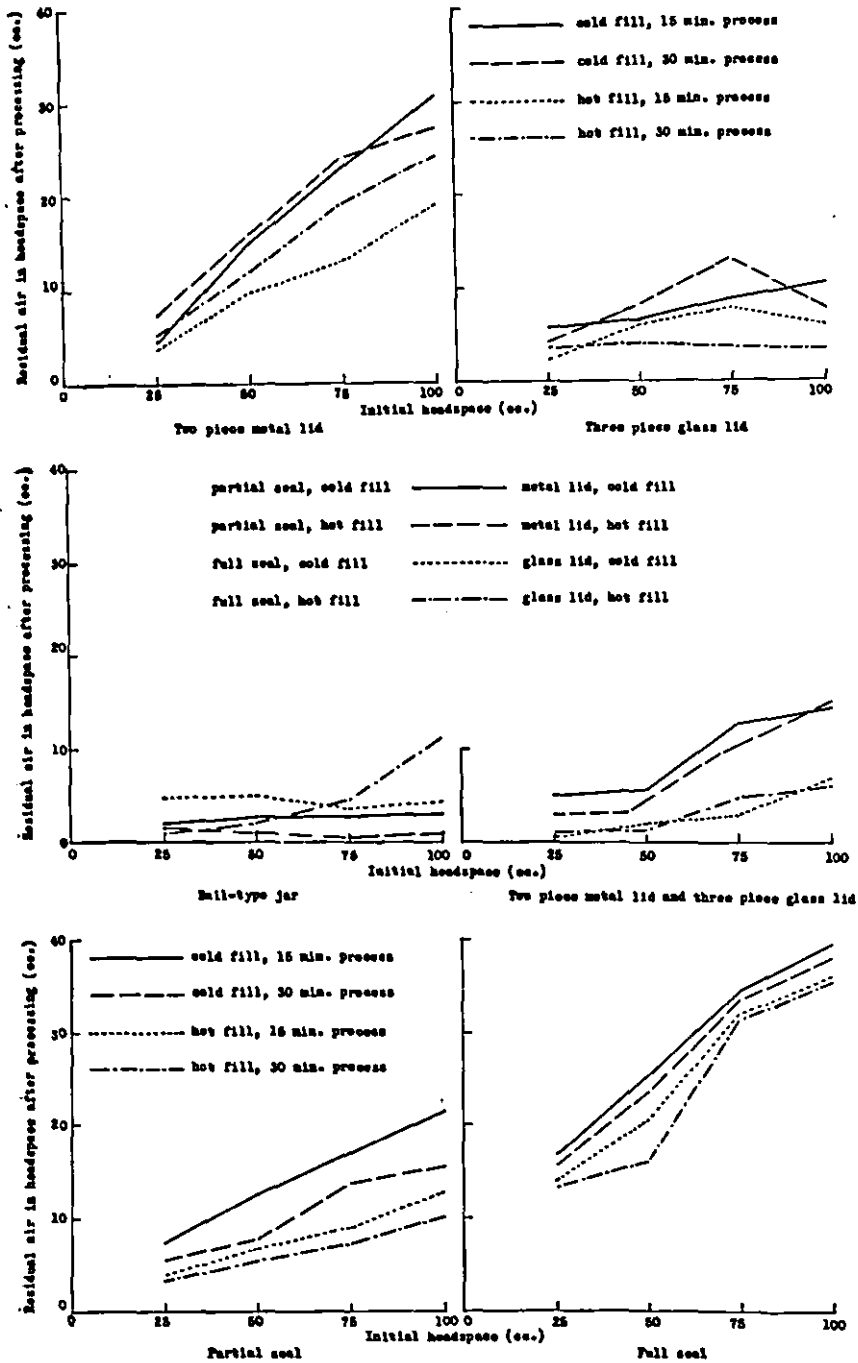


Figure 5.

Top: Volume of Residual Air in Headspace of Home-Canning Jars Processed in Boiling Water Bath.

Middle: Volume of Residual Air in Home-Canning Jars Processed One Hour at 240°F. in a Pressure Canner.

