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Preservation of dried figs with special emphasis on pasteurization

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PRESERVATION OF DRIED FIGS WITH SPECIAL EMPHASIS ON PASTEURIZATION

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1. Introduction and History

Specialization of all fruit-growing, and fruit preservation in its various forms, has made the production of figs an art in itself. The fig industry has become one of the important trades of America. It has steadily grown from practically insignificance to hold its place with the more prominent products of the country. A report made by Consul Emmett of Smyrna in 1890 states the following:- 1 - "A box of figs grown and packed in California reached here this autumn, and was inspected and universally praised by many dealers. In some instances it was impossible to persuade the parties that said figs were grown outside of the Aidin District; in fact, some went so far as to designate the orchard. Those who grasped the full importance of this American enterprise predicted that Turkey's supremacy in the fig was waning."

The earliest Hebrew books mention the fig; Homer, Plato and other Greek writers refer to it, and the Egyptian pyramids contain pictures of the fruit.

Fig, the popular name given to various plants of the genus Ficus, of the mulberry family (Moraceae), comprising about 800 species which are characterized by a pear-shaped fruiting receptacle. Someof the species are low trailing shrubs, others gigantic trees chiefly indigenous to tropical forests. Their leaves are alternate and abound in a milky juice, usually acrid, though in a few instances sufficiently mild to be used for allaying thirst. The juice contains

caoutchouce in large quantity. (18)

The well-known figs of commerce are obtained from *Ficus carica*, a bush or tree about 18 or 20 feet high, with broad, rough, deciduous leaves, deeply lobed in the cultivated varities, but in the wild plant sometimes nearly entire. The branches bear almost sessile receptacles in the axils of the leaves. The male flowers are mostly in the upper part of the cavity, and are few in numbers. As it ripens the receptacle enlarges, and the many single seeded pericarps become imbedded in it. The fig seems to be indigenous to Asia Minor, Syria, Palestine, Iraq and Africa, but now occurs wild in most, and is cultivated in all the Mediterranean countries.

The Arabs carried the fig tree to Europe, and raised fig culture to a degree of importance which it has never since attained out-side of its old home, Asia Minor. The Arabic in-invasion extended through northern Africa to Spain and Portugal, and in these countries fig culture began to flourish and became of great importance. Comparatively, it is only of recent date that the Smyra figs have supplanted all others in English and American markets. (16)

The nutritious fruit can be preserved easily, and was one of the earliest objects of cultivation. Asia Minor, the Spanish Peninsula, and the South of France supply a large portion of market figs.

The fig tree produces two sets of shoots, and two crops of fruit in a season. The shoots formed by the first or spring sap put forth figs in July and August. These figs which form

the second crop ripen during the autumn. The shoots formed by the second flow of sap from the first crop of each year. In warmer climate these ripen during June and July, but not before September or October in the United States.

The fig will grow in almost any semi-tropical location, but it attains its highest development on a rich, moist, but well drained soil, that contains abundant humus. A good supply of lime, phosphoric acid, and potash is also needed. (14) Unless the soil is quite rich, these must be supplied by fertilization.

The figs are one of the oldest cultivated fruits. It is nutritious, wholesome, and of attractive appearance.(30) When ripe the figs are picked and spread out to dry in the sun. Those of better qualty being much pulled and extended by hand during the process. The prepared fruit is packed in barrels, rush baskets or wooden boxes for commerce.

Figs constituted an important item in 1821, when 259,217 pounds were imported. The maximum quantity imported in 1896 was 11,635,493 pounds valued at $629,488, while the greatest value was that of 1882, which amounted to $678,341.87. (35)

In the United States, the fig is grown commercially in several southern and southwestern states, but chiefly in California, Texas and Louisiana. Since 1900 figs of Smyra quality have been grown in California, whose total production in 1927 was about 24,000,000 pounds. In Texas in the same year about 10,000,000 pounds of fresh figs were utilized in the commercial manufacture of preserves. The varieties are

numerous and of various colors, from deep purple to yellow or nearly white,

The tabulation given below shows the United States fig production in recent years. (7)

	1931 tons	1932 tons	1933 tons
California:			
dried	17,000	17,000	19,000
not dried	6,300	6,500	5,900
Texas:			
not dried	1,851	504	-----

Of the California production listed as "not dried" as proportion went into the production of canned figs. California canned fig production amounted to 77,482 cases in 1931, 147,573 in 1932, and 127,782 cases in 1933. In 1933, the glass pack amounted to 3,308 cases.

Imports of figs in 1933 amounted to 5,857,317 pounds as compared with 1932 imports of 5,966,921 pounds. Of the 1932 imports,4,237,952 pounds came from Turkey, 971,178 pounds from Greece and 695,140 pounds from Italy.

The California figs are considered by some people to fully equal the imported product in quality. They contain approximately as much sugar, possess a very good flavor and are often cleaner and more attractive in appearance. Besides being edible in the fresh state, the fig can be canned, preserved, or dried in which conditions it is sold as a commercial article. Its chief importance, however, is as a dried fruit, thousands of tons being annually consumed in the United States and England alone. (17)

Figs are grown occasionally in temperate climates. They

were brought to England, it is said, by Cardinal Cole, in 1525, during the reign of Henry VIII. Fresh figs are everywhere a favorite dish for the dessert, cut, eaten with sugar and cream, like strawberries. They are also stewed and prepared in almost every imaginable form. (34)

The fig requires a semi-tropical climate, but horticultural varieties have been grown in much colder climate than of the habitat of the wild fig. (15) The fruit is grown for the tables as far North as Paris,in France and in the South of England. It has been known to fruit in the open Michigan without protection other than a high board fence enclosure. Figs may be grown under glass, being planted permanently in a border after the manner of hothouse grapes. In the Southern and Gulf States, the exact time of production and origin of the many of the more important varieties are unknown.

Figs have been cultivated in the Pacific Coast states for more than two centuries, as it is thought that they were in the Mission gardens at Loretto, Lower California, before 1710. When the earliest California nurserymen began to grow figs, they first secured the Black Mission variety which the Spanish padres had brought from Mexico, and the little white Marseilles, which was at Santa Clara, and Santa Barbara before the discovery of gold. (3) The importation of figs, dried canned, or preserved, into regions unsuited for their growth, forms an immense and increasing group of industries.

Plate I.

Common Types of Bulk and Packaged
Fig Boxes

II. Review of Literature

A. General

The object of this research was to study the factors of time, temperature and humidity in the heat treatment of packaged figs. The aim was to find the ideal factor which would sufficiently pasteurize the figs, and at the same time keep them in a good marketable condition for several months.

The best Turkish Eleme figs are imported from Smyrna. They are so soft textured, thin-skinned, and packed in boxes. The fruit has a variety of uses, not only in the dried form, but also for eating fresh and in such manufactured forms as jam, marmalade, preserves, canned figs, candy, bakery products, breakfast and health foods, beverages, and medicinal preparations. The fig is one of the healthiest of fruit trees, easily suited as to soil and moisture, and well adapted to a wide area in California. The quality of California grown figs at their best is admittedly unsurpassed. (30)

According to Tibbles, (33), dried figs are butritive by virtue of their sugars; they are pectoral, demulcent, and laxative; eaten to excess they cause pain, flatulence, and diarrhea. As a food they are a valuable source of heat and energy, one pound having a feul value equivalent to 1,475 calories.

