



A study of the quality and bacterial content of home canned peas as affected by varied methods and periods of processing
by Mary Esther Evans

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Montana State University
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Abstract:

1. In this study of home canning, peas of the Laxtonian and Perfection varieties were used. The Laxtonian peas were shelled by hand in the laboratory, while the Perfections were shelled by machine in the field.

2. The peas were processed by three different methods and for varied periods, as follows:- Oven method - 90, 120, 150, 180 and 210 minutes* Water bath method - 180, 216, 252, 288 and 324 minutes. Pressure cooker method - 30, 40, 45 and 50 minutes.

3. The tests that furnished the data for this study were carried out at an altitude of about 5000 feet above sea level, where the temperature of boiling water varies from 202° to 204° P.

4. The percentages of spoilage occurring in the peas canned by the various methods and periods were as follows: Oven - Laxtonian - 90 minutes - 72.7% " 120 " 90.9 " 150 " 16.7 " 180 " 40.0 Perfection 210 " 51.4 Water Bath - Laxtonian - 180 minutes - 36.4% " 216 " 8.3 Perfection 216 " 70.8 Laxtonian 252 " 8.3 Perfection 252 " 46.2 Laxtonian 288 " 0.0 Perfection 288 " 9.6 Laxtonian 324 " 8.8 Perfection 324 " 4.2 Pressure Cocker — No spoilage So All of the jars of peas were examined for "bacterial content-. The organisms isolated from the spoiled peas were mainly spore-forming facultative aerobes, often found in soil.

The higher rate of spoilage noted in the Perfection peas that were shelled in the field confirms other experimental work which has shown the relation between spoilage in peas and soil contamination.

7. When the unspoiled peas were judged for palatability, those processed for the higher water bath periods, 283 and 324 minutes, and some of the peas processed in the pressure cooker for 50 minutes were scored higher than the others.

8. Many peculiar flavors were noted by the judges. It is suggested that one of these, a "beefy" taste, may be associated with a glutamate having a meat-like flavor.

9. The penetrometer tests showed that the majority of the peas, processed by all the periods and methods, tended to be too soft rather than too hard.

10. The color of the canned peas, as determined by comparison with standard color disks, was found to undergo a decided change during six months* storage in the dark* This color change was attributed to the destruction of chlorophylls in the oven-canned peas processed for periods ranging from 90 minutes to 210 minutes, spoilage occurred to such an extent that this method with the periods used cannot be recommended. The quality of the peas did not prove desirable, and the probability of success from lengthening the periods of processing by this method is not indicated.

12. The amount of spoilage among the jars of peas processed by the water bath method for periods of 180, 216, and 252 minutes was too great to permit the recommendation of these periods of processing by the water bath method at an altitude of about 5000 feet, The quality of the unspoiled peas seemed to indicate that further extension of the processing period would produce satisfactory results.

15. The loss from spoilage of -the peas, processed by the water bath method for the two longer periods, 288 and 524 minutes, was no greater than the amount which might be expected to occur because of slight imperfections in the equipment for home canning. The quality of these peas was judged to be good, in regard to palatability, texture, and appearance.

14. There was no spoilage among the pressure cooked peas for any of the processing periods. However, the 50 minute period peas were more pleasing in flavor than those processed for shorter periods, and were comparable to peas processed by the water bath method for 288 and 524 minutes.

A STUDY OF THE QUALITY AND BACTERIAL CONTENT
OF HOME CANNED PEAS AS AFFECTED BY
VARIED METHODS AND PERIODS
OF PROCESSING

by

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TABLE OF CONTENTS

	page
INTRODUCTION	3
HISTORY	4
EXPERIMENTAL PROCEDURE	16
Methods of canning and processing	16-21
Methods of examination	21
The grading chart for palatability scoring . .	22
The penometer used in determining tenderness	24
Procedure for bacteriological analysis	25
RESULTS	26
Percentage of spoilage and bacterial content .	27
Palatability scores	30
Peculiarities of flavor	32
Relative tenderness	33
Color notations	35-36
Certain physical and chemical properties of unspoiled peas	39
Certain physical and chemical properties of spoiled peas	41
DISCUSSION	42
SUMMARY	53
CONCLUSION	56
ASKNOWLEDGMENTS	57
LITERATURE CITED	58-60

A STUDY OF THE QUALITY AND BACTERIAL CONTENT OF
HOME CANNED PEAS AS AFFECTED BY VARIED METHODS AND
PERIODS OF PROCESSING

INTRODUCTION

Among the most popular products of the home garden are green peas which have for a long time been considered a choice vegetable. Unfortunately the season during which fresh peas may be enjoyed is comparatively short. It is therefore desirable to preserve them in such a way that they will retain their original palatability to the greatest possible degree.

Homemakers have long been aware of the existing problems connected with canning peas, for frequent spoilage has proved their present methods unsatisfactory. Whether this spoilage is due to canning conditions, to the kinds of bacteria present, or to the nature of the vegetable itself is a question which has not as yet been satisfactorily answered. That the nature of the vegetable complicates the problem is quite possible, since peas with their highly concentrated protein and carbohydrate content, and their necessary exposure to contamination through the shelling process are quite different from other vegetables which are ordinarily preserved.

In the study of home canning there has apparently been little effort made to determine by experimental procedure wherein one method or period of processing is superior to an-

other, either in prevention of spoilage or in preservation of desirable quality. It is evident therefore that a comparison of the results of canning peas by varied methods and periods of processing is necessary in order to solve many of the home problems which are connected with the successful preservation of this vegetable.

HISTORY

The early studies of canned foods were concerned with spoilage. There was little difficulty in detecting spoilage, for it was made evident by the undesirable changes which had occurred in the canned food. An excessively soft or discolored product, having a disagreeable odor, and often containing gas bubbles, has always been treated with suspicion by (any) homemaker.

According to Sunderlin, Levine, and Nelson (27) who made a study of indices of spoilage, physical evidence is still the most reliable criterion for spoilage determination. In their laboratory, physical tests consisted of observations of odor and records of suction. Despite the apparent accuracy of physical tests, however, it was concluded that it would be necessary to use both chemical and bacteriological methods to detect all kinds of spoilage.

Chemical methods for spoilage determination as used by

these workers included tests for total acidity, measurement of hydrogen ion concentration and formol titration. Though the results of these tests were not in themselves conclusive they were considered valuable supplements to the other methods.

Bacteriological tests depend on examination of stained smears made directly from the canned food, and the culture of a sufficient quantity of the suspected material. Such studies are more valuable in determining the cause of spoilage than in proving its existence. In 1921 Lang (18) pointed out that home canned products in first class condition were not necessarily sterile, but frequently contained spores which did not cause spoilage, provided the can had a good vacuum and a tight seal. This being accepted, the mere presence of bacteria cannot be absolute proof of spoilage.

For the most part, commercially canned foods have been the subject of these spoilage studies under the leadership of the National Cannery Association. However, some studies have been made on home canned vegetables of the non-acid group, to which peas belong. Sunderlin (27), Lang (18), and Normington (22) have described specific bacteria isolated from canned peas or vegetables of comparable acidity. The organisms most frequently found were aerobic bacteria, which group includes *Bacillus subtilis*, *B. megatherium*, *B. mesentericus*, *B. vulgatus*, *B. cereus*, *B. mycoides*, and others. Anaerobes and thermophiles of many sorts have also been described as causative organisms

in spoilage of canned vegetables.

Identification of the organisms isolated from canned foods helps to ascertain the source of contamination. Normington (22) on finding chiefly soil organisms of the Bacillaceae family assumed that most spoilage bacteria in canning came from the soil. She therefore suggested that the organisms gained entrance to the products through soil or dust on pods transferred to the peas in shelling, dirt from the hands of the shellers, peas dropped on the floor and picked up, or dust settling on the peas during storage before canning.

One of the factors affecting the number of organisms present during the canning process is the condition of the material to be canned. All workers emphasize the maintenance of cleanly conditions during the preparation of the products for canning. Normington (22) cites lack of careful handling and the resultant soil contamination as conditions largely responsible for high bacterial content.

Nearly all bulletins, containing general canning instructions, carry the injunction to can fresh material. If the raw food is kept for some time before canning, the opportunity for multiplication of the bacteria present is great, particularly where there is warmth, moisture, and darkness, so that a delay of even a few hours markedly complicates the problem of successfully processing the product.

Certain unknown quantities increase the difficulty of

applying bacteriology to the solution of canning problems. Most important of these is the initial concentration of spoilage bacteria. Wide variations in this concentration prevent recommended processing methods from being altogether exact and constant (15). This effect of numbers has been consistently demonstrated in heat-resistance studies in the Research Laboratories of the National Cannery Association (4).

Methods of processing canned foods have an important bearing on spoilage percentages, since the destruction of spoilage bacteria is dependent on the effectiveness of the processing method. Processing designates the heat treatment which the product undergoes after the material is placed in the covered can. Very little experimental work has been done to show the relative merits of the different home methods which are in common use,- open kettle, water bath, pressure cooker, and oven processing.