Bottom: Volume of Residual Air in Fully and Partially Sealed Ball-Type Home-Canning Jars Processed in Boiling Water Bath.

investigation of the vitamin C content of home-canned tomatoes showed that a partial seal during processing gave significantly higher vitamin C values than a complete seal. They also pointed out, as have others, that a somewhat higher vitamin C retention occurred in tomatoes canned in tin cans (or possibly glass jars with tin-lined caps or tin insets). From seal and headspace studies on home-canned asparagus, Dawson, Gilpin, Toepfer, and Batchelder (1949) reported that from the standpoint of liquid retention and palatability the most satisfactory method of processing was to exhaust and seal the jars completely before processing. From the standpoint of ascorbic acid retention, the three methods, (1) no headspace, partial seal, (2) one-half inch headspace, partial seal, and (3) one-half inch headspace, exhausted, and completely sealed, were about the same.

Baragar (1949) investigated the liquid loss from glass jars processed in a pressure canner and obtained results essentially similar to those previously reported by Fellers, Levine, and Maclinn (1937), Esselen (1946), and Esselen and Fellers (1948).

CAUSES OF FAILURE IN HOME-CANNING JARS

Breakage

If home-canning jars are used correctly, there is little reason to expect trouble from breakage. However, a brief discussion of the causes of breakage should be of value to persons engaged in teaching home-canning methods and to home canners. Such an appreciation of the factors involved should encourage correct handling of jars in home canning and a reduction or elimination of failures due to breakage. Breakage in home canning may be caused by (1) thermal shock, (2) pressure, or (3) impact.

Thermal Shock

As its name implies, thermal shock breakage is caused by subjecting jars to a sudden change from cold to hot or hot to cold. Home-canning jars can be expected to stand a thermal shock of at least 70°F. That is, if a jar at a room temperature of 70°F. is suddenly filled with food at a temperature of 140°F., it is subjected to a thermal shock of 70°F. An excessive thermal shock may cause breakage because the portion of the glass in direct contact with the hot product expands more rapidly than the cooler portions of the glass next to it.

Home-canning operations such as pouring a hot product into a cold jar or placing a cold jar of product into boiling water are common causes of thermal shock breakage. Such breakage may also occur if the hot processed jars removed from a pressure canner or boiling water bath are placed on a cold surface or are accidentally spattered with cold water.

Typical thermal shock breakage is usually characterized by a crack running around the base or lower part of the jar and sometimes extending up the side. Illustrations of thermal shock breakage are shown in Figure 6. If breakage of this type occurs, one may suspect that the jars were improperly handled by subjecting them to an excessive temperature shock at some step or steps during the washing, filling, processing, and cooling operations.

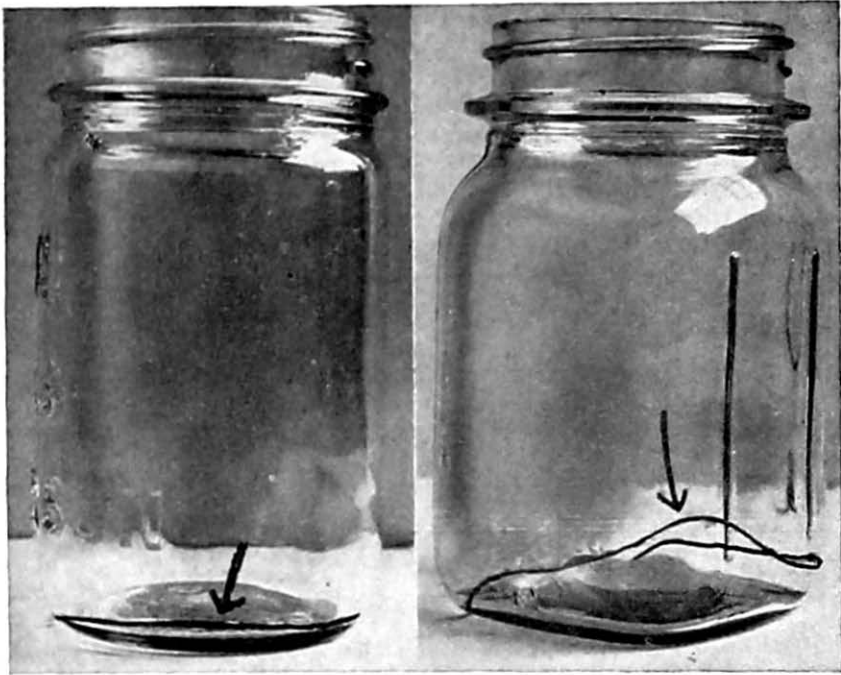


Figure 6. Thermal Shock Break.

