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CONTROL OF SPOILAGE IN TOMATO PRODUCTS

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CARL S. PEDERSON AND ROBERT S. BREED

ABSTRACT

Samples of spoiled tomato products obtained from various homes and from canning companies have been examined, the causative organisms isolated, and the conditions under which the products were canned studied thoroly in an attempt to discover the causes of the spoilage and methods of control.

These studies have shown that with very few exceptions spoilage of tomato products is caused by bacteria belonging to the lactic acid types, and that those ordinarily found belong to one of six types or species. A few yeasts and spore-forming bacteria occur but cause little trouble in these products.

The lactic acid bacteria ferment the sugars present and produce lactic and acetic acids, carbon dioxide, alcohol, and mannitol. None of these products are poisonous, but they produce disagreeable flat and sour flavors in most cases. In some cases the product may be slimy, but this sliminess is also not poisonous.

With very few exceptions, the organisms are not resistant to the heat ordinarily used in canning. Losses are caused by carelessness in cleaning and sorting tomatoes; and by improper methods of operating machinery used in canning and bottling, particularly where hot products are placed in containers that are not to be resterilized afterwards. Likewise, careless methods of handling and storing 5-gallon cans, and the use of wooden vats and barrels contribute to a total loss from spoilage that still is much too large. Suggestions are made regarding methods of avoiding losses from this source.

INTRODUCTION

The various products manufactured from tomatoes are becoming more important from year to year. In 1925, the peak year in tomato canning, almost 20 million cases of tomatoes and over 4 million cases of pulp, paste, and sauce were canned in the United States. The value of the catsup made in 1925 is estimated at about $28,000,000. Between 15 and 16 per cent of this catsup was made in New York State, the majority of the larger companies having one or more factories operating within the State. A large part of the pulp that is canned is used in the manufacture of catsup, but some is used in soups, sauces for pork and beans, spaghetti, and similar products. The production of tomatoes within the State is rarely sufficient to supply the needs of these factories and therefore a large amount of pulp is shipped into New York from southern or western markets to fill these needs. Each year a serious loss takes place in the canned and, less frequently, in the bottled material, due to bacterial or yeast growth or to careless handling.

The amount of these losses is hard to determine, since the material is usually discarded with no record of the amount wasted. In certain packs it may be less than 1 per cent, but it may also be so serious as to cause practically a total loss of a given pack. Similar conditions have been noted in the canning of tomatoes in the home, one housewife having reported that she lost her entire pack of 4 dozen quarts of tomatoes.

No estimate can be made of the direct financial loss or of the loss of prestige to the canner caused by spoiled food which reaches the consumer. It is the belief of the writers that the losses can be cut to a small fraction of their present amount by reasonable care on the part of the canner.

HISTORICAL

A review of the literature dealing with the proper canning of foods would be an interesting and instructive study; but since it is not necessarily connected with this work, only a few papers that have a particular bearing on the subject will be mentioned.

Undoubtedly the most complete discussion of the various difficulties met with in canning tomatoes are the works of Howard and Stephenson (1917A)[1] and the more recent work of Bigelow and Stevenson (1923).

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[1]Refers to Literature Cited, page 16.

Every canner should be familiar with these papers, since they point out very clearly many of the difficulties of producing a sanitary product. Bigelow and Cathcart (1921) have shown the close relationship between the acidity of various products and the time required for sterilization. Magoon and Culpepper (1921) have shown the rate of transmission of heat in cans and glass jars. Ayers and Osborne (1927) have made a similar study using catsup bottles. Altho this type of work has been carried out with numerous products by others, these workers have made determinations on canned tomatoes or catsup under practical conditions. Bigelow (1926) has pointed out the relationship between the solidity of the pack and the transmission of heat. The effect of salt, sugar, and acid as preservatives for tomato products has been pointed out in Bulletin No. 538 of this Station.

Bacon and Dunbar (1911) have analyzed numerous cans of spoiled tomatoes and found that the end products of the fermentation are certain acids and alcohol which have very little harmful effect. The fermentation of tomato products produces no such public health problem as does the growth of *Bacillus botulinus* in non-acid vegetables and fruits.