B. Caprification of the Fig

Caprification is the method employed for hastening the

maturation of figs. Without caprification the figs will not mature either seeds or figs. Certain hymenopterous insects of the genera Blastophaga and Sycophaga, enter the minute orifice of the receptacle and thus convey the pollen to the stigma. (18) They ensure the fertilization and consequent ripening of the fig.

As described by Eisen, (15), branches of the wild fig are suspended above or beside those of the cultivated tree. The insect Blastophaga grossorum crawls from the caprifig into the Smyrna fig and fertilizes it. If pollen is not introduced the fig may fail to develop and finally fall to the ground. The fig insects were introduced into California in 1899, with the result that Smyrna figs, known as Calimyrna figs in California are now grown there. Caprification was not practiced in the United States before 1880. The first importation of Smyrna fig trees was made by Gulan P. Rixford about that time, when three varieties of Smyrna figs and a single caprifig tree were introduced.

C. Fig Spoilage

I n 1927 the United States Department of Agriculture fixed a ten per cent tolerance of insects on all imported figs; that is, not over 10 per cent of the individual figs may show the presence of dead or living insects, larvae, eggs, web, excrement, dirt or smut. Up to that time the 19,000 to 20,000 tons of figs coming into the country each year, according to Green, (22), were seldom more than culls. "Black ugly syrup oozed from them and spread over the

floors, dirt worked its way into the bags; and multitudes of dejected worms crawled out." As no figs would be permitted to enter the country, or be placed on sale therein, which contained more than a total of ten per cent of wormy, dirty, or diseased fruit, nearly all the imported figs are now being cut open, carefully inspected and fumigated before they are sent out from the exporting countries.

The following classification is adopted when figs are examined by the United States Department of Agriculture.(8)

Fig Classes

Insect Infested

a. If worms or insects or their pupae, dead or alive, are present in the interior of the fig.

b. If excreta are distributed in the interior of the fig.

Moldy

a. If the fig shows a moldy or smutty condition in an area equaling or exceeding 3/16 inch (0.5 cm.)

Sour

a. If fermented as evidenced by distinct sour taste or odor, or the darkening in color characteristic of fermentation or souring.

b. If infested with internal rot (endosepsis.)

Filthy

Figs are regarded as filthy if contaminated with dirt or extraneous matter.

a. Containing extraneous matter or filth pressed into

the fig.

b. Containing sand or earthy material.

c. Showing other evidence of unsanitary production or handling.

<u>Worthless</u>

Figs are regarded as worthless if so immature, woody, or fibrous as to be practically valueless as a food.

<u>Passable</u>

Figs are acceptable for consumption if not included in any one of the five preceeding objectionable classes.

Davey and Smith, (13), have done extensive research on fig spoilage and report that there are three specific types of spoilage designated as "smut and mold," "souring," and "endosepsis." All of these are caused by commom saprophytic microorganisms which are able to invade the fruit cavity previous to its maturation. In mature figs after the eyes have opened the fruit from some trees showed as high as 50 per cent infection with <u>Aspergillus niger.</u> Many figs after the eyes opened showed a considerable variety of fungi, Aspergillus, Rhizopus, Alternaria, Cladosporium, Penicillium, Hormodendrum, various species of yeast, and a number of species of bacterial

Smith and Hansen, (30), have reported of the serious problem the California fig industry has in the high percentage of spoilage in the fruit. This condition was accentuated by the action of federal authority in decreasing the legal tolerance of infested figs to ten per cent. The principle

troubles affecting the figs are those enumerated above. These forms of spoilage have hindered the success of the fig industry.

Misses Phillips and Smith, (25), have clearly indicated that the rotting and spoiling of figs is not an ordinary process of decay or the effect of weather conditions. Their work suggested the following principles.

1. The rotting of figs is caused by different kinds of fungi, bacteria, yeasts and similar organisms, which start to develop inside the fruit.
2. The decay germs are carried into the figs by insects; a fig is always sound and sterile unless it has been entered by some insect.
3. Almost all the trouble starts while the figs are still on the tree and not after they have fallen to the ground.
4. The rotting or souring of figs is not caused by weather conditions, soil, moisture, or irrigation, but these conditions may hasten or retard the trouble by causing the figs to ripen and dry more or less slowly.

a. Endosepsis

Caldis, (9), showed that this particular type of spoilage affects only caprified (pollinated) figs, that it is caused by the fungus Fusarium moniliforme Sheld, and that it is transmitted exclusively by the caprifying (pollen-carrying) insect Blastophaga psenes L.

Endosepsis affects the Calimyrna or any other fig which

has been caprified by the Blastophaga wasp. Caldis found that all parts of the State of California were infested with this fungus, and it is probably in every caprifig tree in the state and in most individual caprifigs. The rot is caused by a white fungus, whose spores are carried by the wasp from one generation of caprifigs to another, and thence to the edible crop. Often there is quite an accumulation of dead blastophagas and wings inside the eye of the fruit, and this makes a good starting point for the fungus.

b. Souring

Many investigators have suggested the relation of cryptogamic microoganisms and insect carriers to fig souring. Nearly all the work done referred to the idea of insect transmission, particularly by the dried-fruit beetle (Carpophilus), and the vinegar fly (Drosophila).

According to Smith and Hansen, souring is a form of spoilage in which the contents of the ripe fruit fermented and soured, and liquid drips from the eye. Souring is caused by yeast, followed by the action of bacteria and molds. It is started by insects, especially the dried fruit beetle (*Carpophilus hemipterus*), entering the figs. It is spread by these and other insects, specially the vinegar fly, (Drosophila). The insects breed throughout the year in decaying fruit of all kinds when they become infested with yeasts and other decay producing organisms.

The Mission and Kadota figs are less affected by souring than the other varieties due to the fact that the eye of the

fruit is too small to allow the beetle to enter.

c. Smut

Fungi of various kinds produce the condition in figs known as "smutty" or "moldy". The disease is caused by the common black mold Aspergillus niger. Other species of molds produce various colors, depending on the shade of their spores, e.g., yellow, green, pink, and gray. Smith and Hansen again attribute the cause to the dried-beetle as being the main agent in starting spoilage in the fig. Davey and Smith,(13), have in their recent work clearly shown that the idea of the dried-fruit beetles being the sole vector of the fig smut is no longer tenable. Other workers on figs have discovered occasional attacks by molds on the outside skin. Among the most common is a form of mold (Alternaria sp.) which produces decayed spots on the outside.

d. Insects

The Indian Meal Moth. (plodia interpunctella.) This is widely distributed and occurs in dried fruits as well as dry grains, seeds, nuts and many other foods. (12) The female moths lays from 300 to 400 eggs, singly or in groups, on the food. The eggs hatch within a few days. The larvae are yellowish-white and average about one-half inch in length. They are profuse web spinners and their webs, covering the fruit and containers, are more injurious to the appearance of the dried fruit than any other form of damage caused by this insect. The fully grown larvae

enclose themselves in small white cocoons about one-half inch long. The newly hatched larvae are very small and active and have a remarkable ability for locating dried fruit. (2)

The Fig Moth. (Ephestia cautella Walk), This is very similar in appearance and habits to the Indian meal moth. To a minor degree the habrobracon, a parasite of the Indian meal moth larva, is also found.