Pressure Breakage

Pressure breakage is caused by the development of a sufficiently high pressure within the container. When properly used, most home-canning jar closures vent off internal pressures at a relatively low pressure and prevent excessive internal pressures from being developed. Such breakage occurred during the last war when jars with the three-piece glass lid were fully sealed and processed in an oven — two practices which are definitely not recommended. Pressure breakage may also result when juices are processed in bottles sealed with a crown-type cap if sufficient headspace is not left in the bottle to permit expansion of the contents during heating.

Typical pressure breakage is usually characterized by the break originating on the side of the container in the form of a vertical crack which, as it progresses in both directions, divides and forks into two fissures. These fissures in turn may continue to divide or fork many times as illustrated in Figure 7.

The occurrence of pressure breakage during the canning operation is definite evidence of a faulty practice which permits excessive pressures to develop within the container. Such breakage should not occur when recommended canning procedures are followed.

Impact Breakage

Impact breakage is a term which may be applied to breakage caused by the contact of mechanical force with a jar, such as dropping, or hitting or bumping

by another jar or hard object. Breakage under such conditions does not follow definite patterns of thermal shock and pressure breaks. The fissure may radiate in all directions from a central point or origin of the breakage. This point is frequently at the point of contact of the force causing the breakage. The immediate cause of such breakage is usually obvious and can be attributed to carelessness or excessively rough handling.

Uneven Sealing Surfaces and Checks

It is important that the sealing surface of the jar be uniform, level, and even in order to make contact at all points with the sealing rubber or compound in



Figure 7. Pressure Break.

the closure; otherwise a faulty seal with subsequent leakage may result. Jars occasionally show a depression or dip in the sealing surface. If the dip is not too great, the jars will still seal. However, if it is too deep, the gasket or sealing compound in the lid will not make a tight seal with the sealing surface. This condition is illustrated in Figure 8. Metal lids which do not show an indentation in the sealing compound at all points after processing often provide evidence of an uneven sealing surface, and the jars should be inspected and discarded if faulty. Uneven sealing surfaces can also be detected by placing the jar with the sealing surface against a flat surface. If the sealing surface does not make contact with the flat surface at all points or if the jar may be "rocked" excessively, it is evidence of an uneven condition.

Checks are small fissures or cracks which extend through the glass, usually at the sealing surface as illustrated in Figure 9. Because they are not readily detected, it is suggested that in looking for checks, the jar be held in the hands and rotated in a bright light or near a window. Minute as they are, checks will often permit the passage of air and bacteria into the jar after processing, with

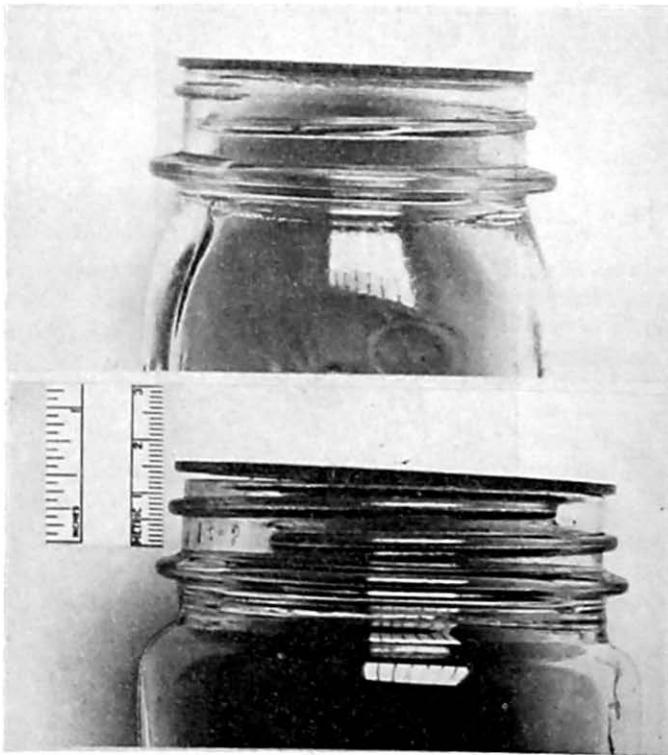


Figure 8.