METHOD OF STUDY

Various canning factories have been visited in New York State, Canada, and elsewhere during the course of this study. If the factory had an appreciable amount of loss in either canned tomatoes, pulp, or catsup, a thoro examination of the plant was made in an attempt to determine the cause of such losses.

The methods of cleaning the tomatoes, the sorting, trimming, peeling, and packing were noted. The possibilities of changes in temperature during packing were studied. In canning pulp and bottling catsup, the type of holding vats in use, and the amount of cooling in these vats and in the pipe lines, especially during breakdowns, were noted. Methods of storage used by various canners and the ensuing difficulties met with were found to be important.

The canned product itself was studied in detail, noting whether or not the can was defective or damaged. The spoiled cans could quickly be sorted from the good product by the bulging ends.

Many samples of catsup or canned tomatoes packed in homes were also received, and the method of canning by the housewife studied. In many cases queries were answered and from the discussion much val-

uable information obtained regarding home canning, even tho no samples of the spoiled material were obtained. The spoilage of tomatoes canned in glass could be noted by the clouding, and sometimes a gassy condition of the juice. Often the substance of the tomatoes was badly broken down.

The cans were opened under sterile conditions, and some of the material inoculated into a fresh medium for isolation and further study of the causal organisms. At the same time preparations were made for microscopic examination.

Catsup was examined in the same way, but it was somewhat more difficult to select the spoiled product. Sometimes white mold-like spots could be seen near or on the bottom of such bottles, while the catsup might have had a gassy or blown appearance. The contents of these bottles were usually forced out violently when opened unless the cap was loose, in which case some of the catsup usually could be seen on the outside of the neck of the bottle.

THE SPOILAGE ORGANISMS

The bacteria and yeasts isolated were studied in detail and classified. This detailed and technical description is found in Technical Bulletins Nos. 150 and 151 of this Station. The source of the organisms and the relative frequency of occurrence are given in summarized form in Table 1.

TABLE 1.—SOURCE AND TYPES OF ORGANISMS FOUND IN SPOILED TOMATO PRODUCTS.

Product examined	Number of samples	Organisms isolated									
		No growth	*L. lycopersici*	*L. gayoni*	*L. pentoaceticus*	*Leu. pleofructi*	*L. mannitopoeum*	*L. plantarum*	Yeasts	Spore-forming rods	Mixed cultures
Pulp	44	5	2	3	11	8	0	22	2	0	15
Tomatoes	19	4	1	5	1	9	0	5	0	1	6
Catsup	29	16	1	0	2	0	9	2	1	0	1
Chili sauce	1	0	0	0	0	0	0	0	0	1	0
Pork and beans	8	0	0	0	0	8	0	8	0	0	8
Rotten tomatoes	50*	0	0	0	0	+	0	+	+	0	+
Total	101	25	4	8	14	25	9	37	3	2	30

*Estimated. + Organisms present.

An examination of the data shows that certain non-spore-forming organisms occur most frequently, the yeasts less frequently, while the spore-formers occur very rarely in tomato products. Of the two spore-formers isolated, one was present in chili sauce and very little growth had taken place. The single bottle of chili sauce was the only spoiled one which the company reported. The other spore-former was from a quart jar of tomatoes canned at home. Very little could be learned of the methods of canning used. Mickle, in unpublished data secured during a previous investigation (Technical Bulletin No. 110 of this Station), noted two cases of spore-formers in pulp but did not isolate and identify the organisms.

The non-spore-forming organisms isolated in the present study belong to six species of Gram-positive, lactic acid forming organisms. *Lactobacillus plantarum* (Orla-Jensen) Bergey converts sugar practically quantitatively to lactic acid. (See Technical Bulletin No. 151 of this Station.) The organism is found in practically all types of tomato products (Table 1). This bacterium does not produce a typical "swell" in canned goods, but the edges of the cans are bulged somewhat, and the contents are strongly acid, cloudy, and often decidedly slimy. Microscopically, the organism is a rod of medium size.