The Dried Fruit Beetle. (Corpophilus hemipterus Linn.) This is the most injurious of the beetles that infest dried foods. The larvae reduce the fruit to a fine powder or "frass", (12), which is the excrement. This insect ordinarily infests the fruit (particularly figs) while it is still in the field, where it thoroughly infests the premises. It is very active in laying eggs on figs during cooling of the fruit after processing.

The Saw-toothed Grain Beetle (Silvanus surinamensis Linn.) The saw-toothed grain beetle is capable of causing extensive damage to dried fruit and vegetables. The females lay from 100 to 200 eggs. (2) They are particulary destructive to figs, not only destroying the inside of the fig, but also boring minute holes through the skin. In cold storage the insects remain dormant, but are not killed unless the storage is prolonged three to four months.

D. Chemical Composition of Figs

In the literature reviewed by Chemical Abstracts, Experiment Station Bulletins etc., no complete analyses of dried figs were found. Several partial analyses of fresh

and dried figs were however obtained. Paladino (24), Tibbles (33), Eisen (16), Benavet (5), Gardner (21), Sherman (29), Gandhi (20) and Morgan (23) have reported the date included in Table I.

From the following table it may be noticed that there is a great variation in the results. With the exception of Eisen none of the other authors mention the kind of figs used for the analysis. The alcoholic yield of figs according to Benavet is almost equal to that of plums; 15-20 kilograms of 90 per cent alcohol or 30 to 33 liters of 54 per cent alcohol is given by 100 kilograms of dried fruit. One hectare of fig trees produces 800 to 900 liters of 90 per cent alcohol. The process of fermentation is also described.

The nutritive value of figs as shown by its chemical composition is equal if not superior to many other fruits, such as dates, raisins etc. As mentioned by Benavet, figs after fermentation make a good stock food. They are very suitable for the fattening of cattle, but are not recommended for dairy cows.

Tibbles and other analysts give the sugars of fresh figs as consisting entirely of dextrose and levulose, with an average total of 11.55 per cent. In dried figs these sugars vary from 50 to 62 per cent ; the average being 52 per cent. The acidity according to Wiley, amounts to 0.71 per cent of malic acid; other analysts have found as little as 0.4 and as much as 1.1 per cent.

Table I. Chemical Composition of Figs

	Moisture	Protein	Fats	Sugars	Crude Fiber	Ash	Gum and Mucilage	N-free Extract	Nitrogen	P_2O_5	Silica	Chlorine	CaO	MgO	K_2O	Ga_2O	Fe_2O_3	SO_3	CuO	Authors
Fresh fruit flesh	80.00	0.70	0.30	16.20	1.30	0.70	0.80													Paladino
Fresh figs									2.38	0.38			0.85		4.69					Gardner
Fresh Poona figs	75.0			17.2 +																Gandhi
Fresh fruit skin	86.00		0.10	5.40	5.76	2.52	2.74													Paladino
Fruit before fermentation	-	4.3	0.3	71.2																Benavet
Fruit after fermentation	85.71	1.75	0.27	-	3.37	1.08	-	7.82												Benavet
Entire dried fruit	57.00	4.10	2.20	26.06	8.00	-	0.18													Paladino
Dried figs	28.0	4.3	0.3	74.2	-	2.4	-	-	-	0.332	-	-	.299	-	-	-				Sherman
Dried figs						2.04	-	-	-	0.265	-	-	.227	-	-	-	.0043	-	.00044	Morgan
Dried Poona figs	-	4.7	0.7	89.3 *	2.1	3.2														Gandhi
Dried figs ash										12.76	-	2.05	10.90	-	57.16	2.38		3.90		Tibbles
Percentage of total ash											2.34	0.83				19.6				Gardner
Ash of Smyrna figs (eleme)										1.3	5.9	2.7	18.9	9.2	28.4	26.3	1.5	6.7		Eisen

* Digestible carbohydrates

+ 15.2% reducing sugars

By the consumption of milk and cheese the protein and fat deficiency of figs can be remedied. The latex, or milky juice, of the fig tree contains various enzymes. One is a peptonizing agent, which acts upon fibrin in the same way as pepsin, and also coagulates milk; another transforms starch and glycogen into sugar. Hansen (30) found that a syrup made from dried figs possessed similar properties to the latex.

Microoganisms on Dehydrated Fruits.

As applied to food, dehydration, desiccation, or drying is the process of removal of the surplus water from the food substances in a manner preventing the destruction of the cellular tissues, maintaining the energy values and preserving the color, flavor, and physical condition of the food. Fellers (19) describes dehydration as the "reduction of moisture to a point where microorganisms are unable to proliferate and cause spoilage." According to the amount of soluble solids present in the fruit, this moisture content critical point varies from 20 to 30 per cent.

Dehydration is probably the oldest method the human race has employed for the preservation of food, for it has been known for hundreds of years among the most primitive people.

Prescott (28) working with artificially dehydrated vegetables and fruits, found varied microbial flora of dried peaches, tomatoes, bananas and vegetables. He isolated no toxicogenic bacteria, but both spore-and non-spore

formers were isolated. Saprophytic molds, as spores, were most common. During storage he found that the humbers of microoganisms decreased, providing the moisture content remained approximately constant.

Fellers (19) made several laboratory tests on artificially inoculated dehydrated fruits, such as dates, rainsins, figs, and prunes using Esch. coli and Eber. typhosum for the test. He found that a 30 minute-exposure to 160°F. with a relative humidity of 75 per cent destroyed all organisms. Prescott made storage tests using fresh vegetables and fruits which he inoculated with Esch, coli, Bact. paratyphosus, A & B., Bact. enteritidis, Bact. suipestifer, Bact. typhosus, Cl. botulinum Micrococcus pygenes, Mic. aureus, and B. subtilis. After thorough dehydration no typical pathogen was recovered. Fellers calls attention to the possibility of contamination between the dryer and the consumer. Though too dry to grow, bacteria may die immediately but remain dormant until more favorable conditions of moisture and temperature arrive. He found that bulk dried fruits harbor more microoganisms than packaged fruits.

Nichols (28) found no sample of dried fruit sterile, but many had only a few bacteria and molds. Prescott (27) has reported that certain yeasts would grow in and ferment 60 per cent sucrose solution and Bact. vermicosum would produce fermentation of 70 per cent sucrose in a mixture with cottonseed meal, and that Staphylococcus aureus destroyed

cane sugar geletin in a concentration of 48 per cent. Although bacteria tend to disappear or to become inactive when the moisture falls below 40 per cent, he quotes many instances when percentages of water much smaller than this will still permit growth.

While the concentration of fruits, such as figs, peaches, apples and apricots is sufficient to inhibit development, it sometimes requires but a small addition of moisture to mermit growth and consequent deterioration by molds and yeasts or their enzymes. The length of storage largely determine the number of organisms present. Bulk dried fruits may readily pick up organisms through improper handling and storage.