Top: Jar with Even Sealing Surface.

Bottom: Jar with Dip in Sealing Surface.

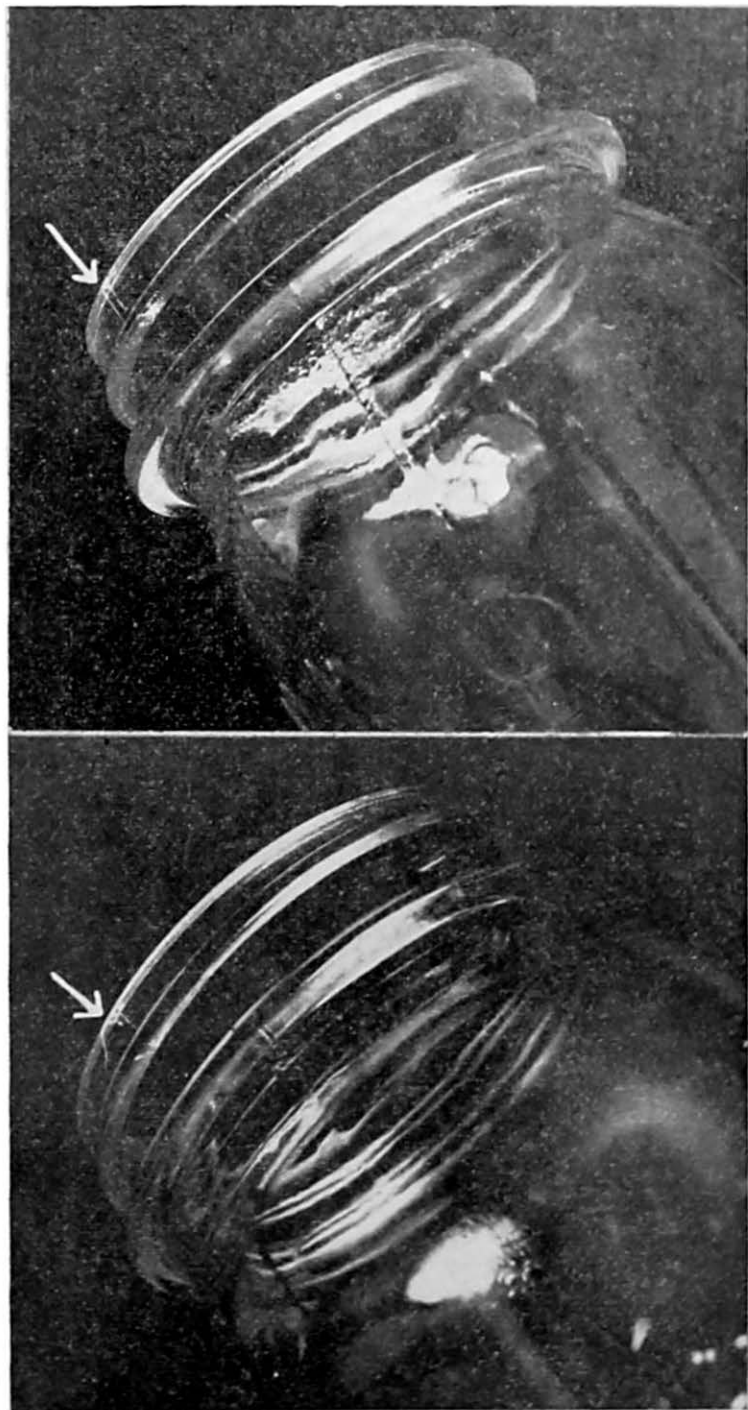


Figure 9. Check in Sealing Surface.

subsequent loss of vacuum and spoilage. In inspecting jars for use prior to canning, attention should be paid to detect the presence of checks. All faulty jars should be discarded.