Lactobacillus lycopersici Mickle, *Lactobacillus gayoni* (Müller-Thurgau and Osterwalder) Pederson, *Leuconostoc pleofructi* (Savage and Hunwicke) Pederson, *Lactobacillus pentoaceticus* Fred, Peterson and Davenport, and *Lactobacillus mannitopoeum* (Müller-Thurgau and Osterwalder) Pederson are gas-producing organisms, that is, they produce abundant carbon dioxide, as well as alcohol, acetic acid, and lactic acid. In canned products, they produce a decided "swell", the force of the pressure often bursting the can. In catsup, the cap is sometimes forced open, but if not, when the cap is removed, the contents are violently forced from the bottle, sometimes spattering several feet away. Certain strains of these organisms produce a slimy condition.

Microscopically, the organisms show certain distinguishing characters. *Lactobacillus lycopersici,* originally found in a mild tomato catsup, is a long rod, occasionally in chains of organisms extending across the field of the microscope. *Leuconostoc pleofructi,* on the other hand, is an extremely short rod or coccus form. It rarely, if ever, occurs in catsup, but is often found in any of the less acid products. The other three organisms are not readily distinguished microscopically, all occurring as short rods in culture media, but as rods of medium length in tomato

products. A few simple laboratory tests are required to distinguish between them. (See Technical Bulletin No. 150 of this Station.)

Yeasts often occur in tomato products, but before they can grow the container must be opened to allow air to enter. This type of spoilage is not of serious consequence in products other than catsup because of the aerobic nature of the organisms and the fact that tomato products are consumed shortly after opening. Catsup, on the other hand, when opened may stand around for some time before it is used. This type of spoilage has been described by Ayers (1926).

In a number of cases no growth of bacteria could be obtained from spoiled material, even tho the product was gassy and bacteria could be seen in the original material. In most of these cases the organisms were of the long rod type, apparently *L. lycopersici,* an organism that is readily killed by its growth products.

The original source of these organisms is a question which remains unanswered. They may possibly survive in soil for a long period, but do not multiply rapidly unless given this more suitable environment. Some of the forms have been found in other fermenting products, such as silage, sauerkraut, spoiled wines, fermenting beets, and potatoes. It was of interest to study rotten tomatoes obtained from a pit into which they had been thrown. Altho the prevailing type of organism was of the Gram-negative, aerobic, rotting type, the Gram-positive long rod type could be seen and two of these types were isolated.

EFFECT OF BACTERIAL GROWTH ON THE PRODUCT

In only a small number of cases were spore-forming organisms found. In the majority of cases, yeasts or the various types of lactobacilli were present. These organisms attack the sugars of the tomatoes, converting them to lactic and acetic acids, carbon dioxide, alcohol, and mannitol. The fermentation may be likened to the fermentation of silage and of sauerkraut. Very little action takes place upon the protein or other nitrogenous constituents. The product is not poisonous but has a disagreeable flat and sour taste, and is therefore unfit for use. In some cases a distinct and disagreeable sliminess is present, but this also is not poisonous. Bacon and Dunbar (1911) have made chemical analyses of a number of such spoiled products, and altho they did not determine the causative organisms, their results indicate action upon the sugars rather than upon the proteins.

HEAT RESISTANCE

The canner is most deeply interested in the amount of cooking or processing necessary to kill the organisms causing spoilage. This is particularly important in the canning of tomatoes since overcooking usually results in a sloppy, undesirable product. It is also important from the standpoint of economy of operation. With this in mind, the heat resistance of these more common types of organisms was determined. Tomato juice was used in this study. The juice was prepared by filtering cooked and mashed tomatoes or pulp thru several thicknesses of cheesecloth. This clear liquid was placed in 250 cc Erlenmeyer flasks and sterilized. The flasks were then placed in a bath at the desired temperature. When the temperature of the tomato juice attained that of the bath, 5 cc of actively growing culture were added and thoroly mixed. Samples were taken at the time intervals as shown in Table 2 and plated immediately. The plates were incubated for five days at 77°F (25°C) and then counted. A summarized account of the results are given in Table 2.

