Causes of Fermentation in Canned Vegetables.

by

Edith B. Justin.

Table of Contents.

When one thinks of the number of people who depend upon canned products for the greater part of their vegetable supply and of the immense amount of labor and capital expended each year in the canning industry, one may readily see the importance of having the vegetables canned in such a manner that the consumer may receive them in perfect condition. The loss which may come to the canning companies, the dealers, and the consumers, if for any cause the vegetables are made unfit for use, is also apparent. Great losses do sometimes occur, and factories which have been successful for a number of seasons may absolutely fail during one season. At such times the vegetables ferment, causing the cans to swell and rendering them unfit for use. Investigations made in recent years show this to be the result of definite bacterial or chemical action. It is our purpose to bring together all the known causes of this loss, and, if possible, to suggest some measures by which the amount of fermentation in home-canned vegetables, as well as in factory-canned products may be diminished.

In the canning factories we generally find the following conditions: The vegetables are sorted and thoroughly cleaned, both by hand and machine, depending upon the kind of vegetable. The machines are often large and the work is rapidly done. When the vegetables are prepared for cooking, they are "blanched", that is, they are placed in boiling water for a few moments, then they are weighed into the can; the cans are sealed, labeled and processed. This means the cooking of the vegetables. The object is to heat the cans long enough to cook the vegetables, and to a temperature high enough to render them sterile. The finished product is then ready for storage.

When vegetables spoil, they are said to have undergone fermentation. This may be defined as the decomposition of an organic substance by some other organic substance. Two kinds of fermentation have been described in canned vegetables.

1. "Swelling."

This kind is named from the appearance of the cans. The normally depressed ends bulge outward on account of the pressure of the gas which is produced. Occasionally such cans explode. The material contained in them is decomposed, produces a foul odor, and is worthless as food. In swelled cans the decomposition of the material is effected in such a way that much gas and little acid is produced.

2."Souring."

The cans give no external evidence of being spoiled, but when opened the contents emit a sour odor and have an acid flavor. Here the decomposition has resulted in little or no gas and much acid. If soured cans are heated they will sometimes swell. Such vegetables are not good, although they are sometimes used as food. The character of the decomposition depends partly upon the nature of the original substance and partly upon the nature of the substance causing the fermentation.

In a few cases vegetables are spoiled on account of the poor quality of tin used in the cans, which are corroded, bringing about a chemical action that renders the vegetables useless. These instances are, however, rare and may be easily prevented by using good tin.

The spoiling which has made trouble in all canning processes is due to the fermenting of the vegetable by bacteria. These organisms belong to the vegetable kingdom, classed among the

lowest Thallophytes. They are unicellular, about 1/25000 inch long, varying in size form and characteristics. Like other forms of life, their growth is encouraged or retarded by certain conditions. Moisture, soluble nutrient material, favorable temperature, absence of light, an acid or an alkali media, depending upon the species of bacteria, proper gaseous environment, as the presence or absence of oxygen, are conditions favorable for their growth. There are two stages of bacterial life:

1.Vegetative form where they grow and multiply by fission or division.

2.Spore form where they rest or wait for conditions favorable for growth.

Many species of bacteria cannot pass into the spore form or "resting stage." If the bacteria are spore producing, the spores are formed when the conditions for growth are restricted; the other bacteria will die if the conditions become too unfavorable. Bacteria which grow in direct contact with the air are called aerobic, those which grow in the absence of air, anaerobic. When in the vegetative stage, a few minutes boiling will kill the bacteria. Hence, only organisms which are very resistant to heat can cause fermentation in vegetables which have been cooked in tightly sealed cans. Spores are very resistant to all unfavorable conditions, especially absence of food and moisture, and will live for a long time. The temperature at which they may be destroyed varies greatly with the kind of bacteria, but is comparatively high.

Canned vegetables undergo fermentation more readily than canned fruit. In fruit there is a large per cent of sugar and to this is usually added more sugar, as a preservative. This makes such a strong sugar solution that the organisms cannot grow.

In addition to this there is a lack of nitrogen and a large amount of acid in fruit which tends to check the growth of, and perhaps destroy the organism. Vegetables which contain a large per cent of nitrogen, such as peas, beans, and asparagus, ferment more readily than the starchy ones. In many vegetables acid is lacking, the amount of sugar and nitrogen is such as to favor fermentation, there is plenty of nutriment in solution or capable of becoming soluble by the action of enzymes secreted by the bacteria. Therefore vegetables in general can be preserved only by proper sterilization with moist heat.

In several different factories where there was a great loss owing to swelling, investigations were made as to the cause. At the Wisconsin Station two kinds of bacteria were isolated from cans of spoiled peas. One is described as a rod shaped bacterium which fermented sugar solutions with the production of gas. Both organisms were spore forming. The temperature of "processing" was raised and the swelling prevented, while the peas were not injured.