When the open kettle process is used the canning material is thoroughly cooked in an open kettle and while hot is packed into jars which have been thoroughly scalded. The jars are at once completely sealed. Both the adequate cleansing of the jars by scalding and the high temperature of the canning material at the time when the jars are filled, are factors in the success of the open kettle process. Most important, however, is the acidity factor. By general experience the conclusion has been reached that only those foods, such as fruit, which

have a relatively high acid content, can be safely processed by the open kettle method.

The water bath method of processing is also carried out at the temperature of boiling water. The food may or may not be precooked, that is, given a short heat treatment before being placed in jars. After being filled and sealed, the jars are immersed in a boiling water bath, and are allowed to remain for the length of time recommended for the particular food which is being canned.

The pressure cooker method also requires that the food be packed in the jars, with or without precooking, before being placed in the pressure cooker. The food is then subjected to a relatively short period of heating by means of steam under pressure. The temperature maintained in the pressure cooker is considerably above the boiling point of water, the recommended temperature for peas being 240° F. The higher temperatures obtainable in the pressure cooker have made this method appear essential for processing those foods which are admittedly difficult to can successfully. Since the initial cost of the pressure cooker practically prohibits the ownership of this piece of equipment in many cases, it seems desirable to make a careful comparison of this method with the less expensive methods of processing.

Oven canning is the most recent processing method. The jars are filled with food which has been precooked, and are

sealed before being placed in the oven. Although the oven temperature is kept at about 250° F. there have been no data reported in the literature concerning the internal temperature reached.

Experimental data to show the relative effectiveness of these methods of processing are not extensive. Normington (22) has carried out some experiments in canning vegetables by the water bath and pressure cooker methods. Her results indicate that there is very little difference in amount of spoilage in the pressure cooked vegetables and those processed by the water bath method.

An important condition affecting the occurrence of spoilage in canned foods is acidity, mentioned above in connection with open kettle processing. Peas, as typical non-acid vegetables, are never canned by the open kettle method, and it is the recommendation of the United States Bureau of Home Economics (26) that peas be processed solely by the pressure cooker method. Some workers, however, have proposed the addition of acid to non-acid foods in order that such foods may be processed at a temperature of 212° F. Cruess (9), after demonstrating by experimental work that lowering the pH decreased the amount of sodium benzoate required to prevent the growth of certain organisms, concluded that the preservation of non-acid foods might be greatly facilitated by the addition of acid. Skinner and Glasgow (24) have made practical application of

Cruess' suggestion in the home canning of asparagus. By the use of vinegar the processing time at 212° F. was reduced from three hours to one and one-half to two hours, with an accompanying decrease in the percentage of spoilage over that occurring when no acid was used. By bacteriological examination it was found that those jars treated with acid showed the presence of organisms less frequently than did those not treated. Whether or not the amount of acid added detracts from the normal flavor of the product is still in question.

Conditions of altitude are also known to affect the success of canning processes, particularly those in which steam pressure is not used. In the case of water bath processing, provision has been made for canning at higher altitudes by a general theory based on physical laws. This rule, as given by the United States Bureau of Home Economics (26), is "for all altitudes above 1000 feet the time should be increased 20 per cent for each additional 1000 feet." For oven canning a time increase of 50 per cent is recommended. Unfortunately there are no data to show the comparative effectiveness of pressure processing, oven, or water bath processing for prolonged periods.

The effect of storage on spoilage of canned goods has been merely mentioned by most writers reporting spoilage studies. Some experimental work on this subject was done by Biester, Weigley and Knapp (2) at the University of Minnesota in 1920. Several different kinds of vegetables, both acid and

non-acid, were processed by the water bath method. Some jars were stored in an ordinary root cellar for four months, some were stored in a bacteriological incubator for ten days, while others were stored in the root cellar for ten days. The keeping quality of the canned products was judged according to taste by the members of the Home Economics instructional staff. Results showed that the greatest percentage of spoilage took place in the jars stored for 10 days in the incubator. One of the conclusions was that storage conditions may markedly affect the percentage of spoilage. The desirability of storage immediately after canning was also indicated.

By far the greater number of the studies which have been made on canned foods have been related to spoilage and its causes. Only recently has the quality of unspoiled canned foods been investigated. However, before studies of quality can be made some standards of quality must be adopted. These have been supplied for use in judging many of the common fruits and vegetables by the Food and Drug Administration of the United States Department of Agriculture (11). The standard of quality and condition for canned peas is given as follows:- "Standard canned peas are the normally flavored and normally colored canned food consisting of the tender, immature, unbroken seed of the common or garden pea (*Pisum sativum*), with or without seasoning (sugar, salt), and with or without added potable water. The product is practically free from foreign material

and, in the case of products containing added liquid, the liquor present is reasonably clear."

The varieties of peas for canning should be chosen to conform to these requirements inasmuch as the quality may be affected by the variety. The Association of New York State Canners, Inc. has stated that the varieties of peas preferred for canning consist of an early variety having a smooth skin, and later varieties, sugar peas or sweet peas, having a wrinkled skin and sweet flavor (20). In regard to variety of seed, studies have also been made to determine the relative percentages of hard shell in peas and bean varieties (12). Hard shell, or the presence of impermeable seeds, was recognized by permeability tests in which there was evidence of great variation in the resistance of seed coats to the entrance of water. No correlation between color and hard shell was observed and there appeared to be no marked difference between the smooth and wrinkled varieties in percentage of hard shell. The least percentage of hard shell indicates the greatest tenderness of seed coats.

The quality of the peas is probably more dependent upon prompt harvesting than on variety, since low sugar and high starch content are typical of peas of low quality, whether as a result of delayed harvesting or as a varietal characteristic. Boswell (7) has shown through biophysical and biochemical studies of the stages of ripening of peas that prompt harvesting upon the attainment of marketable size is imperative to avoid

the decrease in sugar content and increase in starch content which occurs as the peas mature. From the standpoint of quality, late planting is to be avoided, since higher temperatures make a timely harvest increasingly difficult.

Even though the peas are harvested at the stage when they are of highest quality, a generally recognized deterioration occurs on standing. The chemical changes which take place at this time are in all probability, according to Kertesz, (17) due to the action of enzymes. He has observed that changes in freshly picked peas kept at a temperature as low as -20° C. for twenty-four hours are marked. This observation, however, is qualified by the author's comment that enzymatic action may have had sufficient opportunity to bring about these changes during the short period before the peas reached the low temperature. He states also that deterioration during storage in pods is probably not so rapid or extensive as that occurring in shelled peas. Gowen's work showing that calcium begins to migrate to the skin and causes an appreciable toughness within a few hours is cited by Sayre, Willaman and Kertesz (23). These workers have studied the correlation of a higher percentage of lime in the skin with its greater toughness, regardless of thickness of the skin. In addition to the changes in chemical composition which Boswell listed in studies of maturing peas, Sayre, Willaman and Kertesz have noted an increase in calcium.

The toughening effect of calcium on peas is again mentioned in connection with canning procedures. Water containing an excessive amount of calcium should not be used because of its detrimental effect on the tenderness of peas (3). For the same reason commercial salt high in calcium is to be avoided. However, Greenleaf has found that most commercial salts are usable since the amount of calcium in grader brine is not absorbed unless it exceeds 1% (13).

The best quality of canned peas has a fairly clear liquor. A cloudy appearance is thought by Loudon and Spencer (19) to be caused by rough handling in blanching, or by the inclusion of split or broken peas in the jars. Peas which are too mature or are overcooked in the blanching process often burst and allow the starch to escape into the liquid. Other writers have explained that some of the starch in the peas is dissolved during sterilization and this slowly coagulates to form a milky suspension of white particles. Several weeks may be necessary to complete the precipitation but eventually all of the starch originally dissolved is coagulated (25).

Very little has been written concerning the effect of storage on the quality of home canned foods. In connection with the storage problem, Biester, Weigley and Knapp (2) attempted to compare the resulting palatability of the products. From that standpoint, the quality of canned vegetables stored in the root cellar was judged to be superior to that of the canned vegetables

stored at incubator temperature.

The standard of quality and condition for canned peas as given under the McNary-Mapes amendment to the federal food and drug act has been quoted (11). To help the commercial canners meet the requirements of this amendment, devices for standardization have been suggested. Foremost of these is an apparatus for determining the tenderness of certain canned fruits and vegetables (6). This device has been successfully used to measure the tenderness of canned peas, serving as an accurate and impersonal judge of this factor of their quality (6).

The McNary-Mapes amendment also requires that canned peas be "normally colored". This term excludes distinctly off-colored peas, brown, brownspotted, white or yellowish white. For experimental purposes and comparative work, however, an accurate method of color determination is necessary. A standard device for the measurement of color has been described in detail by Dorothy Nickerson, Color Technologist of the Bureau of Agricultural Economics (21). Based on the Munsell color system, this method has been used extensively in grading agricultural products, notably cotton and other textiles, hay, cereals, canned foods, and meats, and is readily adapted to color determination in canned peas.