The fact that dehydrated foods are not cooked or sterilized as they are prepared and packed for sale, brings up a question as to the control of these microoganisms. "The relation of bacteria and molds to spoilage in food products is of particular interest to the consumer." (Fellers)

Plate II.

Four Varieties of Bulk Dried Figs

Experimental Section

Moisture Determination

Moisture determinations were made by the Bidwell-Sterling (6) method with reasonable accuracy in about $1\frac{1}{2}$ to 2 hours. A Bidwell and Sterling water trap graduated to 1/10 cc. and reading to 5cc. was fitted by means of a cork into a 500 cc. Pyrex round bottom, short ring-neck flask, and a reflux condenser was placed above the trap. (Plate III.)

The flask, trap, and inner tube of the condenser were cleaned with sulphuric acid-potassium-dichromate solution before and after each third run. The trap was cleaned after each run. The trap and flask were then rinsed with alcohol and ether and thoroughly dried.

About fifty grams of figs were taken from different layers in the box and cut up into small pieces by means of a dry clean scissors. From this a twenty gram sample was weighed on a fairly sensitive balance. The sample was transferred to the flask containing 150cc. of technical toluene, and about 6 grams of glass beads were added to prevent charring of the figs and to help their better distribution.

The flask was connected to the trap and the condenser and placed on a tripod on which and asbestos wire gauze was placed. The materials were boiled for two hours. The water usually collected in the trap by the end of this period.

Any droplets that stuck to the sides of the trap were pushed down by means of a thin copper wire about ten inches long. The reading multiplied by 5 gave the percentage of water that was in the fruit.

The four different varieties of figs used, namely, Adriatics Calimyrna, Mission, and Smyrna figs were all treated for moisture content in the manner described above. The moisture content of each variety is, before and after pasteurization, given in tables II, III, IV, & V. along with the different temperatures and humidities employed and the length of time to which the fruit was submitted to pasteurization.

Plate III.

Bidwell-Sterling Apparatus for the Determination of Moisture

Table II.

Moisture Content of Adriatic Figs Before and After Pasteurization

Temperature Degrees F.	Relative Humidity. Per cent	Moisture Content of Untreated Figs. Per cent	Time in Minutes: 20	30	40	50	60	70
			Moisture Content of Pas. Figs. per cent					
147	82	20.5	21.0	20.5	22.0	22.0	22.0	22.5
159	100	21.5	21.5	21.5	22.0	22.0	22.5	22.5
160	78	22.0	21.5	21.8	21.7	21.8	22.0	22.0
164	91	21.5	21.5	21.7	22.0	22.4	22.2	22.8
168	68	21.0	22.0	22.5	22.5	22.7	23.0	23.1
170	94	20.0	-	-	-	21.0	22.8	22.5
170	100	19.5	19.5	20.3	21.5	22.0	22.5	23.8
173	62	21.0	19.5	20.0	20.5	21.0	21.0	20.0
175	65	21.5	21.5	21.0	21.5	21.6	21.8	22.0
177	81	21.4	21.3	21.5	22.0	22.3	22.0	22.2
180	87	21.5	21.5	22.0	22.5	22.5	22.7	22.9
187	70	21.0	21.5	21.9	22.0	22.6	22.5	23.0
193	54	23.0	23.0	22.5	22.5	22.0	22.0	21.0

Table III.

Moisture Content of Calimyrna Figs Before and After Pasteurization

Temperature Degrees F.	REllative Humidity. Per cent	Moisture Content of Untreated Figs	Time in Minutes						
			20	30	40	50	60	60	70
			Moisture Content of Pas. Figs Per cent						
144	90.5	20.0	20.0	20.5	21.0	21.5	21.5	21.5	22.0
146	83	19.5	20.0	20.0	19.0	19.0	20.5	20.5	20.5
146	85	22.3	22.5	22.5	23.0	22.0	22.5	22.5	23.0
150	100	20.0	20.5	21.0	22.0	22.0	22.5	22.5	22.5
151	76	21.5	21.5	22.0	22.0	22.3	22.5	22.5	22.5
164	91	20.5	20.8	21.0	21.0	21.2	21.5	21.5	21.7
170	95	21.5	-	-	21.8	22.5	22.8	23.0	23.0
170	100	21.6	21.5	22.0	22.8	22.5	23.0	22.8	23.5
177	81	20.3	20.7	21.0	21.0	21.3	21.5	22.5	21.5

Table IV.

Moisture Content of Mission Figs Before and After Pasteurization

Temperature Degrees F.	Relative Humidity Per cent	Moisture Content of Untreated Figs Per cent	Time in Minutes &&& 20	30	40	50	60	70
			Moisture Content of Pas. Figs Per cent					
155	100	20.0	20.5	20.7	20.8	21.0	22.0	22.0
160	78	18.5	17.0	17.0	18.0	16.5	17.0	18.0
165	56	19.5	17.0	18.0	18.5	18.0	19.0	17.5
164	91	20.0	20.3	20.5	20.1	21.0	21.6	21.5
165	78	19.5	16.5	18.0	17.5	18.5	18.5	19.0
165	80	19.0	16.5	18.0	17.5	18.5	18.0	18.0
170	94	20.5	-	-	22.0	22.0	23.0	23.5
170	100	19.25	20.0	20.0	21.5	22.8	22.8	23.0
173	61	19.0	18.0	18.0	18.0	19.0	18.5	18.0
175	69	20.0	17.0	17.5	18.0	18.5	19.0	19.0
177	81	22.5	22.5	22.0	22.4	22.0	22.5	22.5
178	93	19.5	19.5	19.5	20.0	20.0	20.5	21.0

Table V.

Moisture Content of Smyrna Figs Before and After Pasteurization

Temperature Degrees F.	Relative Humidity Per cent	Moisture Content of Untreated Figs Per cent	Time in Minutes: 20	30	40	50	60	70
			Moisture Content of Pasteurized Figs Per cent					
150	76	19.5	19.5	19.8	20.0	19.5	19.5	20.0
154	100	20.0	21.0	20.5	21.0	21.5	21.5	22.0
157	70	21.0	21.0	22.0	22.5	22.5	22.0	22.0
158	69	19.7	20.5	18.5	19.0	20.0	20.5	19.8
160	68	20.0	20.0	21.0	21.5	21.5	22.0	20.0
160	90	19.0	19.5	19.5	19.7	20.5	20.8	21.0
164	91	20.0	20.0	20.3	20.5	21.0	21.0	21.0
166	59	19.5	19.5	19.7	19.0	17.25	18.5	19.0
170	96	19.0	18.5	18.5	19.0	19.0	19.5	20.0
177	81	19.5	20.0	19.5	19.8	20.8	20.0	20.5
178	55	20.0	18.0	19.0	20.0	21.5	21.5	20.5
182	95	20.5	19.7	20.5	21.0	21.5	21.5	21.5

The Pasteurizer

The pasteurization of figs was done in a sheet metal cabinet 58 x 38 x 46 cm. in size (11). The cabinet was set on a gas plate which served to supply the necessary dry heat. Humidity was obtained from the regular laboratory steam line which could be standardized to within a limit of 2 per cent. A closed copper pan was placed between the steam line and the pasteurizer, which helped to keep the excess moisture in the steam from passing to the cabinet. (Plate IV.)