Uneven sealing surfaces and checks are infrequent in the home-canning jars on the market today because of the inspection given the jars at the point of manufacture. However, faulty jars can be a source of annoyance and spoilage unless the fault is detected and the jars are discarded. In field studies, cases have been reported where the home canner blamed a metal lid or closure as being at fault rather than the jar. The jar would then be emptied, cleaned, and used again for canning. Such a procedure would result in occasional "faulty seals" throughout the canning season, owing to the presence of only one or two jars with checks or a bad uneven sealing surface which were repeatedly re-used. In any case of faulty seals or spoilage apparently due to seal failure, one should carefully inspect the jar as well as the closure. If the jar is at fault, it should be discarded rather than being returned to the stock of good canning jars.

Stones

Occasionally a jar may contain a piece of non-glassy material embedded in the glass. This material, known as a "stone," is usually undissolved silica, an ingredient of the glass. Owing to their difference in composition and properties from the glass itself, stones make the jar vulnerable to temperature shock breakage at that point. A jar showing a stone and breakage caused by temperature shock is illustrated in Figure 10.

TIN CANS

Types of Cans

Two sizes of tin cans are commonly used in home canning: the No. 2 can which holds about 20 ounces or $2\frac{1}{2}$ cups and the No. 2 $\frac{1}{2}$ can which holds about 28 ounces or $3\frac{1}{2}$ cups. Three types of finish are generally used for canning: plain tin, C-enamel, and R-enamel (sometimes called Standard enamel). Although the type of finish in the can does not influence the wholesomeness of the product, the use of enameled cans is recommended for some products in order to prevent discoloration or loss of color in plain tin cans. Thus, for top quality the right type of can should be used for each product. C-enamel cans prevent a gray or black discoloration of low-acid products containing sulfur. The R-enamel cans prevent the loss of color in highly colored fruits and beets packed in plain tin cans. According to the United States Department of Agriculture (1946a, 1947) Jarvis and Puncochar (1942), the following types of cans are recommended for various products:

C-enamel cans—green lima beans, carrots, corn, and certain sea foods such as shellfish and crustaceans.

R-enamel cans—beets, berries, red cherries, fruit juices, plums, pumpkin, rhubarb, sauerkraut, squash, strawberries, sweet potatoes.

Plain tin cans—apples, apricots, asparagus, beans (green and wax), light cherries, fish, meats and poultry, okra, peaches, pears, peas, spinach, tomatoes.

When C-enamel cans are used for packing acid products, such as fruits and spiced fish, the enamel may peel off. This condition does not affect the edibility of the product, but it is unsightly.

As with glass jars, it is important that the cans, lids, and gaskets be in good condition. Badly bent, dented, or rusty cans or lids with scratched or torn gaskets should be discarded.

Exhausting

Unlike glass home-canning jars, tin cans are tightly sealed and do not vent during processing. Therefore, tin cans are "exhausted" or heated, after being filled and before being sealed. The temperature of the food in the can should



Figure 10. Jar Showing Stone and Break Caused by Temperature Shock.

be 170°F. or higher when the cans are sealed. The food is heated to expel air and thus help prevent discoloration and loss of flavors. Sealing the cans hot also prevents excessively high internal pressures from being developed within the container and consequent bulging of can ends and damage to seams during processing.

The filled cans then can be exhausted and heated to appropriate temperature before sealing by placing them in a kettle of boiling water 2 inches from the can tops. A cover should be placed on the kettle, and the water maintained at boiling temperature. A thermometer can be inserted in the center of a can at frequent intervals to determine when the sealing temperature of 170°F. is reached. At this point the cans are removed from the kettle and sealed immediately.

With some products the desired sealing temperature of 170°F. or higher can be reached by filling the product hot and sealing the cans immediately.

Sealing

A mechanical sealing machine is required to seal tin cans. Several types of small hand-operated sealers are available on the market. It is essential that the sealer be in good working order; otherwise faulty seals may be obtained which will result in leakage and subsequent spoilage of the product. The sealer should be maintained and checked for correct adjustment before, and at frequent intervals during, the canning season by following the instructions provided by the manufacturers. A detailed description of can seals and sealing machines has been published by the United States Department of Agriculture (1946b).

The United States Department of Agriculture (1947) suggested a test for further checking the adjustment of the sealer: "To test, put a little water into a can, seal it, then submerge can in boiling water for a few seconds. If air bubbles rise from the can, the seam is not tight."