It is therefore apparent from a review of the canning literature, that there are still many questions to be answered concerning the home canning of peas. Important among these pro-

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blems is that of determining which methods and periods of processing result in a minimum of spoilage, produce peas of desirable quality, and are at the same time practicable. In Montana where many localities have elevations of several thousand feet above sea level, this problem is of special significance. The effect of altitude in lowering the boiling point of water makes satisfactory preservation more difficult and emphasizes the need for a detailed investigation and comparison of the value of various canning procedures.

EXPERIMENTAL PROCEDURE

Two varieties of peas, Laxtonian and Davis' Perfection, were used in this experimental work. Laxtonian peas were available during both seasons, 1931 and 1932, and peas of the Perfection variety were also canned in the summer of 1932. The Laxtonian is a variety known principally as a garden pea and is used chiefly for home consumption and home canning. The Perfection pea is one of the sweet, wrinkled varieties raised rather extensively for commercial canning.

The preparation for canning and the actual processing was done in the laboratory of the Home Economics department of the Montana Experiment Station. The peas were canned as soon as possible after picking and in all cases the canning was done on the same day in which the peas were harvested.

The peas were shelled by hand, with the exception of the Perfection peas which were shelled by machine in the field. The shelled peas, after being thoroughly washed, were precooked in small lots by boiling for five minutes. While hot, they were packed into glass pint jars. Three kinds of jars were used:- Kerr jars with the all metal lids supplied with a cement ring for sealing; Presto with glass top and rubber ring held in place by a metal ring; and the "Atlas" E-Z Seal jars with a glass top, rubber ring, and metal clamp. The liquid level of the filled jars was uniformly one-half inch from the top. During the first season all jars were completely sealed before processing. Since an undesirable loss of liquid occurred in the canning procedure of the first year, and since it seemed possible that the internal pressure caused by complete sealing might bring about loss of liquid, it was decided that all jars in the second season were to be partially sealed. Partial sealing means that the jars were completely sealed and then the metal ring was given a quarter turn backward to slightly loosen the lid.

Throughout each of the successive canning seasons three general methods of processing were employed:- steam pressure cooker, oven and water bath.

Processing under pressure was done in a National steam pressure cooker of the eighteen-quart size. The amount of

water used, two cups, was just sufficient to cover the rack in the bottom of the cooker. Heat was supplied by a 1200-watt Calrod plate of a Hot Point electric range. When the water reached the boiling point eleven pint jars of hot peas were placed in the cooker in two layers with an open rack between. After the cover was adjusted, steam was allowed to escape in a steady stream for five minutes before the petcock was closed. The steam pressure was then allowed to accumulate until the temperature within the cooker was 240° F. At sea level 240° F. is the temperature comparable to a steam pressure of 10 pounds. At higher altitudes, such as the approximate elevation of 5000 feet at which this experimental work was conducted, a correction must be made in the amount of steam pressure required to produce an internal temperature of 240° F. Since the atmospheric pressure at the 5000 foot altitude is about 12.2 pounds per square inch, while at sea level the pressure is 14.7 pounds, the difference of 2.5 pounds must be added to the steam pressure of 10 pounds, making a total pressure of 12.5 pounds. This is necessary for the reason that the standard pressure gauge is so constructed that it records only that internal pressure which exceeds the external atmospheric pressure. The processing period then begins at the time when the pressure gauge reaches 12.5 pounds.

Oven canning was done in a Hot Point electric oven with

an automatic heat control. The temperature was also checked by a Taylor oven thermometer. The oven with the lower baffle plate in place and both the lower and upper units turned to "high" was preheated to 250° F. Care was taken in the arrangement of the jars in the oven to allow for free circulation of the air currents. The jars, so spaced that they would not touch each other, were placed on the rack five inches above the baffle plate. When the jars of hot peas had thus been arranged, the upper unit of the oven was turned off. Since the oven was preheated to 250° F., the processing time began as soon as the jars were placed in the oven.

The container for processing the canned peas by the water bath method was a large wash boiler with a cover and a wooden rack which fitted into the bottom. For the 1932 season smaller boilers were used, and the wooden rack was replaced by individual jar holders. The water in the boilers, sufficient in amount to cover the tops of the jars to a depth of one to two inches, was brought to the boiling point over two 1200-watt Calrod plates of the Hot Point electric range. The jars of hot precooked peas were then placed in the boiling water bath. The processing period was calculated from the time when the water bath resumed boiling.

The methods of processing used in the two successive seasons were the same, but various periods of processing

were employed. A study of the canning recommendations for peas, as given in bulletins issued by extension departments, experiment stations, and commercial firms showed that there was a wide variation in the periods suggested. In oven canning, for instance, the processing periods ranged from 90 minutes to 210 minutes. The recommendations for pressure cooker processing were found to vary from 30 to 60 minutes. In both of these cases, it seemed advisable to use the upper and lower time limits, as well as some intermediate ones. All water bath periods were based on the recommendations made by the Bureau of Home Economics, United States Department of Agriculture (26), that peas should be processed 180 minutes at sea level. They further suggested that the processing period of 180 minutes should be increased 20% for every additional 1000 feet of elevation after the first thousand. By adding 20% of 180 minutes to this period the processing time for an altitude of 2000 feet becomes 216 minutes. In the same way, the increase is calculated for each additional rise of 1000 feet, and at 5000 feet the total time is 324 minutes, the longest period used in this canning work:

For the year 1931 the following periods were used:-

Pressure cooker at 240° F.	- 30, 40, 50 minutes	
Oven at 250° F.	- 90, 120	"
Water bath at 202° F.	- 180, 324	"

For the year 1932:-

Pressure cooker at 240° F.	- 40, 45, 50 minutes
Oven at 250° F.	- 150, 180, 210 "
Water bath at 202° F.	- 216, 252, 288, 324 minutes.

A total of 83 pint jars of peas was canned in the summer of 1931, and 346 pint jars in 1932.

All jars were tested for a tight seal and were cooled at room temperature immediately after canning, and within twenty-four hours they were placed in the unheated basement room where they were stored at a temperature ranging from 50 - 60° F. The storage period for the peas canned in 1931 was seven to eight months. In 1932 part of the jars were opened during the first month following canning, while the remainder were stored for a period of six months before being examined.

Before the jars were opened, records were made of the relative amount of liquid and sediment in each jar. The odor was noted and recorded, and any distinctive odor was described. The relative palatability of the unspoiled peas processed by different methods was determined by tasting. After the peas had been brought to the boiling point, they were then tasted by a group of competent judges who served during both years. Their judgments were recorded on the following score card that had been developed and revised until it seemed to satisfactorily meet the peculiar requirements of judging peas.

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Impressions of texture recorded thereon gave an estimation of the relative tenderness of both the skin and cotyledon of the peas.

Grading Chart for Canned Green Peas

Grade each quality as follows: 00 = Very Poor
0 = Poor
1 = Fair
2 = Medium
3 = Good
4 = Very Good

Sample No.

Quality	1	2	3	4	5	6	7	8	9
FLAVOR									
TEXTURE Skin									
Cotyledon									
AVG. GRADE									

Each jar of peas in which there was no readily discernible evidence of spoilage was subjected to certain physical tests intended to determine the quality of the peas. As far as possible the standards of the Federal food and drugs act as amended July 8, 1930, were used in the evaluation of the samples. By means devised to meet these standards for commercially canned peas, a comparatively accurate determination of color and tenderness was made.

The tenderness or "crush" of the cotyledon was measured by a method devised by Bonney, Clifford and Lepper (6) of the United States Food and Drug Administration. The apparatus which they designed for this purpose is called a "penometer" (fig. 1) and may be used for the determination of tenderness in fruits and vegetables of many kinds. It is possible by means of this apparatus to measure the force required to compress the test piece to a specified fraction of its original diameter. For the crushing test several peas taken from each jar, were selected according to diameter, as determined by a vernier caliper. The size of the peas chosen for the test was indicated by the average size of the variety of peas being examined.

The standard method used for color determination is described in a bulletin by Dorothy Nickerson, color technologist of the Bureau of Agricultural Economics (21). Accurate determination is dependent upon the matching of the color of the product being tested with a color which is the composite of several standard disks. By the arrangement of these color disks, which are caused to spin rapidly, a color identical with that of the peas may be obtained. All measurements are expressed according to the Munsell notation, formulas for which are developed in the bulletin.