From the results it was found that none of the organisms can be considered heat resistant. After 5 minutes at 150°F a definite decrease in number of living organisms of all types is noted.[2] *Leuconostoc pleofructi* is killed almost instantaneously. Some of the other types are more resistant, a few organisms living even after 30 minutes heating. At 170°F all of the organisms studied were killed within a few minutes. The resistance of the spore-forming organisms was not determined, since they occur so seldom and since it would not be practical to cook tomatoes long enough to kill these types.

In this study, the heat resistance has been determined under practically ideal killing conditions. In actual canning many other factors must be considered. Tomatoes, pulp, catsup, or other products are more viscous than tomato juice, and also contain solid material, thus making the penetration of heat slower. In ordinary canning it requires some little time for the center of the can or jar to attain the temperature of the retort, but when the center of a can has reached the desired temperature it will remain there longer after the cooking process. The rate of transmission of the heat at various temperatures is clearly shown in the work of Magoon and Culpepper (1921). If their curves are studied, it will be found that heating at the temperature of 212°F

[2]More complete data may be found in Technical Bulletin No. 150 of this Station.

TABLE 2.—HEAT RESISTANCE OF ORGANISMS ISOLATED FROM SPOILED TOMATO PRODUCTS AS SHOWN BY GROWTH ON PLATES MADE FROM FLASKS HEATED AT DIFFERENT TEMPERATURES FOR VARYING LENGTHS OF TIME.*

SPECIES ISOLATED	NUMBER OF CULTURES STUDIED	TEMPERATURE, °F	NUMBER OF CULTURES FROM WHICH LIVING ORGANISMS WERE OBTAINED AFTER HEATING IN FLASKS FOR NUMBER OF MINUTES INDICATED												
			0.25	1	2	3	5	7	9	12	15	18	20	25	30
L. lycopersici	6	150	6	6	6	4	2	2	2	2	1	0	0	0	0
	3	170	2	2	0	0	0	0	0	0	0	0	0	0	0
L. gayoni	9	150	9	9	9	9	9	9	7	8	7	3	2	0	0
	6	170	6	5	4	4	4	4	2	3	1	0	0	0	0
Leu. pleofructi	7	150	7	6	3	3	1	0	0	0	0	1	0	0	0
L. pentoaceticus	4	150	4	3	–	2	1	1	0	0	1	1	0	0	0
L. mannitopoeum	3	150	3	3	3	3	3	3	3	2	2	2	3	2	2
	5	170	5	4	2	2	1	1	1	1	0	0	0	0	0
L. plantarum	10	150	10	8	7	7	7	7	5	4	2	1	2	1	0
	5	170	3	1	0	0	0	0	0	0	0	0	0	0	0
Yeasts	2	150	2	1	0	0	0	0	0	0	0	0	0	0	0

*The detailed plate counts are given in Technical Bulletin No. 150 of this Station.

about 43 minutes will be required for the center of a No. 3 can of tomatoes to reach a temperature of 150°F. This temperature is one at which a heating of 30 minutes is required to kill all of the organisms.

A temperature of 170°F, the temperature at which killing is rapid, is attained is about 52 minutes. At higher temperatures of processing, that is, 228°F and 250°F, the rise is much more rapid. The time required using quart glass jars is practically the same. Bigelow (1926) states that with a solid pack the heat penetration is slower and the time of process for complete sterilization is necessarily longer than when free liquor is present. Naturally an equivalent or longer time period is required to cool the product.

It is generally known that the lower the number of organisms present in any material, the more easily the material can be sterilized. Therefore, a study of conditions thruout the factory, particularly in regard to introduction of bacteria, is important.

CLEANING AND SORTING TOMATOES

In the majority of factories it was found that tomatoes were usually properly cleaned and sorted, altho in come factories faulty conditions existed. The washing of tomatoes is one of the most important processes in canning and one that requires a careful study on the part of the canner. Tomatoes from heavy clay land require a more careful washing than tomatoes from light sand land. In fact, it seems almost impossible to remove some of the heavy sticky clays and the millions of bacteria that such soil contains. Several good types of washers are available and the problem must be given careful consideration by each canner. Howard and Stephenson (1917B) discuss the relative merits of the various types of washers.