Processing and Cooling

Cans may be processed in a pressure canner or boiling water bath in the same manner as glass jars. At the end of the process when the pressure in the pressure canner has dropped to zero pounds or at the end of a boiling water bath process, the canner is opened, and the cans are immediately placed in clean cold water to cool. Use as much water as necessary to cool them rapidly. The cans should be removed from the cooling water while they are still slightly warm so they will dry in the air.

EFFECT OF STORAGE TEMPERATURE ON QUALITY OF HOME-CANNED FOODS

Although foods may be effectively preserved from microbial spoilage by various means, deterioration due to chemical changes may still take place during storage. These changes include destruction of vitamins, loss of flavor and color, and the development of off-flavors and colors. The velocity of most chemical reactions about doubles for every 18°F. rise in temperature; therefore, it is not surprising to find that the ultimate quality of most canned foods is dependent upon the temperature at which they have been stored.

In a recent review of available information on the relationship between storage

temperatures and quality of processed foods, McConnell, Fellers, and Esselen (1946) summarized these findings as follows:

Storage of canned foods at low temperatures is very effective in preventing deterioration and losses because of corrosion, discoloration, loss of color, flavor, texture, or the development of off-flavors and off-colors. It appears from the available data that 50°F. or less would be preferable for the storage of canned foods, although controlled storage up to 70°F. would result in products superior in quality to those handled in the usual manner of today. Of the vitamins, ascorbic acid, thiamine and carotene are most affected by the storage temperature. There are also reports that vitamin P and pantothenic acid are destroyed during storage at high temperatures. Riboflavin and niacin are quite stable although the former has been found to be destroyed at high temperatures. In general, storage at low temperatures to retard the organoleptic deterioration of canned foods will also prevent excessive losses in vitamin content.

Thus research findings have confirmed the frequent recommendation that home-canned foods should be stored in a cool place. Cool storage is particularly worthwhile if the products are to be stored for long periods. Cool basements or pantries provide ideal storage places for home-canned foods, provided the temperature does not drop to below freezing. Although freezing is not harmful, it may cause the food to become softer in texture; but if the food expands sufficiently during freezing to break the seal or container, it will be susceptible to spoilage.

PREVENTION OF SURFACE DARKENING

The greatest skill and care exercised by the homemaker in home canning sometimes fails to produce a top-quality product because of inherent characteristics of the food itself. Susceptibility to surface darkening is one of those characteristics. Not only is it unattractive, but it may also affect the flavor of the food when it proceeds to any appreciable degree. This discoloration is particularly noticeable in peaches, pears, apple sauce, and certain other light-colored products. Until recently, the cause of this discoloration was unknown. Experiments in this laboratory have demonstrated that canned foods with a low content of ascorbic acid (vitamin C) are the worst offenders. The oxygen (from air) in the headspace of the container combines with any ascorbic acid present. When there is sufficient ascorbic acid, the oxygen is thus used up. However, when there is insufficient ascorbic acid to unite with all the oxygen, the latter oxidizes the food itself and impairs both color and flavor.

Obvious methods of eliminating oxygen from the headspace of the container are:

1. Blanching or scalding the product before filling into the container.
2. Exhausting or preheating foods packed in tin cans before sealing.
3. Filling the container so as to leave no air pockets and only the minimum headspace required.
4. Adding boiling hot water, salt brine, or syrup to the foods.
5. Using a type of home-canning jar and closure which will permit a maximum amount of air to vent out during processing.

In practice some air usually remains in the sealed and processed jar of food in spite of everything that can be done. Through extensive investigations in this laboratory by Powers, Esselen and Fellers (1943) and Powers and Fellers (1945) and by Bauernfeind, Batcher and Shaw (1947), it was shown that small amounts

of ascorbic acid (vitamin C) added to home-canned fruits acted as a preferential oxygen receptor thereby combining with headspace oxygen before it had time to cause a deterioration of the product. Surface darkening and the development of oxidative off-flavors — prevalent quality defects of home-canned fruits — were entirely prevented by the addition of l-ascorbic acid (vitamin C), d-iso ascorbic acid, or d-gluco ascorbic acid at the rate of 125 milligrams per pint jar. The incorporation of a known amount of ascorbic acid in tablet form was demonstrated to be a simple and practical way for the housewife to add a measured amount of ascorbic acid to each jar.