In addition to the physidal tests, a determination was made of the acidity of the liquid in each jar of peas. With

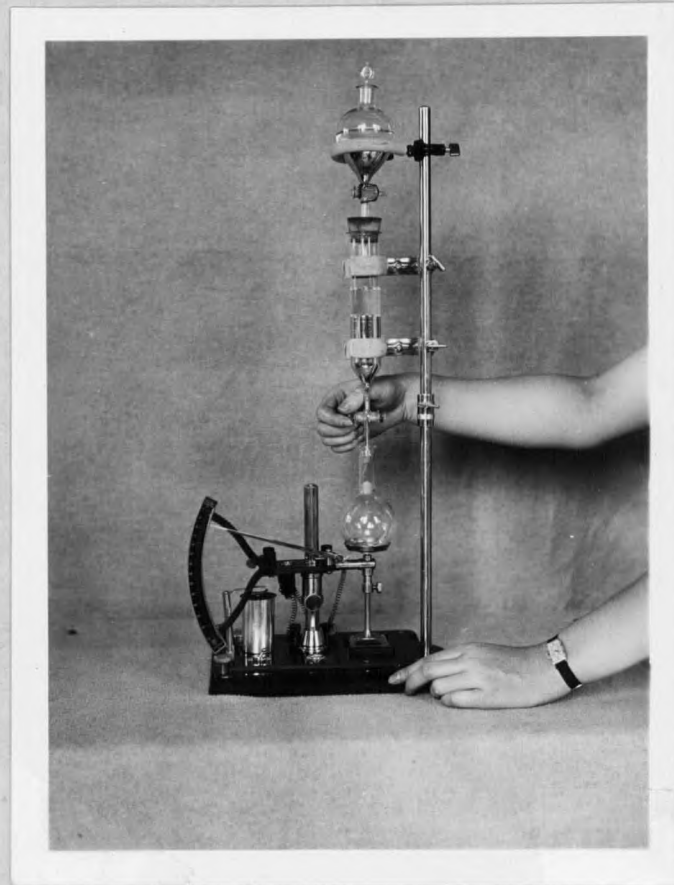


Fig. 1. The penometer used in determining the tenderness of canned peas.

brom cresol purple and methyl red indicators, acidity was measured in pH values by the colorimetric method described by Clark (8).

In general the procedure followed in the bacteriological analysis of the canned peas was very similar to that described by Esty and Stevenson (10). Each jar was washed with mercuric chloride solution, and the cover carefully flamed, before being loosened by a sterile knife. The cover was lifted to admit a sterile pipette by means of which sedimentary liquid from the bottom of the jar was transferred to tubes of culture media, plain nutrient broth for the culture of aerobes and dextrose agar shake cultures to favor the growth of anaerobes. Some of the pipetted material was made into smears to be stained with carbol fuchsin for microscopic examination. The culture tubes inoculated from the peas were incubated at room temperature, 35° C. and 55° C. Those cultures in which growth occurred were plated in nutrient agar and from these plates organisms of different kinds were isolated. Identification was made by the usual cultural and physiological studies.

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RESULTS

In the presentation of these results of a study of the quality and bacterial content of peas canned by varied methods and periods of processing, a calculation of spoilage percentages is a fundamental step in the arrangement of the data. Table I shows the bacterial content and spoilage records of 398 jars of peas processed by three methods, oven, water bath and pressure cooker for the various periods listed. Bacterial content appears to have manifested itself in three ways:- (1) by definite spoilage, (2) by growth in cultures made from apparently unspoiled peas, and (3) by auto-sterilization (28)*, a condition in which there is typical bacterial spoilage in jars from which no cultural growth is obtained. The microscopic examination of stained smears made directly from the canned material verified the presence of cultural growth in the first two cases, and strengthened the evidence for auto-sterilization, mentioned in the third case. The higher percentages of spoilage occur red in the oven canned peas, while the shorter water bath periods result in fairly high losses from spoilage. Peas processed by the longer water bath periods were nearly free from bacterial growth, and those which are pressure cooked, with the exception of the 30 minute period, contain no viable organisms. In some of the jars in groups having moderate percentages of spoilage, living bacteria are present,

* See Tanner, p. 561

TABLE I. PERCENTAGE OF SPOILAGE AND BACTERIAL CONTENT OF PEAS CANNED BY VARIED METHODS FOR VARIED PERIODS.

Variety of Pea	Year	Method of Canning	Processing Period Min.	No. Jars Examined	Per cent. Total Jars Spoiled	Per cent. Unspoiled Jars having Viable Organisms	Per cent. Total Jars with evidence of Auto-sterilization
Laxtonian	1931-32	Oven	90	11	72.7	0.0	0.0
"	" "	"	120	11	90.9	0.0	0.0
"	1932-33	"	150	12	16.7	0.0	8.3
"	" "	"	180	35	40.0	9.5	20.0
Perfection	" "	"	210	37	51.4	5.5	0.0
Laxtonian	1931-32	Water Bath	180	11	36.4	28.5	18.2
"	1932-33	" "	216	12	8.3	0.0	8.3
Perfection	" "	" "	216	24	70.8	28.5	0.0
Laxtonian	" "	" "	252	12	8.3	9.1	0.0
Perfection	" "	" "	252	26	46.2	14.2	0.0
Laxtonian	" "	" "	288	12	0.0	0.0	0.0
Perfection	" "	" "	288	21	9.6	4.3	4.8
Laxtonian	1931-32	" "	324	10	0.0	0.0	0.0
"	1932-33	" "	324	12	8.3	0.0	0.0
Perfection	" "	" "	324	24	4.2	0.0	0.0
Laxtonian	1931-32	Pressure Cooker	30	11	0.0	9.1	0.0
"	" "	" "	40	11	0.0	0.0	0.0
"	1932-33	" "	40	11	0.0	0.0	0.0
Perfection	" "	" "	40	22	0.0	0.0	0.0
Laxtonian	" "	" "	45	22	0.0	0.0	0.0
Perfection	" "	" "	45	9	0.0	0.0	0.0
Laxtonian	1931-32	" "	50	11	0.0	0.0	0.0
"	1932-33	" "	50	9	0.0	0.0	0.0
Perfection	" "	" "	50	22	0.0	0.0	0.0

though the peas seemed to be edible and in good condition. Auto-sterilization occurred irregularly in water bath and oven processed jars.

All of the organisms isolated from jars of spoiled peas were identified as members of the genus *Bacillus* of the Bacillaceae family in Bergey's manual (1). Organisms classified as *Bacillus subtilis* were obtained from spoiled peas processed in the oven for 180 and 210 minutes, and in the water bath for 216, 252, 288 and 324 minutes. *B. vulgatus* and *B. mycoides* were also isolated from spoiled peas processed in the oven for 210 minutes and in the water bath for 216 and 252 minutes. From the unspoiled jars containing viable organisms, *B. mycoides*, *B. graveolens*, and other bacilli which appeared to be very similar to *B. subtilis*, were isolated. The organisms resembling *B. subtilis* differed from it in temperature relations, since they grew more abundantly at 37° and 45° C. than at 30° C. Even though the identification of all the isolated organisms was not carried to completion, their relationship to *B. subtilis* was established by demonstrating that they were gram positive, spore-forming aerobes, usually motile. The ability of some of these organisms to grow under anaerobic, as well as aerobic, conditions was shown by their growth in dextrose agar in tubes and special plates from which the oxygen was removed by absorption in the

reaction of pyrogalllic acid with sodium hydroxide. No strictly anaerobic organisms were isolated.

In the case of auto-sterilization, the bacteria present, presumably responsible for the spoilage, could be classified only by the morphological characteristics which were evidenced by a direct smear stained with carbol fuchsin. Three distinct types of rods were observed, extremely large rods varying greatly in length, long narrow rods slightly bent, and some short wide rods which in some cases seemed very like large cocci. The pH values of the liquid in the jars in which these organisms were found was for the first type 4.4-4.6, for the second type 5.8-6.2, and for the third type 5.4-6.1.

Those peas which gave no evidence of bacterial spoilage, and were considered edible, were tasted by the judges who scored them for palatability. The average results of the scoring are shown in table II. Though the ratings as a whole are low, there are some general trends which may be noted. In the columns marked "average desirability of flavor" and "average grade", beginning with the peas processed 252 minutes in the water bath and ending with those processed 324 minutes by the same method, will be found consistently higher scores.

In scoring the canned peas for palatability the judges were asked to insert comments concerning any predominant

TABLE II. AVERAGE PALATABILITY OF CANNED PEAS AS SCORED BY THE JUDGES.