The results of this work are summarized in the following table:

Peas rich in sugar.	Steam pressure in cooking. lbs.	Temperature. Degs.F.	Time Min.	No.cans processed.	Swells. No.	Swells. %
Usual process	10	232	26	6,175	306	5.0
Experimental process.	15	242	28	11,859	8	(1)
Peas deficient in sugar.						
Usual process.	11	234	17	4,607	135	3.0
Experimental process.	15	242	30	2,520	14	0.5

Increasing both the temperature and the time of heating brought the desired result.

An outbreak of swelling in canned peas, at a New York factory, caused the New York Agricultural Experiment Station to investigate the matter in order to determine (1) the cause of the swelling, (2) the amount of heat necessary to obviate the trouble, and (3) the limit of heating which was practical without injuring the commercial quality of the peas. Factory methods were used in the experiment.

Microscopical examination of the juice from a swelled can showed large numbers of bacteria. Contents of soured cans also contained bacteria. Some of the soured cans contained a coccus form, others a rod form. The swelled cans which made up more than 99 per cent of the trouble, all contained a rod shaped organism. This bacterium was larger than that observed in the sour cans and was usually distinguished by a swelling at one end. It was isolated and sterile cans of peas inoculated with it. They were then resoldered and kept at blood heat. All were swelled within 24 hours. Reexamination showed only the one form present. Sterile cans of peas were inoculated with pure cultures of the rod form and processed for different lengths of time.

Two pound cans of peas were heated to 230° F. (110°C.) at the Experiment Station Laboratory as follows:

Time in minutes	20	25	30	35	40
No. cans heated.	6	6	6	6	3
No. cans swelled	5	6	1	0	0
Percentage swelled	83	100	16	0	0

This and other experiments showed that heating at 110°C.

for 30 minutes did not destroy the germ, that heating from 35 to 40 minutes rather over-cooked the peas, but that a temperature of 115-5/9°C. for 30 minutes was sufficient to destroy the organism. Except under unusual conditions, this amount of heating did not harm the peas. The organism which was isolated is an anaerobic, rod-like form, 4-6 microns long by 1.5 - 1.8 microns wide. Spores are formed, quickly and readily, in the swollen end of the rod. It is actively motile by means of flagella. The growth is best on a nitrogenous media and cane sugar, dextrose and lactose are fermented with the production of gas and acid. The growth on ordinary peptone culture is invisible. The growth on all media is very slow at a temperature of 22°C, while at 37°C there is an abundant growth in 2 to 5 days.

Another experiment is recorded by Dr. The. Gruber. This was particularly in regard to the heat necessary to sterilize vegetables. In processing vegetables, it was found that the smaller cans were sterile while the larger ones spoiled. The temperature necessary to render the large cans sterile was 117°C. for 10 minutes. A few degrees below this was not effective even when the heat was continued for hours. The organism isolated here as the cause of the fermentation was classified as Anaerobion paraplectrum foetidum.

Migula, in System der Bokterien describes the organism as an obligatory anaerobe, 7-10 microns long by 3/4 micron wide. It produces spores, occurs in chains of two and forms round compact colonies. Grows best at 36° to 38° C. and will not grow below 22°C. It grows on nutrient gelatin, nutrient agar, in liquid blood serum, but does not grow on potato.

If there are instances of fermentation where no organism

is isolated, it is no proof that bacteria have not been present. It may be that the methods of isolation were poor or the conditions were unfavorable for growth, as aerobic conditions for anaerobic organisms; or it may be that the food supply had been exhausted and the organisms destroyed by their own specific waste products.

As there are so many species of spore-bearing bacteria, each of which may require a different temperature for its destruction, no standard temperature and time of heating can be given. The temperature must be high enough to totally destroy all living material, and must necessarily depend upon the resistance of the spores. Experiments show that when compressed steam is used, the longer the period of rise of temperature to the particular sterilization temperature is extended, and the longer the actual period of sterilization is prolonged, the higher also will be the interior temperature of the cans, and that heat, if long enough and great enough will prevent fermentation.

Attempts have been made to can vegetables in the home for many years, but the results cannot be called successful. In former times the method much used was to prepare the vegetables as for cooking, boil in an open, but not uncovered vessel 20-40 minutes, pour into jars, seal and set in a dark place as an underground cellar. The usual way of sterilizing the jars was to scald them with water or at best to boil them in an uncovered vessel 20-30 min. Practically all of the vegetables spoiled. Means of contamination were abundant from garden to jar and the methods did not afford complete sterilization.