A wet and dry bulb thermometer with the bulbs inserted through openings in the top of the pasteurizer were used to obtain the temperature and the humidity data. Wire screen trays on which the packets of figs were laid, were placed about five inches below the thermometer bulbs. This, besides allowing for sufficient circulation of the moisture and heat, showed the exact temperature and humidity surrounding the packets.

The Cartons

The cartons that were used to hold the figs for pasteurization measured 14.5 x 7.5 x 3.5 cm. and had an average weight of 10 ozs. A wooden frame in which the cartons were inserted was used to keep the packets from bulging during packing and pressing. The figs were packed in two layers, well pressed together for the better demonstration of heat and moisture penetration.

Effect of Pasteurization on Moisture Content

Moisture determinations were made on several samples of the different varieties of the figs. When the figs were received, moisture determinations showed very slight variations in their

moisture content. All showed a moisture content near 19.5 per cent. Adriatic and Calimyrna samples seldom exceeded this percentage and showed a 20 to 21 per cent moisture. The Mission figs often gave a moisture of 18 to 19 per cent.

On treating these figs in the pasteurizer, an apparent decrease in moisture content was shown, especially in the case of the Mission figs. The other three varieties either gained slightly, or retained their moisture. But as the moisture depended upon the amount of humidity and temperature used in pasteurization where the temperature was high and the humidity low, there was a decided decrease of moisture in all the figs. Where relative humidities as high as 80 per cent or above were used, there was always a gain in moisture.

In determining the moisture content, in as much as each individual fig is likely to vary, and as it was not possible to utilize large samples, it was possible that some of these differences were due to lack of a proper method of sampling.

Dry heat with low humidity destroys the appearance and flavor of the fruit, and makes it dry and hard. In several cases where only steam was used, the figs showed a vast improvement in quality. The higher the percentage of relative humidity employed during pasteurization, the higher was the increase in moisture content of the pasteurized fig. The steam should be so regulated that neither too much is admitted into the pasteurizer causing the high increase in moisture, not yet too little to leave the fruit dry. A temperature of 170°F. with a humidity of 90-95 per cent for 60 to 70 minutes seemed to work well with all the figs. Even fruit that was treated for a shorter period showed an improvement

Plate IV.

(A) The Pasteurizing Cabinet

(1) Dry-bulb thermometer

(2) Wet-bulb thermometer

(3) Gas plate for dry heat

(4) Pan to retain excess moisture

(5) Steam line

over the untreated figs.

Smyrna figs from Turkey packed in bags are usually cut in the middle to be examined for the presence of insects. These figs, owing to the exposure of their fleshy part formed slight amounts of a syrupy solution on their surface. The other figs which are ordinarily whole, were not affected like the Smyrna figs.

The average moisture increase or decrease varied with the different temperatures and humidities used. The changes can be readily seen in the previous tables. An increase of from 0.5 to 3.0 per cent took place depending on the humidity and the length of time the figs were left in the pasteurizer. A decrease in moisture, as was very evident in the case of the Mission figs, usually resulted from a high temperature with low humidity.

As most microorganisms thrive best in substances of high water content, especially if those substances are rich in nutrients, it is necessary that the increase in moisture should not be excessive, From 1 to 3 per cent moisture increase over the 19.5 per cent that the figs originally contained, seems to improve their quality. Although humidities as high as 100 per cent were used, the increase in moisture did not exceed 3 to 4 per cent in the figs. Moisture above 23 per cent should be avoided in order to preclude bacterial or yeasty spoilage.

Prescott, and other investigators (26) in their studies of deterioration of sugar have found, that in sugar containing as little as one per cent of water slight decomposition by fungi could take place. With yeasts and bacteria, high concentration is apparantly much more inhibitive than with fungi, although these organisms too can live and grow upon substances containing small

amounts of water.

Certain yeasts would, according to Prescott, grow and ferment a 60 per cent sucrose solution. Bacteria tend to disappear or become inactive when the moisture falls below 40 per cent. But it is well known that percentage of water much smaller than this will permit growth. While ordinary evaporated fruits contain in general about 20 to 24 per cent moisture, and this concentration is usually sufficient to inhibit development, it sometimes requires but a small addition of moisture to permit growth and deterioration by molds and yeasts or their enzymes.

The basis for the control of dehydration of foods is not only economic, but to guarantee sanitary quality and wholesome material for the protection of health.

Effect of Heat Treatment and Humidity on the Physical Properties of Figs

Before the steam line was installed in the new laboratory a steam pressure cooker was used as asteam generator to obtain the desired humidity. Control was difficult and there seemed to to excessive drying out of the samples. The fruit became dry, the color changed and the flavor was distinctly caramelized. This obstacle was later overcome by the use of the laboratory steam-line. Although some of the fig samples were treated at the same temperature and humidity as those treated when the steam line was not available, the results were much more satisfactory. This was probably due to the difficulty met in regulating the flow of steam from the pressure cooker, and the excess of dry heat used.

Tables VI, VII, VIII, and IX show the effect of pasteurization on the quality of the figs. The fruit was left for a period of from one to two weeks after pasteurization and before grading to allow any moisture taken to be absorbed, and also to observe any changes in the physical quality of the figs during that period. Someof the packets were stored in cold storage, while others were left at room temperature. They were graded on the following basis.

Excellent - All surface sugar dissolved, figs moderately soft, color, flavor and texture unaffected, much better than untreated figs, easily marketable as a high quality fig. Surface moist and flesh soft textured.

Good - Sugar all dissolved; color, flavor and texture relatively unaffected. Readily marketable, but moisture may be slightly low making figs appear dry. Surface not so moist as "Excellent" grade.

Fair - Sugar dissolved or partially dissolved. Color and flavor slightly affected, or showing unabsorbed syrupy surface. Marketable as an inferior grade or questinnable except for use as stewed dried figs.

Poor - Either surface dry, flesh usually hard and rather dry. Flavor and color may be slightly abnormal or sugar not dissolved, color and flavor affected, or dry texture, hardly marketable.

It did not seem very advantageous to store figs in cold storage at a temperature as low as 32°F. The syrup that formed on the surface of the fruit, particularly in the case of the Smyrna figs, formed a rather thick coating of sugar-crystals.

The fruit, although containing the same moisture as the fruit stored at ordinary room temperature, seemed less pliable and somewhat firm to the touch. Temperatures of 50-60°F. are much more favorable for the storage of figs.

Nearly all the untreated dehydrated figs have a coating of sugar on their surface which affects adversely their attractiveness. This sugar is very apparent on the Mission figs. Due to their dark purplish blue color, the white sugar crystals on the surface gives them a rusty grey appearance which is unattractive to persons not acquainted with this variety.

When the figs were treated for periods ranging from 20 to 70 minuted at temperatures from 150 to 185°F. and humidity of 65 to 98 per cent, all of the sugar was dissolved forming a thin syrupy cover on the surface, which greatly improved the appearance of the fruit.

Smyrna figs being softer in texture than the other varieties showed this characteristic most of all. Those that were packed in bags and cut in the middle would sometimes become sticky when high humidities were used. This extra moisture did not remain on the surface of the fruit longer than a week or ten days. It is usually absorbed by the fruit, or dries by evaporation during this period of time. As these figs were more compactly packed in the cartons, it took longer for the heat and moisture to penetrate than with the other figs.