Variety of Pea	Year	Method of Canning	Processing Period Min.	Av. Desirability of Flavor	Av. Tenderness of Skin	Av. Texture of Cotyledon	Av. Grade
Laxtonian	Spring 1932	Oven	90	--	--	--	00
"	" "	"	120	--	--	--	00
"	" 1933	"	150	1	1 *	1 *	1 *
"	Fall 1932	"	180	1 *	2 *	1 1 *	1 1 *
"	Spring 1933	"	180	1	2 *	1 1 *	1 1 *
Perfection	Fall 1932	"	210	1 *	1 *	2 *	1 *
"	Spring 1933	"	210	1	3 *	2 *	1 *
Laxtonian	" 1932	Water Bath	180	1	1	1	1
"	Fall "	" "	216	1	2	1	1 *
"	Spring 1933	" "	216	1	1	2	1 *
Perfection	Fall 1932	" "	216	1	1	2	1 *
"	Spring 1933	" "	216	1	2	1 *	1 *
Laxtonian	Fall 1932	" "	252	2	3 -	2 *	1 *
"	Spring 1933	" "	252	2	3	2 *	1 *
Perfection	Fall 1932	" "	252	2 *	2	2	1 *
"	Spring 1933	" "	252	1	2	1 *	1 *
Laxtonian	Fall 1932	" "	288	2	2 *	2 *	1 *
"	Spring 1933	" "	288	2 *	2	2	1 *
Perfection	Fall 1932	" "	288	2	2	2 *	1 *
"	Spring 1933	" "	288	2	2	2 *	1 *
Laxtonian	" 1932	" "	324	3	2	3	1 *
"	Fall "	" "	324	2	3	3	1 *
"	Spring 1933	" "	324	2	3	1	1 *
Perfection	Fall 1932	" "	324	2	2 *	2 *	1 *
"	Spring 1933	" "	324	2	2	2 *	1 *
Laxtonian	Spring 1932	Pressure Cooker	30	2 *	2 *	2 *	1 *
"	" "	" "	40	1 *	3	2 *	1 *
"	Fall "	" "	40	2	4	2	1 *
"	Spring 1933	" "	40	1	1 *	1 *	1 *
Perfection	Fall 1932	" "	40	1	2	2	1 *
"	Spring 1933	" "	40	1	2	2	1 *
Laxtonian	Fall 1932	" "	45	2 -	2 *	2 -	1 *
"	Spring 1933	" "	45	1 *	2	1 *	1 *
Perfection	Fall 1932	" "	45	1	1 *	2	1
"	Spring 1933	" "	45	1	2	1	1
Laxtonian	" 1932	" "	50	1 *	1	1	1
"	Fall "	" "	50	2	3 *	2 -	2 -
"	Spring 1933	" "	50	2	2 *	2	2
Perfection	Fall 1932	" "	50	2	2	2 *	1
"	Spring 1933	" "	50	1	2	1	1

peculiarities of flavor. This resulted in an accumulation of descriptive words ascribed to the various kinds of canned peas. Since many of the words suggesting peculiar flavors appeared repeatedly for the peas of each processing method and period, it was thought that they could be studied more easily when listed according to the frequency with which each particular flavor was noted, as in table III. The words recurring most frequently are listed in the first column, while those mentioned less often are found in the succeeding columns. It will be noted in the oven and pressure cooker groups that the words "hay", "bland" and "old" appear most often, while "grassy" "rubber" and not infrequently "sweet" or "natural" occur in reference to the peas processed by the water bath method.

The scores in table II for the texture of the cotyledon are not high although in many cases they are above those in the column marked "average grade". Low scores may mean either that the cotyledons were very hard and dry or that they were undesirably soft and watery. The results in table IV furnish evidence that the peas were, in general, too soft rather than too hard. Table IV shows the classification of tenderness tests made by the use of a penometer. The United States Food and Drug Administration (11) gives no standard for satisfactory cotyledons other than the stipulation that they be crushed by a weight of mercury not exceeding two pounds or approximately

TABLE III. PECULIARITIES OF FLAVOR NOTED IN CANNED PEAS, AS DESCRIBED BY THE JUDGES.

Variety of Pea	Year and Season	Method of Canning	Processing Period Min.	Predominant Peculiarities of Flavor Arranged in Order of Frequency				
				1	2	3	4	5
Laxtonian	Spring 1933	Oven	150	hay	rubber	oil	grassy	sweet
"	Fall 1932	"	180	"	old	grassy	bland	rubber
"	Spring 1933	"	180	bland	sour	rubber	hay	fish
Perfection	Fall 1932	"	210	old	spoiled	hay	bland	metallic
"	Spring 1933	"	210	metallic	(only one unspoiled jar)			---
Laxtonian	" 1932	Water Bath	180	old	beefy	sweet	---	---
"	Fall "	" "	216	grassy	rubber	oil	caramel	bland
"	Spring 1933	" "	216	rubber	grassy	oil	starchy	hay
Perfection	Fall 1932	" "	216	grassy	old	hay	bland	caramel
"	Spring 1933	" "	216	"	sweet	spoiled	acid	old
Laxtonian	Fall 1932	" "	252	bland	grassy	rubber	oversweet	hay
"	Spring 1933	" "	252	hay	"	natural	spoiled	old
Perfection	Fall 1932	" "	252	sweet	"	bland	good	old
"	Spring 1933	" "	252	hay	"	old	spoiled	rubber
Laxtonian	Fall 1932	" "	288	old	natural	grassy	"	"
"	Spring 1933	" "	288	grassy	sweet	natural	hay	old
Perfection	Fall 1932	" "	288	"	bland	oil	sweet	hay
"	Spring 1933	" "	288	"	rubber	hay	oil	sweet
Laxtonian	" 1932	" "	324	oversweet	acid	---	---	---
"	Fall "	" "	324	grassy	natural	sweet	old	rubber
"	Spring 1933	" "	324	"	oil	rubber	metallic	hay
Perfection	Fall 1932	" "	324	"	bland	good	caramel	sweet
"	Spring 1933	" "	324	"	hay	sweet	bland	rubber
Laxtonian	" 1932	Pressure Cooker	30	sweet	oversweet	---	---	---
"	" "	" "	40	old	"	---	---	---
"	Fall "	" "	40	rubber	beefy	bland	grassy	hay
"	Spring 1933	" "	40	grassy	bland	hay	egg yolk	old
Perfection	Fall 1932	" "	40	beefy	old	sweet	sour	spoiled
"	Spring 1933	" "	40	hay	bland	grassy	spoiled	rubber
Laxtonian	Fall 1932	" "	45	bland	rubber	"	oil	hay
"	Spring 1933	" "	45	"	grassy	oil	rubber	"
Perfection	Fall 1932	" "	45	spoiled	hay	bland	old	grassy
"	Spring 1933	" "	45	hay	grassy	old	bland	spoiled
Laxtonian	" 1932	" "	50	too sweet	caramel	---	---	---
"	Fall "	" "	50	hay	bland	rubber	oil	grassy
"	Spring 1933	" "	50	bland	rubber	good	sour	---
Perfection	Fall 1932	" "	50	hay	sweet	spoiled	bland	old
"	Spring 1933	" "	50	"	oversweet	old	rubber	spoiled

TABLE IV. CLASSIFICATION OF PENOMETER TESTS TO SHOW THE RELATIVE TENDERNESS OF CANNED PEAS.

Process and Period	Variety	Total No. Tests	Classification of Tests						
			Very Soft	Soft	Medium	Firm	Very Firm	Hard	Sub-Standard
Pressure Cooker									
30 min.	Laxtonian	51	4	19	16	10	1	1	0
40 "	"	76	5	25	32	8	2	4	0
40 "	Perfection	57	5	22	10	9	4	5	2
45 "	Laxtonian	48	2	12	20	7	5	2	2
45 "	Perfection	33	4	3	13	2	3	7	1
50 "	Laxtonian	21	3	5	5	4	0	3	1
50 "	Perfection	63	5	26	15	7	7	3	0
Water Bath									
180 min.	Laxtonian	10	0	1	8	1	0	0	0
216 "	"	20	0	4	9	4	1	2	0
216 "	Perfection	23	1	12	3	7	0	0	0
252 "	Laxtonian	33	5	15	8	0	4	1	0
252 "	Perfection	46	3	19	9	8	1	2	4
288 "	Laxtonian	25	2	10	4	2	4	3	0
288 "	Perfection	63	6	21	15	8	3	7	3
324 "	Laxtonian	30	6	11	5	4	2	2	0
324 "	Perfection	67	3	27	21	5	4	5	2
Oven									
150 min.	Laxtonian	18	1	3	1	6	2	4	1
180 "	"	57	1	9	24	9	5	5	4
210 "	Perfection	47	6	14	5	9	3	7	3

900 grams. In this experimental work, the peas which required more than this weight are classified in the column "substandard". Cotyledons, termed "hard", are those which were crushed by weights above 500 grams; "very firm" peas required 400 to 500 grams; "firm", 300 to 400 grams; "medium", 200 to 300 grams; "soft", 100 to 200 grams; and "very soft", less than 100 grams. The degree of softness of canned peas is not designated, as is the hardness, by the standards of the federal food and drugs act. It was very evident, however, that the peas classed as very soft in table IV are not of desirable texture. According to the opinions of the judges who tested the product for palatability, it seems probable that the peas classified as "medium" or "firm" are most pleasing in texture.

A standard color test was also applied to determine variations in the color of peas processed by varied methods and for varied periods. In tables V and VI the average color notations are listed for hue, brilliance and chroma. These color terms are defined by Nickerson (21) in the following way: Hue is that attribute of color which classifies colors as reddish, yellowish, greenish or bluish; brilliance is used to distinguish between a light color and a dark color; and chroma distinguishes a strong color from a weak color. The original readings were taken in percentages of the total area of the revolving disk which consisted of standard colors.