Today preparations of ascorbic acid, designed especially for use in home canning and freezing, are available in some localities. If such a material is not available, the ordinary vitamin C or ascorbic acid tablets sold in drug stores can be used for this purpose. Since each tablet is made to contain either 25, 50, or 100 milligrams of ascorbic acid and since the unitage must be declared on the label, it is easy to determine the number of tablets needed for a pint jar: $1\frac{1}{4}$ tablets of 100 milligram (2000 I.U.) potency, or $2\frac{1}{2}$ tablets of 50 milligram (1000 I.U.) potency, or 5 tablets of 25 milligram (500 I.U.) potency. If the vitamin C content is declared in terms of International Units (I.U.) rather than in terms of milligrams, one need only divide by 20 to convert the International Units into milligrams. At current prices for ascorbic acid tablets such surface discoloration can be prevented at a cost of less than two cents per jar.

SEPARATION OF TOMATO JUICE

Tomato juice enjoys an important place in many home-canning programs on a basis of its palatability as well as its importance as a source of ascorbic acid (vitamin C). Quite often home-canned tomato juice separates considerably that is, the red solids settle to form a layer in the lower portion of the container while a clear pale yellow juice remains in the upper portion. Many homemakers object to the appearance of tomato juice which shows a marked degree of settling even though it is perfectly good. From time to time complaints have been received that such juice was "curdled."

Tomatoes like other fruits contain pectin, a substance which acts as a stabilizer in the juice and gives it body. It also tends to prevent the separation of the solid particles from the liquid, keeping them suspended in the liquid rather than allowing them to settle to the bottom leaving a clear yellow liquid at the top of the jar. Tomatoes also contain a very active enzyme which is liberated from the plant cells when tomatoes are cut. This enzyme causes a degradation of the stabilizing qualities of the pectin. This action may be prevented or minimized if the enzyme is destroyed by heat soon after the tomatoes are broken up or cut. Wildman (1930), Kertesz (1938), and others have shown that 70 percent or more of the pectin may be degraded if tomatoes are cut up or crushed and allowed to stand for even a few minutes before being heated. Thus, if the tomatoes are heated to boiling very rapidly after being cut up or are crushed as they are being heated, prior to the extraction of the juice, the enzyme is destroyed before it can react with a significant proportion of the pectin. On the other hand, if the tomatoes are cut or crushed and allowed to stand, or if they are cut and pressed

through a strainer to extract the juice before heating, a considerable amount of the pectin is degraded, and the resulting juice has a greater tendency to settle out as illustrated in Figure 11.

Though it may not have as much body as a tomato juice that was made from hot-extracted tomatoes, tomato juice showing excessive separation is quite satisfactory if shaken or mixed just before it is used. The above precautions for preventing separation and maintaining body in tomato juice also hold for juice which is being prepared to be concentrated in the preparation of catsup, puré, or tomato paste or sauce where a good body is a desirable characteristic of the product.