At a temperature of 147°F. and 79 per cent humidity for 20 minutes, the sugar was dissolved from the surface, but

remained undissolved between the layers of the fruit. A longer time was necessary to allow heat and moisture to reach the center of the packed carton. Treating the figs for 40 minutes caused either partial or complete solution of the sugar, which depended on the amount of heat and moisture admitted into the pasteurizer. Periods of 50, 60, and 70 minutes were always sufficient to dissolve all of the sugar. Higher temperature and humidities allowed a better and quicker penetration of heat and moisture to the center of the cartons.

Adriatic figs treated at 193°F. and 54 per cent humidity showed a slight improvement over the controls in the 20, 30, and 40 minute run. But keeping them in the pasteurizer for 50, 60 and 70 minutes at the above temperature and humidity, made the fruit lose moisture and become dry with the addition of a caramelized flavor, although there was only a very slight change in color.

When pasteurizing the figs, it has been found more propitious to leave the covers of the cartons, partially open so as to allow a more efficient contact of the steam with the figs. As soon as the cartons are taken out, it is necessary to shut the covers completely to prevent the escape of moisture by evaporation from the heated fruit.

Table VI.

The Effect of Temperature-Humidity on the Quality of Adriatic Figs

Termperature Degrees F.	Humidity Per cent	Time in Minutes					
		20	30	40	50	60	70
150	100	Fair	Fair	Good	Good	Good	Good-Excellent
160	78	Fair	Good	Good	Good	Good	Excellent
164	91	Fair	Good	----	----	Excellent	Good
170	100	Good	Good	Good	-----	Excellent	Excellent
177	81	----	----	Good	Excellent	Excellent	Excellent
180	87	Fair	Good	Good	Excellent	Excellent	Good
187	70	Fair	Good	Good	Good	Excellent	Good
193	54	Good	Good	Fair	Fair	Poor	Poor
170	95	----	----	----	Good-Ex.	Excellent	Excellent

Table VII.

The Effect of Temperature-Humidity on the Quality of Calimyrna Figs

Temperature Degrees F.	Humidity per cent	Time in Minutes 20	30	40	50	60	70
144	90	Fair	Fair	Good	Good	Good	Good
146	85	Fair	----	Good	Good	Excellent	Excellent
147	82	Poor	Fair	Fair	Good	Good	Excellent
150	100	Poor	Good	Good	Excellent	Good	Excellent
151	76	Fair	Fair	Fair	Good	Excellent	Good
164	91	Fair	Good	----	Good	Good	Good
170	95	----	----	Good	Good-Ex.	Excellent	Excellent
170	100	Fair	Good	Good	----	Good-Ex.	Good-Ex.

Table VIII.

Effect of Temperature-Humidity on Quality of Mission Figs

Temperature Degrees F.	Humidity Per cent	Time in Minutes 20	30	40	50	60	70
155	100	Fair	Good	Good	Good	Good	Good
160	77	Poor	Fair	Good	Fair	Good	Fair
164	91	Fair	Good	----	----	Good-Ex.	Good
168	68	Poor	Poor	Poor	Fair	Good	Fair
165	78	Fair	Good	Good	Good	Good	Good
165	80	Poor	Fair	Fair	Fair	Fair	Fair
165	56	Poor	Poor	Poor	Fair	Poor	Poor
170	67	Poor	Poor	Fair	Good	Fair	Poor
170	95	----	Good	Good	Good-Ex.	Excellent	Excellent
170	100	Fair	Good	Good	----	Excellent	Excellent
173	61	Fair	Fair	Good	Good	Fair	Fair
175	69	Fair	Fair	Good	Fair	Fair	Fair
177	81	$\frac{3}{4}$---	----	----	Excellent	Excellent	Good
178	93	Fair	Good	Good	Good	Excellent	Good

Table IX.

Effect of Temperature-Humidity on the Quality of Smyrna Figs

Temperature Degrees F.	Humidity per cent	Time in Minutes 20	30	40	50	60	70
145	81	Poor	Poor	Poor	Fair	Good	Good
149	79	Fair	Fair	Fair	Good	Good	Good
150	76	Fair	Fair	Fair	Fair	Good	Good
153	78	Fair	Fair	Fair	Good	Good	Good
154	100	Fair	Fair	Fair	Fair	Good	Good-Ex.
156	72	Fair	Fair	Fair	Good	Good	Good
160	70	Fair	Fair	Good	Good	Good	Good
160	90	----	----	Good	Good	Good-Ex.	Good-Ex.
161	65	Fair	Fair	Fair	Good	Good	Good
165	66	Fair	Fair	Fair	Fair	Good	Good
164	91	Fair	Good	----	----	Good-Ex.	Good-Ex.
166	59	Poor	Poor	Fair	Fair	Fair	Fair
170	78	Fair	Fair	Good	Good	Good	Good
170	96	Fair	Good	Good	Good-Ex.	Excellent	Excellent
175	61	Fair	Fair	Fair	Fair	Good	Good
177	81	----	----	----	Good	Good	Good
182	95	Fair	Fair	Good	Good	Good	Good
194	53	Fair	Fair	Fair	----	Poor	Poor

Plate V.

Pasteurized (left) and non-pasteurized (right)

Packages of the four varieties of figs

Heat Penetration

Two thermometers were inserted into two separate packets of figs, one in a vertical position and the second in a horizontal position. (Plate VI.) The vertical thermometer was placed throught the center of one of the figs to show the heat that penetrated to the centar of the fruit, while the horizontal thermometer was placed between the two layers of the figs to show the penetration of heat into the carton.

The rate of heat penetration depends not only on the heat, but also on the humidity maintained. When low humidity and a high dry temperature were used, it wasobserved that heat penetration was much slower than when high humidity and a lower temperature were used.

After the pasteurizer was brought to the required temperature and humidity, the cartons were placed on the wire trays and left there for fifteen to twenty minutes before heat penetration was observed by the rise of the mercury in the inserted thermometers. The timing of the pasteurization period started when the temperature in the interior of the cartons was reached to 135-140 ^{o}F. The temperature readings were then recorded at periods of twenty minutes for the first carton, and at 10 minutes intervals for the rest of the cartons.

Primarily, heat penetration is of interest due to the fact that uhless the right temperature is reached inside the cartons, and within the fruit itself; most microoganisms, especially the spore-formers will not be destroyed. Sinde

the elimination of these microorganisms is dependent upon the use of heat, it is important to know what temperature has penetrated the fruit. Therefore, knowing the temperature in the cartons of figs, and the time and temperature necessary to destroy microorganisms of dried fruits, it was easy to attain the desired object by the use of the thermometers.

The following graphs show the general form of heat-penetration into the cartons and inside the fruit itself. As one of the thermometers was placed between the layers of the figs, there was a more rapid-penetration owing to the spaces between the individual figs. The second instrument gave a lower reading by a few degrees, as its bulb was inserted into the fruit. But as the heat increased, the two thermometers eventually came to the same point and showed the same temperature.