TABLE V. AVERAGE COLOR NOTATIONS FOR CANNED PEAS EXAMINED IN THE FALL BEFORE STORAGE.

Variety of Pea	Year and Season	Method of Canning	Processing Period Min.	Average Color Notation		
				Hue	Brilliance	Chroma
Laxtonian	Fall 1932	Oven	180	6.44Y	5.648	5.53
Perfection	" "	"	210	6.29Y	5.720	5.38
Laxtonian	" "	Water Bath	216	6.20Y	5.876	5.86
Perfection	" "	" "	216	6.54Y	5.747	5.44
Laxtonian	" "	" "	252	5.98Y	5.790	5.42
Perfection	" "	" "	252	6.01Y	5.692	5.57
Laxtonian	" "	" "	288	5.98Y	5.603	5.68
Perfection	" "	" "	288	5.91Y	5.716	5.56
Laxtonian	" "	" "	324	5.75Y	5.473	5.58
Perfection	" "	" "	324	6.72Y	5.677	5.55
Laxtonian	" "	Pressure Cooker	40	6.58Y	5.680	5.70
Perfection	" "	" "	40	6.15Y	5.638	5.51
Laxtonian	" "	" "	45	6.05Y	5.728	5.57
Perfection	" "	" "	45	5.86Y	5.694	5.40
Laxtonian	" "	" "	50	5.88Y	5.786	5.64
Perfection	" "	" "	50	5.90Y	5.732	5.43

TABLE VI. AVERAGE COLOR NOTATIONS FOR CANNED PEAS EXAMINED IN THE SPRING AFTER STORAGE.

Variety of Pea	Year and Season	Method of Canning	Processing Period Min.	Average Color Notation		
				Hue	Brilliance	Chroma
Laxtonian	Spring 1933	Oven	150	2.59Y	5.614	5.27
"	" "	"	180	2.86Y	5.790	5.56
Perfection	" "	"	210	2.55Y	5.790	5.60
Laxtonian	" 1932	Water Bath	180	5.21Y	4.968	5.45
"	" 1933	" "	216	2.18Y	5.824	5.38
Perfection	" "	" "	216	3.19Y	5.594	5.40
Laxtonian	" "	" "	252	2.46Y	5.799	5.56
Perfection	" "	" "	252	2.49Y	5.854	5.50
Laxtonian	" "	" "	288	2.59Y	5.539	5.08
Perfection	" "	" "	288	2.73Y	5.884	5.71
Laxtonian	" 1932	" "	324	3.81Y	5.038	5.23
"	" 1933	" "	324	2.61Y	5.778	5.63
Perfection	" "	" "	324	3.69Y	5.620	5.37
Laxtonian	" 1932	Pressure Cooker	30	4.51Y	5.170	5.36
"	" 1933	" "	40	4.75Y	5.179	5.33
Perfection	" "	" "	40	2.78Y	5.723	5.38
Laxtonian	" "	" "	45	2.24Y	5.622	5.51
Perfection	" "	" "	45	3.09Y	5.555	5.44
Laxtonian	" "	" "	50	1.86Y	5.769	5.45
Perfection	" "	" "	50	2.58Y	5.288	5.28

Formulae for arriving at the color notations are given in a bulletin issued by the United States Department of Agriculture (21).

In table V, which gives the results of color tests made on the canned peas examined in the fall, it will be seen that the hue notations range from approximately 5.75Y to 6.75Y. When it is known that 5Y in Munsell's color circle represents a pure yellow and that 7Y approaches green-yellow, and 1Y approaches yellow-red, it will be seen that a notation of 5 - 7Y signifies a greater percentage of green coloring than a notation of 2 - 5Y. In table V the lower hue notations appear in peas processed by the longer water bath methods, with the exception of the Perfection peas processed for 324 minutes. The notation listed for the peas processed in the pressure cooker for 45 and 50 minute periods are also slightly lower than those for the peas processed in the oven and for the shortest water bath time. In table VI, which contains the results of color tests made on the peas examined in the spring, these group differences are not so apparent but notations for the Laxtonian peas processed in the water bath for 180 minutes and in the pressure cooker for 30 and 40 minutes are significantly high. Comparing tables V and VI, which represent peas opened immediately after canning and peas opened after six months' storage, a marked difference is noted. The peas stored for six months have distinctly lower hue notations. It

will be noted in both tables that the notations for brilliance and chroma do not vary markedly among the different methods and periods of processing or between the two seasons.

There are several factors, other than palatability and color, which definitely influence the quality of canned peas. Important among these are the odor of the peas, and the average amount and condition of the liquid. In order to demonstrate the influence of the method and period of processing on these factors, the data concerning them have been assembled in table VII. Although the odor was scored in nearly every case by an individual, rather than a group of judges, the results may be compared with the palatability scores listed in table II. In the two tables the higher scores for desirability of flavor are consistently paralleled by the higher scores for odor. An exception may be noted, however, in the case of the peas processed by the pressure cooker for 50 minutes where the odor scores are distinctly lower than the judgment of flavor. Difference between the odor of the peas opened immediately after canning and after storage are not apparent.

However, there appears to be a difference in the condition of the liquid in the canned peas examined in the fall before storage as compared with that in the jars opened six months later. In nearly every case there is, after storage, a slight increase in the degree of cloudiness.

TABLE VII. AVERAGE DATA REGARDING CERTAIN PHYSICAL AND CHEMICAL PROPERTIES OF UNSPOILED PEAS.

Variety of Pea	Year and Season	Method of Canning	Processing Period Min.	Average pH.	Liquid		Condition	Average Odor* Remarks
					Average Amount - Inches			
					Kerr-Presto	E-Z Seal		
Laxtonian	Fall 1932	Oven	180	6.1	1.7	---	clear	1 hay
Perfection	" "	"	210	6.1	1.4	---	sl. cloudy	1 "
Laxtonian	" "	Water Bath	216	6.2	2.4	---	" "	2 "
Perfection	" "	" "	216	6.2	3.2	4.3	cloudy	1 "
Laxtonian	" "	" "	252	6.1	2.7	---	sl. cloudy	2 "
Perfection	" "	" "	252	6.2	2.8	---	cloudy	2- hay, rubber
Laxtonian	" "	" "	288	6.2	2.6	---	clear	1 rubber
Perfection	" "	" "	288	6.1	3.0	4.3	sl. cloudy	1 "
Laxtonian	" "	" "	324	6.1	2.7	---	" "	2- "
Perfection	" "	" "	324	6.1	2.3	---	cloudy	1 rubber
Laxtonian	" "	Pressure Cooker	40	6.3	2.4	2.8	sl. cloudy	1- hay
Perfection	" "	" "	40	6.1	2.5	3.4	very cloudy	0 " rubber
Laxtonian	" "	" "	45	6.1	2.0	2.5	cloudy	0 "
Perfection	" "	" "	45	6.1	1.8	2.5	"	0 strong hay
Laxtonian	" "	" "	50	6.2	2.1	2.6	"	0 " "
Perfection	" "	" "	50	6.0	1.3	2.0	very cloudy	1 hay
Laxtonian	Spring "	Oven	90	6.1	---	2.5	cloudy	0 "
"	" "	"	120	6.0	---	3.0	sl. cloudy	0 "
"	" 1933	"	150	6.1	1.8	---	" "	1 "
"	" "	"	180	6.2	2.2	---	cloudy	1 "
Perfection	" "	"	210	---	1.3	---	very cloudy	0 "
Laxtonian	" 1932	Water Bath	180	6.3	3.4	3.8	sl. cloudy	1 undercooked
"	" 1933	" "	216	6.1	2.6	---	" "	1+ "
Perfection	" "	" "	216	6.0	3.1	---	cloudy	2 "
Laxtonian	" "	" "	252	6.1	2.4	---	sl. cloudy	1+ hay
Perfection	" "	" "	252	6.2	2.9	---	cloudy	1+ "
Laxtonian	" "	" "	288	6.1	2.4	---	sl. cloudy	2 "
Perfection	" "	" "	288	6.1	2.8	4.3	cloudy	1+ "
Laxtonian	" 1932	" "	324	6.2	3.2	4.1	sl. cloudy	2- "
"	" 1933	" "	324	6.1	2.6	---	cloudy	2 "
Perfection	" "	" "	324	6.1	2.7	---	"	2 "
Laxtonian	" 1932	Pressure Cooker	30	6.0	1.7	3.1	"	1+ "
"	" "	" "	40	6.0	1.8	3.4	"	1+ metallic
"	" 1933	" "	40	6.1	1.8	3.0	"	1 hay
Perfection	" "	" "	40	6.1	2.4	3.2	"	1 " rubber
Laxtonian	" "	" "	45	6.0	2.1	2.6	"	0 " "
Perfection	" "	" "	45	6.0	2.2	2.4	"	0 strong hay
Laxtonian	" 1932	" "	50	5.9	1.9	2.8	sl. cloudy	1 hay
Laxtonian	" 1933	" "	50	6.9	1.8	---	cloudy	0 "
Perfection	" "	" "	50	6.0	1.6	1.9	"	1- "

* System of scoring:- 00 = spoiled; 0 = poor; 1 = fair; 2 = good

In regard to the amount of liquid contained in the jars, table VII shows that the average liquid level in the jars processed by the water bath method is noticeably higher than that in the jars which were canned in the oven and pressure cooker.