Ordinarily the sorting and trimming line in the better regulated factories gives very little trouble. During the busier seasons there is a tendency to try to increase the rate of canning by speeding up the belt or placing a larger number of tomatoes on the sorting and trimming lines. In the speeding up process, the trimmers and sorters are much more inclined to overlook green spots or partially decayed tomatoes. They fail to realize that passing the rotted spots results in the introduction of a great number of bacteria. The hard, somewhat corky, green and white spots remain hard in the cooking process and therefore do not conduct the heat as well as the ripe tomatoes. These conditions are more often found in pulp making than in the canning of tomatoes. In the home, altho rotten spots may always be removed,

housewives often do not realize the importance of the green spots in preventing complete sterilization. Many housewives have noted that in certain years spoilage is excessive and they say that it has been a poor tomato year. It may have been in respect to unequal ripening and the subsequent larger amount of white or green corky spots.

CANNING MACHINERY

Even with the great strides that have been made in the improvement of canning machinery, breakdowns or accidents occur so that work must be interrupted. This is especially important in packing catsup, chili sauce, or pulp in which the product is not sterilized after being placed in the container. The product in the pipe lines or in holding tanks cools very quickly. In one plant in which catsup was being bottled at 180°F, it was found that during a shut down the temperature fell to 140°F in the necks of some of the uncapped bottles. This is quite too low to be of value in killing bacteria that may have entered from various sources, and therefore the bottles should have been pasteurized or the catsup reprocessed.

In some factories the bottles are turned on their sides so as to heat the neck and cap with the hot catsup, but even then there is not enough heat to sterilize as viscous a product as catsup at a temperature of 140°F. Whether or not catsup should be processed after filling depends upon the temperature and conditions at filling. Naturally, in the case just described, the catsup should again be processed, but it might be much more economical to remove the catsup from the bottles as well as the cooled material in the pipe line and reheat that portion. Often it is an unnecessary expense as well as a waste of time to pasteurize catsup and chili sauce in the bottle.

Many companies have installed glass-lined holding vats for catsup or pulp and a number have metal vats, but there are still a few wooden containers used for that purpose. Canners will continue to have trouble as long as they continue to use such wood containers without taking the extra precautions necessary. Catsup or pulp get into the cracks and between the staves and on the wooden paddles, and it is practically impossible to wash them out. In fact, water simply dilutes the catsup, making conditions more ideal for growth and for reinoculation of newly made catsup. Even steam sterilization usually fails in that the steam is condensed to water before penetrating thru to all the crevices.

In one factory thousands of cases of catsup had been returned because

of spoilage. A thoro examination of the machinery revealed the fact that the wooden holding vats were the only possible source of infection. Very little trouble was ordinarily experienced in this factory but during the rush season of one year they were obliged to use wooden vats as well as their glass-lined holding vat. Unfortunately no data were kept as to the time of manufacture or the temperature of filling so a direct check-up could not be made, but since by far the greatest amount of spoilage experienced for years occurred that year, one naturally would conclude that there may have been some relation of this spoilage to the use of the wooden holding vats. The organisms isolated in this case were almost pure cultures of *L. mannitopoeum,* one of the heat-resisting types, and a very active gas-producer.

THE CONTAINER AND STORAGE

Ordinarily tomatoes are packed in No. 2, 3, or 10 cans in factories, or in pint or quart jars in the home. Catsup is packed in one-half pint, pint, or gallon bottles or in No. 10 cans and pulp in 5-gallon or No. 10 cans.

The pint or quart jar is ordinarily used in the home. There are many common mistakes in its use that may result in a spoiled product. Altho practically everyone is careful in the proper sterilization of jars and covers, quite often the rubbers are neglected. This latter comes in contact with the product but is not sterilized readily by the hot product, even tho the jar is inverted while hot. A few cases have been found in which the rubber was not put on correctly. A large percentage of housewives practice inverting the jar immediately after sealing, thus insuring sterilization of the cover by the hot tomatoes and also showing whether or not the product is properly sealed. Occasionally cases have been noted where the product was not sealed while hot and air has thus been allowed to enter.