<u>Destruction of Esch. coli by Pasteurization</u>

A product to be called pasteurized must be freed from all non-sporulating pathogenic microorganisms, without serious alteration of physical or nutritive value of that product. Products made from originally suitable material but which have become undesirable, unpalatable and nutritionally of low value through the use of insanitary or objectionable methods of handling or as a result of infection with objectionable organisms such as yeasts, molds, bacteria, insects, etc., should not be permitted to be sold. The greatest enemies of the dehydrated products are certain forms of weevils and other insects, which may gain acess to them, lay their eggs in the material, and

Figure I. Heat Penetration Between Layers of Figs Packed in 10-ounce Cardboard Cartons Under Controlled Humidity and Temperature.

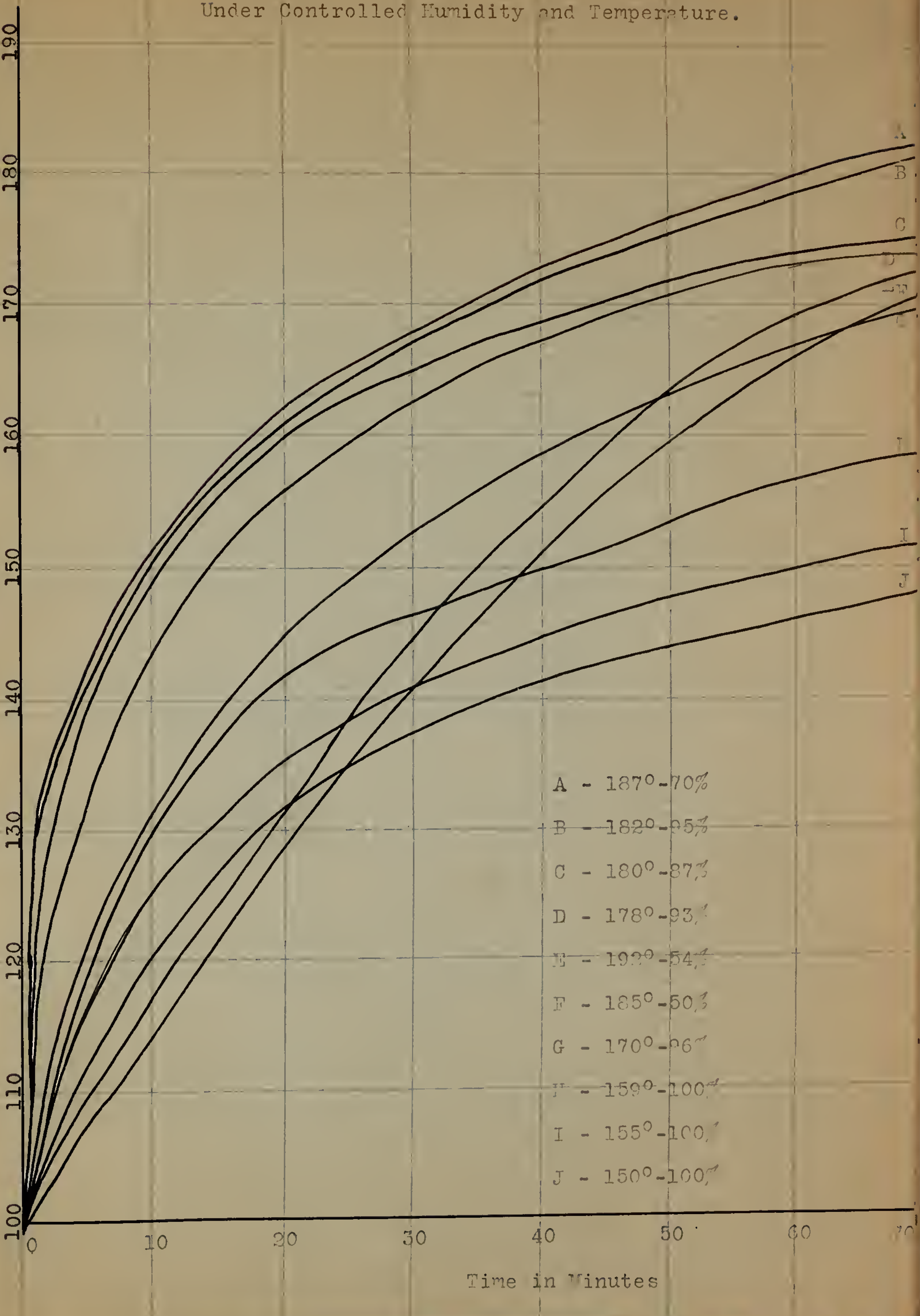

Figure II. Heat Penetration into the Flesh of Figs in 10-ounce Cardboard Cartons at Various Temperatures and Relative Humidities.