Table VIII contains data concerning the condition of the spoiled peas. It will be seen that the scores for odor are very low, as would be indicated by the general acceptance of disagreeable odor as a dependable criterion for the detection of spoilage. The increase in cloudiness which appears with bacterial growth is also a condition which has been consistently noted in spoilage studies.

Included in tables VII and VIII are the average pH values of the liquid contained in the jars of the unspoiled peas. The averages for peas processed by varied methods and periods remains fairly constant. Spoilage, however, is marked in nearly every instance by a lower pH value.

TABLE VIII. AVERAGE DATA REGARDING CERTAIN PHYSICAL AND CHEMICAL PROPERTIES OF SPOILED CANNED PEAS.

Variety of Pea	Year and Season	Method of Cooking	Processing Period Min.	Average pH.	Liquid		Condition	Average Odor* Remarks
					Average Amount - Inches Kerr-Presto	E-Z Seal		
Laxtonian	Fall 1932	Oven	180	5.4	0.8	---	clear	00 hay
Perfection	" "	"	210	6.0	2.1	1.5	very cloudy	00 sour, putrid
"	" "	Water Bath	216	6.5	3.3	---	" "	00 " "
"	" "	" "	252	6.1	3.0	---	" "	00 " "
"	" "	" "	324	6.3	3.0	---	" "	1
Laxtonian	Spring "	Oven	90	5.8	2.4	3.3	cloudy	00
"	" "	"	120	5.8	2.1	3.1	sl. cloudy	00 putrid
"	" 1933	"	150	5.2	2.0	---	very cloudy	00 "
"	" "	"	180	5.2	2.0	---	" "	00 sour, cheesy
Perfection	" "	"	210	6.1	2.1	2.8	" "	00 putrid
Laxtonian	" 1932	Water Bath	180	---	3.3	---	" "	00
Perfection	" 1933	" "	216	5.6	3.2	4.5	" "	0 sour, putrid
Laxtonian	" "	" "	252	6.0	2.5	---	" "	00 putrid
Perfection	" "	" "	252	6.0	3.0	---	" "	00
"	" "	" "	288	5.4	2.8	4.3	" "	00 sour
"	" "	" "	324	5.8	3.0	---	" "	00

* System of scoring:-

- 00 = spoiled
- 0 = poor
- 1 = fair
- 2 = good

DISCUSSION

The spoilage percentages given in table I of the results show quite conclusively that the oven method of processing, for the periods tested in this experimental work, is not satisfactory for canning peas at an altitude of about 5000 feet. Although there is little experimental data concerning oven canning, Tanner (28) has stated that oven processing is not to be recommended under any circumstances for non-acid foods. He attributes the failure of oven canning to the extremely slow heat penetration which occurs in jars placed in the hot air medium.

The unspoilied oven canned peas were not scored very high for palatability. This lack of desirable flavor, together with the great loss of liquid from the jars, gives little assurance that lengthened periods of processing by this method would give satisfactory results.

The water bath processing for periods of 180, 216 and 252 minutes resulted in spoilage quite comparable in amount to that of the oven canned peas. The 180 minute period may immediately be classed with the oven processing periods as unsatisfactory, both in respect to spoilage and the resulting product. There are, however, some noticeable irregularities in the percentages given for the jars processed in the water bath for 216 and 252 minutes, in that the Perfection peas had

spoilage percentages of 46.2 to 70.8 in contrast to 8.3 percent, among the Laxtonians processed for 216 and 252 minutes, table I. Mention has been made of the fact that the Perfection peas were shelled by machine in the field, whereas the Laxtonian peas were brought unshelled to the laboratory. Normington (22) has indicated specifically the necessity for cleanliness in shelling, and other writers have also pointed out the effect of care in handling the shelled peas on the total contamination of the canning material. The spoilage percentages among the Perfection peas is probably due then to the greater exposure of the shelled peas, a condition which the Laxtonians did not undergo.

The spoilage of the Laxtonian peas canned by the 216 and 252 minute water bath periods is no greater in amount than the spoilage loss among the Laxtonians processed for 288 and 324 minutes. However, the spoilage percentages among the Perfection peas, which were presumably more highly contaminated, permit the conclusion that these shorter water bath periods do not allow for any great variation in numbers of bacteria present. The influence of raising the average "bacterial load" or contamination is pointed out by Tanner (28) and Bigelow (4). Since great variations in bacterial contamination must be expected under the conditions existing during home canning procedures in different localities and during

different seasons, no method or period of processing which does not allow for a reasonable range in this respect should be recommended.

The quality of the unspoiled peas processed at 216 and 252 minutes is fairly good, shown by the average liquid level in the jars, by the palatability judgments, and remarks concerning peculiarities of flavor. These indications that the method warrants further investigation using longer processing periods, are borne out by the favorable results of the 288 and 324 minute periods of the same method.

It was to be expected that the large proportion of spoilage in the jars of peas processed by the oven method and by the shorter periods of the water bath method would be accompanied by extensive bacteriological findings. In the results mention has been made of the types of organisms found. They correspond in part with those isolated by Lang (18), Wyant and Tweed (30), Bitting (5), and Normington (22), all of whom have studied spoilage in home canned vegetables. The identification of *Bacillus graveolens*, an organism not mentioned by any of these workers is not particularly significant, since this bacillus is of the same group as the other aerobic spore-formers and differs only in its ability to grow well at higher temperatures, as well as at 30° C., the optimum temperature for most of these organisms. Tanner(28) has summarized

the significance of the organisms such as were found in this experimental work. He states that aerobic spore-forming bacteria are ordinarily less heat resistant than the anaerobic spore-formers; that their presence indicates either insufficient processing of leaky cans, but that their presence might be due to under-processing, especially in the case of foods processed in boiling water.

In connection with the isolation of aerobic organisms from the canned peas, there arises a question concerning the amount of air which was included in the jars. A space of one-half inch was left between the liquid level and the lid of each jar. Theoretically, a rather complete vacuum is formed in this space by the condensation of the steam which gathers there during the processing period. How much air remains in this space or is dissolved in the liquid is not known. However, it is known that very little oxygen is required by some aerobic organisms, particularly those which are facultative, as were some of the bacteria isolated during this experimental work. It may be assumed, too, that faulty sealing is more prevalent in home canning where glass jars and rubber rings are employed, than in commercial work where tin cans are ordinarily used.

The occurrence of viable organisms in some of the unspilled jars is immediately suggestive of faulty technique,

since Lang (18) and others have stated that unspoiled canned products of low acidity rarely contain living bacteria. However, this condition was confined quite definitely to the peas canned by the oven method and shorter water bath periods, in which all organisms were not destroyed, as is shown by the spoilage percentages. It is quite obvious that if these organisms were introduced through poor technique they would have appeared also in some of the unspoiled jars processed by the more successful methods. Further evidence is found in the fact that the organisms occurring in the unspoiled peas are *Bacillus graveolens*, not isolated from any of the spoiled jars, and *Bacillus mycoides*, not associated singly with spoilage in these peas. The fact that *Bacillus graveolens* and the other unidentified aerobic spore-formers in the unspoiled peas are organisms which do not grow so well at room temperature as at 40° to 50° C. may account for the absence of actual spoilage in jars where these organisms were found to be still living. It is quite possible then that prompt cooling and immediate storage at a temperature ranging from 15 to 25° C. inhibited the development of these organisms to the extent that spoilage did not occur. This view concerning inhibition due to storage conditions is that generally held in regard to thermophilic bacteria which do not cause spoilage unless the temperature of their environment becomes favorable.

One of two things has probably happened to those organisms which appear in large numbers in the stained smear made directly from the spoiled peas, but which do not grow when samples of the canned peas are transferred to the usual culture media. First, the culture media and incubating conditions may not be satisfactory for the peculiar requirements of these organisms. Secondly, the organisms may have grown normally until the products of metabolism, such as organic acids, have accumulated to such a degree that the death of the bacteria results. This is the phenomenon which Tanner (28) aptly refers to as auto-sterilization. In this experimental work, the acidity determination in at least a part of these cases which are classed as auto-sterilization is low enough (4.4 - 4.6) to suggest destruction of the organisms by the excessive accumulation of acid.

The species of the identified organisms is significant in suggesting the sources of contamination. Bergey (1) mentions soil as the habitat of each of the organisms identified in this work. It should be explained, however, that *Bacillus subtilis*, commonly known as the "hay bacillus" is found not only in the soil but in hay, on the foliage of plants, and in many other similar locations. It is then, readily seen that organisms of this genus might be found in abundance on pea vines.