Fruit and acid vegetables are quite successfully canned, using the method just described. Bacteria and spores are more easily destroyed by heat and do not grow so readily, if acid is

present.

The object in home canning is to cook the vegetable, destroy any organisms which may be present, and prevent the entrance of others. Only fresh, sound vegetables should be used for canning. Those which are dirty, old, wilted, bruised or immature will not give good results. Cleanliness in the utensils and the persons handling the vegetables is essential. Glass jars with new rubber rings and porcelain-lined or glass caps are best. If, instead of cooking the vegetable and pouring it into the jar, a method of cooking similar to that of the factory is employed better results will be obtained. The method suggested is the following:

Prepare the vegetables as for cooking, place in boiling water a few minutes, then in the jars; fill jars with water, seal and heat in steamer. Since steam under pressure is not available at home, other means must be used to destroy resistant spores. Heating in the steamer 1-2 hours will destroy all the bacteria and mold. If no resistant spores are present, there will be no trouble. In order to insure sterilization it is well to reheat the jars in the steamer one hour for two days, making one hour per day for three successive days the time of heating. This allows the spores to develop into the vegetative forms, in the intervals between heatings, where they may be destroyed. Until the jars are heated for the last time, they should be kept at a temperature near 37°C. so that the spores will grow. Only a small per cent of the vegetables will spoil if heated for two hours on two consecutive days. Fermentation cannot always be told by the appearance of the vegetable, but the odor is usually decisive.

The following is the result of an experiment in asparagus canning by Ula M. Dow. The asparagus was canned in one-pint Mason jars. The raw asparagus was placed in the jar, the jar filled with water, placed in cold water, and heated for stated length of time after water was brought to a boil.

Experiment No.	I	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Number of jars.	4	4	3	4	3	3	4	3	3
Time heated, in hours.	1	2	1	1	3	3	3	2	2
Days heated.*	3S	3A	2A	1	3A	2A	1	1	2
Jars spoiled	2	0	0	4	0	0	0	?	?

* S= successive; A= alternative

The asparagus in the jars of Ex. VIII and Ex. IX was canned in July while that of the other experiments was canned in June. Jars of Ex. VIII and Ex.IX had specks of yellow material which look like flowers of sulphur all through the asparagus. In some jars the odor was good; in others the odor was good until the vegetable was heated, when it became offensive.

The results of my work are as follows:

In the first experiment the jars inoculated from were the spoiled jars of the experiment just recorded. Both gelatin and agar plate cultures were made and sub-cultures were made from the best colony of each kind of bacteria.

Table I.

Date.	Jar No.	Ex. No.	Plate No. and material inoculated.	Remarks.	Colonies
Apr. 3.	2	I.	1-asparagus 2-liquid 3-dilute liquid	Petri dishes not sterile. Abundant growth of light gray mould. Also colonies of bacteria.	R
Apr. 3.	3	I	1-asparagus 2-liquid 3-dilute liquid.	Petri dishes not sterile. Growth of mould. Jar opened 7 hrs. before cultures were taken.	S
Apr. 14	1	IV	1-asparagus 2-dilute liquid 3-asparagus 4-liquid	Mold of different kinds in colonies. Not like that in former cultures. The same kind of colonies in plate cultures from all the jars of Ex.IV. probably from mould spores about the caps of the jars. No appearance of mould in asparagus.	T
Apr. 14.	2	IV.	1-asparagus 2-liquid		U
Apr. 14.	3	IV.	1-asparagus 2-liquid		V
Apr. 14.	4	IV.	1-asparagus 2-liquid		W
Apr. 23.	2	VIII.	6 plates		X
Apr. 23	3	IX.	6 plates		Y

Table II.

Colonies from Table I.

Date	Plate No.	Colony.	Description of colony.	sub-culture agar slant.
	R			
	Agar 2	A	white, round, small.	1
	Agar 2	B	thin, spreading, white.	
	Gel. 2	A	fungus	2
	S			
	Agar 1	A	small, yellow	
	Agar 1	B	white, starshaped	3
	Agar 1	C	white, irregular, spreading	
	Agar 2	A	white, large.	4
	Agar 2	B	heavy, yellowish white	5
	Agar 3	A	gray white, heavy	
	Agar 3	B	white, irregular, spreading	6
	Agar 3	C	fungus	7
Apr 25.	T			
	Agar 1	A	mold, gray	8
	Agar 1	B	light, yellow, spreading	9
	Agar 1	C	small, yellow, round	
	Agar 2	A	convex, yellow, round	9
	Agar 4	A	white, irregular, spreading	
	Gel. 1	A	heavy black mold	10
Apr. 25	U			
	Agar 1	A	light gray mould	11
	Agar 1	B	greenish gray mould	12
	Agar 2	B	brown gray mould	13

Table II. (con.)