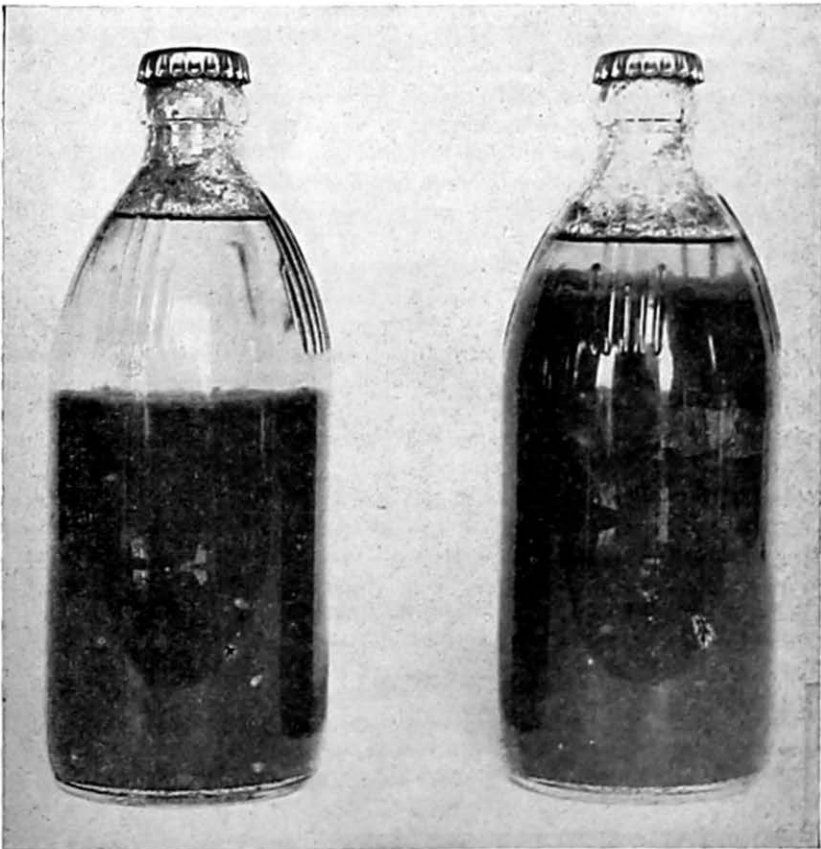


Figure 11. Effect of Method of Extraction on Separation in Tomato Juice.

Left: Tomatoes Not Heated to Boiling Immediately After Being Cut.

Right: Tomatoes Cut and Heated to Boiling Right Away.

DIAGNOSIS OF CAUSES OF HOME-CANNED FOOD SPOILAGE

A case history of the spoiled product is very valuable in diagnosing the cause of spoilage. The use of a questionnaire to be filled out by the home canner or person submitting the spoiled container has been found to be very useful. The information requested should include such things as:

1. Canner's name, address, date
2. Product
3. Date canned
4. Why is the product considered spoiled?
5. Source of raw material: home garden; local produce; shipped in
6. Length of time held before canning
7. Canning procedure used:
 - a. Preparation of raw material. Was it blanched?
 - b. Processing method—pressure canners, boiling water bath, oven—how long? What temperature and pressure?
 - c. If a pressure canner was used, was it adequately vented? When was pressure gauge last tested?
 - d. Was copper or iron equipment used in the preparation of the product?
8. How soon after processing did the spoilage occur?
9. Temperature of storage (cool, medium, or warm)
10. If a jar, was a full or partial seal used during processing?
11. Was spoilage confined to one or two jars of a batch or did the majority of jars spoil?
12. How long were jars, closures, or cans stored before being used?

In determining the cause of spoilage, all the various factors that might contribute to it must be considered. With home-canned foods it has been observed that frequently the cause of trouble is quite obvious after a study of available evidence. In other cases a rather complete laboratory examination by an experienced technologist is indicated. Such an examination involves a careful physical examination of the container and closure as well as bacteriological and chemical tests on the product itself.

An outline for the laboratory examination of canned foods has been presented by the Association of Official Agricultural Chemists (1945). Leverenz and Williams (1945) have presented a simplified outline on the cause and prevention of spoilage and poor quality in home-canned foods. Spoilage in canned foods, its prevention and diagnosis, has also been discussed in detail by others, including Townsend (1945), Baumgartner (1949), and Tanner (1944).

SUMMARY

From available information, it would appear that the incidence of spoilage in home-canned foods is remarkably low in view of all the factors that may be involved. It has been estimated that spoilage in home-canned foods during the past few years has ranged from 0.5 to as high as 8 or 10 percent in some cases. In preventing and reducing home canning troubles, procedures, techniques and equipment must be made as foolproof and safe as possible so far as the housewife is concerned. Every effort should be made to eliminate the pitfalls that may be encountered by home canners. In this respect, serious consideration should be given to improve the methods of dealing with the human element in home canning and of impressing upon people the necessity for obtaining directions for correct canning procedures and for following all directions explicitly.

In the preceding pages have been presented some of the factors to be considered in good canning procedures with emphasis on sources of trouble and how they may be avoided. This information should also be useful to persons concerned with home-canning programs in diagnosing and preventing some of the troubles that may be encountered by home canners.

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