The results of the canning by the water bath method for periods long enough to compensate for the lower boiling point maintained at an altitude of 5000 feet, are not in accordance with the predictions of many of the workers who make canning recommendations. Even Normington (22) whose comparison of the amount of spoilage in the pressure cooked and water bath processed vegetables showed very little difference in results, concluded that the processing of cold packed canned vegetables should be carried out by the steam pressure method, to secure the greatest probability of success. In this work, however, the loss from spoilage among the peas processed for the two longer periods, 288 and 324 minutes, is not greater than the amount which might be expected to occur because of faulty jars and rubbers, allowing leakage. Of a total of 35 jars processed in the water bath for 288 minutes, two were spoiled. For one of these jars, there is a record of a cracked lid which was replaced. The re-processing period following this was evidently not sufficient to destroy the bacteria introduced when the lid was changed. Among the 46 jars of peas processed for 324 minutes in boiling water, spoilage was noted in only two jars.

Assuming that the proportion of spoilage among the peas canned by the extended water bath periods is small enough to warrant the use of this method in home canning, it is then

desirable to compare the quality of these products with the quality of the pressure cooked peas, which were free from spoilage and from any evidence of micro-organisms, as will be noted in table I. The peas processed by the pressure cooker method, with the exception of the fifty minute period, do not rank so high in palatability as do the peas processed by the water bath method, as shown in table II. The descriptive words used by the judges in reference to the peas of these two groups, table III, further emphasize the differences between the products of these two methods of canning. Whether the preference for the peas processed by the water bath method may be associated with the more frequent occurrence of flavors described as "sweet" and "natural", or whether "grassy" and "rubber" flavors are less offensive than the "hay" and "bland" taste ascribed to the pressure cooked peas, is not a point to be readily decided.

So little has been written concerning the substances responsible for flavors that these peculiar tastes present in canned peas must be explained chiefly in theory. If the "hay" flavor accounts for the low scores given the peas processed in the pressure cooker for 40 and 45 minutes, some reason must be found to explain why peas of the 50 minute period, canned by the same method, and having also a "hay" flavor, were scored higher. The judges have mentioned "sweet"

and "oversweet" more often in connection with these peas of the 50 minute period and it is possible that the "hay" flavor is masked by sweetness. If the knowledge of the chemical compounds related to flavor were more extensive, an explanation might be offered on the basis of possible volatile products which may be formed by the longer heating period at high temperature. It is quite conceivable that these substances, rendered more volatile by longer heat treatment, would be partially driven off by the short period of boiling which each of the samples undergoes before being tasted. Much of the disagreeable flavor would then be disseminated, permitting the more desirable flavors to govern the judgment of taste. Shorter heat treatment, it might be assumed, would not have the same volatilizing effect and the unpleasant flavors would predominate, as they do in the 40 and 45 minute peas.

The extensive collection of flavors described by the judges indicates that there are numerous unknown substances formed by the decomposition of peas during the canning process. One of the peculiar flavors mentioned occasionally throughout the groups of canned peas, but particularly among those processed at higher temperatures, is a "beefy" taste. A beefy or meat-like taste has been described in connection with some salts of glutamic acid (29). Of these compounds monosodium

glutamate has the most pronounced meat-like flavor, and it is manufactured extensively in China and Japan where it furnishes the meat flavor so often lacking in the restricted diets of the Orient (16). Although no mention has been made of the occurrence of this compound in peas, it would be interesting to determine whether monosodium glutamate is associated with the beefy flavor which seems to occur in peas under certain canning conditions. The high percentage of glutamic acid which is present in the proteins of peas and in the glutathione occurring in peas is at least suggestive that this glutamate may be formed.

The chemical reactions related to color change are nearly as obscure as those relating to the production of flavors. A very good explanation for the color change produced by cooking vegetables in water is postulated by Halliday and Noble (14). They assert that the color change is due, not to solution of the green color in the cooking-water, but rather to the decomposition of the insoluble coloring substance, chlorophyll. Heat and acid are most effective in its destruction. The water used in precooking the peas for this experimental work had a pH value of 7.8. Referring to table VII, it will be seen that the canning process caused the peas to lose a sufficient amount of acid to give the liquid in the jars a pH value of about 6.0 to 6.2. In some types of chemical reactions this change

in acidity may be considered of real significance. As regards the effect of storage on color which was evidenced by a loss of green coloring, it may be assumed that the chemical reaction caused by the presence of acid may go on for some time after the condition of increased acidity is first established. That this reaction takes place in the absence of light may be concluded from the fact that all the canned peas used for this experimental work were stored in wooden cupboards which were kept closed.

SUMMARY

1. In this study of home canning, peas of the Laxtonian and Perfection varieties were used. The Laxtonian peas were shelled by hand in the laboratory, while the Perfections were shelled by machine in the field.
2. The peas were processed by three different methods and for varied periods, as follows:-
 - Oven method - 90, 120, 150, 180 and 210 minutes.
 - Water bath method - 180, 216, 252, 288 and 324 minutes.
 - Pressure cooker method - 30, 40, 45 and 50 minutes.
3. The tests that furnished the data for this study were carried out at an altitude of about 5000 feet above sea level, where the temperature of boiling water varies from 202° to 204° F.
4. The percentages of spoilage occurring in the peas canned by the various methods and periods were as follows:-

Oven - Laxtonian - 90 minutes -	72.7%
" " 120 " "	90.9
" " 150 " "	16.7
" " 180 " "	40.0
Perfection 210 " "	51.4

Water Bath - Laxtonian - 180 minutes -	36.4%
" " " 216 " "	8.3
Perfection 216 " "	70.8
Laxtonian 252 " "	8.3
Perfection 252 " "	46.2
Laxtonian 288 " "	0.0
Perfection 288 " "	9.6
Laxtonian 324 " "	8.3
Perfection 324 " "	4.2

Pressure Cooker - No spoilage

5. All of the jars of peas were examined for bacterial content. The organisms isolated from the spoiled peas were mainly spore-forming facultative aerobes, often found in soil.
6. The higher rate of spillage noted in the Perfection peas that were shelled in the field confirms other experimental work which has shown the relation between spoilage in peas and soil contamination.
7. When the unspoiled peas were judged for palatability, those processed for the higher water bath periods, 288 and 324 minutes, and some of the peas processed in the pressure cooker for 50 minutes were scored higher than the others.
8. Many peculiar flavors were noted by the judges. It is suggested that one of these, a "beefy" taste, may be associated with a glutamate having a meat-like flavor.
9. The penometer tests showed that the majority of the peas, processed by all the periods and methods, tended to be too soft rather than too hard.
10. The color of the canned peas, as determined by comparison with standard color disks, was found to undergo a decided change during six months' storage in the dark. This color change was attributed to the destruction of chlorophyll.
11. In the oven-canned peas processed for periods ranging from 90 minutes to 210 minutes, spoilage occurred to such an extent that this method with the periods used cannot be recommended. The quality of the peas did not prove desir-

able, and the probability of success from lengthening the periods of processing by this method is not indicated.

12. The amount of spoilage among the jars of peas processed by the water bath method for periods of 180, 216, and 252 minutes was too great to permit the recommendation of these periods of processing by the water bath method at an altitude of about 5000 feet. The quality of the unspilled peas seemed to indicate that further extension of the processing period would produce satisfactory results.
13. The loss from spoilage of the peas, processed by the water bath method for the two longer periods, 288 and 324 minutes, was no greater than the amount which might be expected to occur because of slight imperfections in the equipment for home canning. The quality of these peas was judged to be good, in regard to palatability, texture, and appearance.
14. There was no spoilage among the pressure cooked peas for any of the processing periods. However, the 50 minute period peas were more pleasing in flavor than those processed for shorter periods, and were comparable to peas processed by the water bath method for 288 and 324 minutes.

CONCLUSIONS

1. When peas are canned at an altitude of about 5000 feet by the oven method of processing for periods ranging from 90 minutes to 210 minutes, the results are unsatisfactory as judged by the high degree of spoilage and the poor quality of the unspoilied peas.
2. When peas are canned at an altitude of about 5000 feet by the water bath method for the periods of 180, 216 and 252 minutes, there results an unsatisfactory product from the standpoint of spoilage, although the quality of the unspoilied peas is fairly high.
3. Canned peas of good quality and minimal spoilage percentages are produced by processing by the water bath method for a period as short as 288 minutes at an altitude of about 5000 feet.
4. Peas canned by processing for 50 minutes in a pressure cooker at a temperature of 240° F. and a pressure of 10 pounds (corrected for an altitude of 5000 feet) are free from spoilage and are of good quality.

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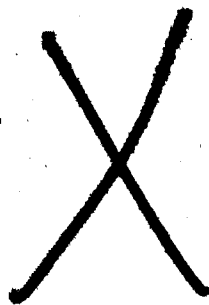
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