Date.	Plate No.	Colony.	Description of colony.	sub-culture agar slant.
Apr.25.	V			
	Agar 1	A	white mould	14
	Agar 1	B	white mould	15
	Agar 1	C	mould, gray brown at center, lighter at edge.	16
	Agar 2	A	gray brown mould	17
	Gel. 1.	A	Mould gray brown at center lighter at edge.	18
Apr.25.	W			
	Agar 1	A	light white growth	
	Agar 1	B	Gray brown mould	19
	Agar 2	A	gray mould	20
	Agar 2	B	small grayish white	21
	Agar 2	C	large round rose-colored	22
May 8	X			
	Gel. 4	A	mould, light gray	23
	Gel. 4	B	brown gray mould	24
May 8	Y			
	Agar 2	A	dark gray mould	25

Table III.

Date.	No. tubes.	Time heated.	No. spoiled.	Remarks.
May 12	3	1 hr.-1 day	3	
May 12	3	1 hr.-2 days	0	Inoculated with mould from sub-cultures 10, 14,18.
May 12.	3	1 hr.	3	Cooked asparagus before putting it into tubes.

The conclusion drawn from this is that the mould does not cause fermentation in vegetables. None of the spoiled tubes showed any growth of mould.

Table IV.

Date.	No. tubes.	Time heated.	Result.
May 13	21	1 hr.	On May 15 the asparagus in 9 test tubes was spoiled= B; the other 12 were good = A.
May 15	A 9, B2	1 hr.	A 9 kept. A 3 also kept. B 2 spoiled more.

From this we draw the conclusion that resistant spores were not present in some of the test-tubes. In the others the spores were readily formed.

Table V.

Plate Cultures from Tubes B in Table IV.

Date.	Description of tube inoculated from.	Plates	Colonies.
May 26	Yellowish scum over top of asparagus.	1 and 2.	numerous, small yellow.
May 26	White membrane over top of asparagus	3 and 4.	cultures not good.
May 26	Liquid green, small white membrane of center.	5 and 6.	numerous different kinds, small, white, yellow, orange.
May 26.	Asparagus.	7 and 8	none.

Table VI.

Date.	Sub-culture inoculated with.	No. Tubes.	No. Heating after inoc.	No. Spoiled.
May 22	1	2	3- 1 hr.	0
	2	2	3- 1 hr.	0
	4	2	3- 1 hr.	2 (a)
	5	2	3- 1 hr.	2 (b)
	6	2	3- 1 hr.	2 (c)
	9	2	3- 1 hr.	0

No definite conclusion can be drawn from this. The result is contrary to most experiments. As shown by another table, cultures were made from the spoiled asparagus and inoculated into tubes of sterile asparagus.

The cultures were made by inoculating agar slant tubes (1) which contained condensation water with a drop of liquid from the spoiled asparagus, inoculating other agar slant tubes from this one (2), and others from (2), as shown in Table VII.

Table VII.

Asparagus inoculated from.	Culture No's.	Result.
(a)	1, 2, 3, 4.	All cultures good
(b)	5, 6, 7, 8.	All cultures good
(c)	9, 10, 11, 12.	Cultures 9 and 10 good. No growth on 11 and 12.

Table VIII.

Date	No. tubes.	Sub-culture inoculated.	Time heated.	Result.
June 9-11	2	(a) - 2	1 hr -3 dys.	
	2	(b) - 8	"	All the tubes were good June 15.
	2	(c) - 10	"	

This accords with the results of most experiments. As the asparagus here was inoculated from cultures taken from that which spoiled, and made sterile the germ is probably not so resistant as the other experiment showed.

Plate cultures were made from six jars of peas. They were canned during the spring of 1907. The raw peas were placed in glass jars, the jars filled with water, sealed and heated in steam

for one hour on three consecutive days. The peas were not in good condition. Two jars gave a disagreeable odor, while several others seemed over-cooked. There were no colonies of bacteria, but there were several colonies of mould. This was of the gray sort found in former cultures.

Summary.

Fermentation in vegetables is usually the result of bacterial action.

The bacteria which cause fermentation in canned vegetables are spore forming.

Fermentation can be prevented by destroying the organisms. This may be accomplished by heat, either high enough to destroy the spores, or by a lower temperature at intervals; this allows the spores to develop to the vegetative form between heatings. The spoiled asparagus all seemed the same, but no colonies of bacteria were found which were similar in all the plates. It may be that the organism here, as well as those found in the factories is anaerobic.

References.

Farmers Bulletin No. 73

New York Agricultural Experiment Station Bulletin No. 29.

Pure Products Vol. IV, No. 5.

Experiment by Ula Dow.