In factories, the smaller type cans and bottles are closed by means of a closing machine and the canned product is sterilized after closing. If the can is closed properly, then given sufficient sterilization and handled reasonably carefully so as not to open seams, spoilage should be eliminated. In actual practice, minor accidents may occur in closing cans or in handling and a small amount of spoilage occurs. If a great amount of spoilage occurs, it can usually be traced to faulty sterilization. The retort may not register properly or air pockets may be left in the retort so that the product does not reach the desired temperature. Occasionally the cooking time is insufficient.

In storing this type of container, various methods are used. A few canners place the product in cartons or boxes immediately. In order to avoid stack burning, this should not be done until the product is properly cooled. Furthermore, the material remains warm for days and produces ideal growth conditions for bacteria. A second method of storing is in open stacks in the warehouse. Ordinarily boards are placed between every tier or every second or third tier of cans so as to equalize the weight over the entire can. It was found that where boards were not used between tiers that very often cans were slightly dented and swells were more common. Bigelow and Stevenson (1923) give some very valuable suggestions in regard to cooling and storing.

Trouble may also occur in storing battles of catsup. The greatest fault found was that of placing the filled bottles in the final packages while still hot. A great amount of stack burning may follow such practice. Many canners tip their bottles on end to keep the cork moist and to prevent leaking.

The 5-gallon can and the wooden barrel were always found to give the greatest amount of trouble. The latter container has fallen practically into disuse since it has been found to be impossible to sterilize. The 5-gallon can was found to be the most abused container of all. Tomato pulp can be stored in 5-gallon containers with practically no loss provided a reasonable amount of care is used. In several factories in which this container was used for storage, the loss was negligible, while in others in which its use was abused the spoilage was enormous.

In one factory cans were used several times before being discarded, the cans never being tested for leaks, or discarded if small rust spots appeared. In another factory empty cans were passed from floor to floor thru a chute so poorly arranged that the cans could be said to fall from one floor to another. These cans also were not tested just previous to use. In another instance cans were stored on a damp cinder floor to cool. The acid in the cinders ate small holes in the cans, some of which produced leaks immediately, while others caused weak spots, many of which gave way later.

Rough handling of cans with the resulting opening of seams, improper soldering leaving small openings, and shipping from point to point some time before use were other common practices found.

The 5-gallon can is a large container, and not very strong. It therefore requires careful handling. The companies making such cans take the greatest precautions in handling and shipping their product and guarantee the greater percentage to be free from leaks. In spite of this,

the can ought to be tested immediately before use. This can be done at a slight expense by immersing the can in water and forcing compressed air at about 2 pounds pressure thru the opening.

Immediately after filling, the can should be sealed and passed carefully to the store-rooms, cooled by water, dried, and then stored in a clean, dry room with a good circulation of air, with thin boards placed between tiers to equalize the weight. If the pulp is to be used at some distant point, shipping should not be done until a few days before using because of the danger of breaking seams in handling and thus producing small leaks which permit bacteria to enter.

In one factory cans of pulp were found stored in a damp basement piled on top of each other with nothing between the various cans. Practically every can was covered with rust spots. One swelled can had broken open, spraying the cans surrounding it and running over all the cans below it. This produced splendid material for rusting the cans more quickly and inoculating them as soon as an opening was produced. Needless to say, the company reported a large loss of pulp.

CONCLUSIONS

The spoilage of canned tomatoes and tomato products is usually caused by various species of non-spore-forming rods or cocci of the genera *Lactobacillus* or *Leuconostoc*.

Occasionally yeasts and spore-formers are found in such spoiled products.

Altho the heat resistance of the spoilage organisms is relatively low, heat is not conducted rapidly by the product and therefore an extra period of processing becomes necessary.

The spoilage is similar to the fermentation of sauerkraut and pickles, the sugar being converted to acids, alcohol, and gas. The products of fermentation are not poisonous but may cause an undesirable taste.

Certain general faults have been found in canning operations both in the factory and the home. There is a tendency during the busy season to speed up the operations, causing a laxity in sorting and trimming, and introducing green spots as well as partially fermented tomatoes. Not enough care is taken in the resterilization of material which has been allowed to cool before the proper closing of the containers.

Some study should be given as to the proper use and storage of containers, especially by those canners who have an excessive amount of spoilage which they cannot account for in any other way.

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