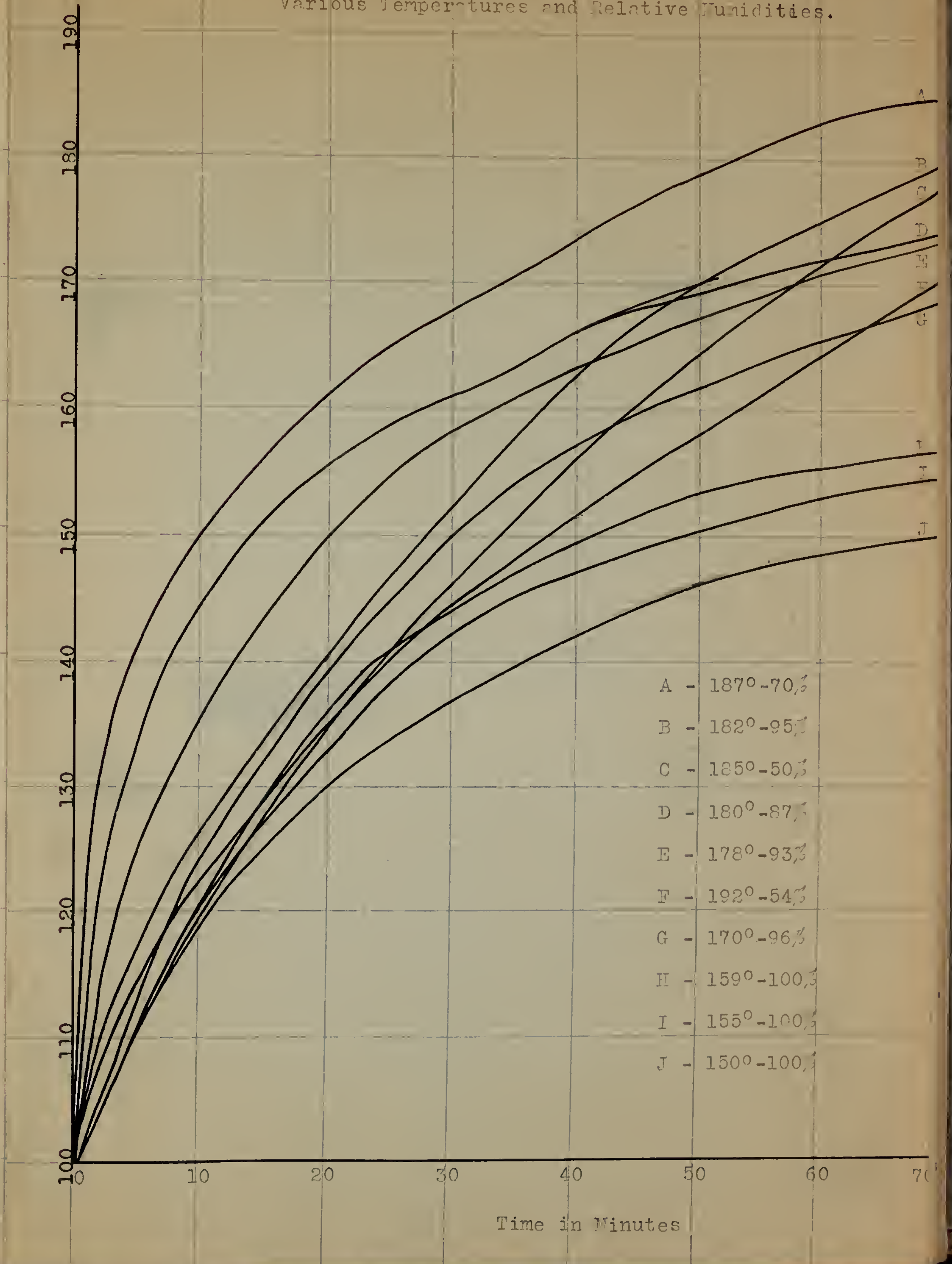

Table VI.

Position of thermometers in heat-penetration studies

(Vertical thermometer inserted in center of fig.)

(Horizontal thermometer inserted between layers of figs.)

and render them undesirable for food because of the development of worms and larvae. (28)

Nearly all foods are spoiled either by chemical agents known as enzymes or by biological agents, microorganisms and insects. Tanner and Granville (32) , through their experiments on pasteurization have concluded that members of the Colon-Typhoid group in milk in the numbers in which they would occur are destroyed by heating for thirty minutes at 140°F. (60°C.)

The colon bacillus, because its thermal death-point more closely approaches the pasteurization temperature, has been often used in this capacity. Beavens (4) working on Esch. coli as an index to proper pasteurization in milk found that despite the fact that the pasteurization temperature should be sufficient to kill the organisms, certain percentage of them survived. He noted this occurrence in 32 per cent of the number of samples. From his results he found that the coli test cannot be used as a true index to proper pasteurization.

Esch. coli was used in this work as an index of pasteurizing efficiency for the reason, that while the organism is not ordinarily pathogenic in itself, it closely resembles the organisms responsible for "food poisoning"; in that it develops in the intestinal tract of man and most other animals in much the same manner as pathogenic bacteria, and also because it is easier to detect by the use of differential media than any other of the food poisoning microorganisms.

Its thermal death point is approximately the same as that at which the pathogens are also destroyed. (11)

Fellers, who has done much work on the pasteurization of dried fruits, reports that the numbers of organisms were greatly reduced. The average reduction of microorganisms in dates, prunes and raisins varied from 93 to 99 per cent. Figs, which were more difficult to handle gave inconsistent results. Temperatures of from 160° to 185°F. in the fruit, at humidities of 70 to 100 per cent held for 30 to 90 minutes were found to be effective.

The cartons of figs to be pasteurized were inoculated with one of three strains of <u>Esch. coli</u> used; tubes of sterilized distilled water were inoculated with the bacteria, then swabbed over the figs with a piece of sterilized cotton wrapped around a glass rod. The cartons were then placed into the cabinet and pasteurized in the regular manner. As the cartons were taken out from the pasteurizer, they were cooled to room temperature, and a fig from each carton was put into a separate tube of sterilized distilled water. A drop from each of these tubes was then poured into a tube of lactose broth, and the tubes were incubated at 98°F. (37°C.) for 24 hours. Any tubes that at the end of this period showed gas formation were taken and transfer was made from these tubes by means of a platinum loop to Endo's agar plates. The plates were similarly incubated as the tubes and the appearance on the plates of the typical coli-colony within twenty-four hours was taken as a partial confirmation for the

presence of Esch. coli.

The results of the destruction of the organisms are shown on table X. It will be noticed that temperatures of 170° to 194° F. with a humidity ranging from 53 to 96 per cent were sufficient to kill the microorganisms within thirty minutes. In the twenty minutes run they nearly always remained viable, except at higher temperatures and humidities. At 165° F. with a humidity of 56 per cent, Esch. coli survived the 40 minutes run. Lower temperatures with high humidities killed the organism within fifty minutes. Treatment of 50, 60 and 70 minutes at the temperatures and humidities shown on the table, was adequate to destroy the microorganisms. In certain instances there was doubt in the forty minutes run where low temperatures and high humidities were used. Gas was formed in the lactose broth tubes forty-eight hours after incubation, and only slight growth was given on Endo's Agar plates.

Table X.

Effect of Time-Temperature-Humidity on the Esch. coli

Content of Inoculated Figs

Temperature Degrees F.	Humidity Per Cent	Time in Minutes 20	30	40	50	60	70
170	96	+	−	−	−	−	−
172	98	∓	−	−	−	−	−
180	87	−∓	−	−	−	−	−
178	93	−∓	−	−	−	−	−
150	100	+	+	+	−	− −	−
155	100	+	∓	−+	−	−	−
159	100	∓	−+	−+	−	−	−
154	100	+	+	−∓	−	−	−
187	70	+	−	−	−	−	−
183	70	∓	−	−	−	−	−
164	91	∓	−+	−+	−	−	−
177	81	+	+	−	−	−	−
194	53	+	−	−	−	−	−
160	90	+	−+	−+	=	−	−
153	78	+	+	+	−+	−	−
165	56	+	∓	+	−∓	−+	−

+ = *Esch. coli* present

− = *Esch. coli* absent

Persistence of Esch. coli on Dehydrated Figs (Storage Tests)

The same three strains of Esch. coli were used to determine the length of time that the microorganisms will survive on dried figs. About ten grams of figs were cut up small and put into each of 250 cc. flask with about 100 cc. of distilled water. They were then sterilized, cooled and each of the three flasks was inoculated with one of the strains of the bacteria. Two cartons of figs were then inoculated with each of the organisms by means of a sterilized cotton swab. Three caftons, each inoculated with one of the strains were stored in the cold storage room at about 34°F., and the other three cartons thus inoculated were left at room temperature.

At periods of three to four days the six cartons were taken out and a piece of one of the figs from each carton was cut and put into a test tube containing 10 cc. of sterilized distilled water. The tubes were shaken for several seconds and a drop from each of the tubes was poured into one of six lactose broth gas-tubes. The lactose tubes were incubated for twenty-four hours at body temperature, and gas formation was taken as an indication for the presence of the organ ism. A confirmation was made by transfer from the lactose tubes to Endo's agar, and the formation of typical coli-colonies indicated the presence of the organism. This procedure was carried out for seven weeks, during which perio all the tubes inoculated with the organisms stored in the cold room showed gas formation, while those that were stored in the laboratory at room temperature ceased to show any evidence of survival at the end of the fifth week. Some tubes that showed no gas formation when inoculated after the seven weeks within 24 hours,

formed gas at the end of a forty-eight hour incubation. This is probably due to the presence of yeasts on the fruit which are present in large numbers.

Previous work done by Fellers (19) showed that Esch. coli survived but thirty days on figs. This might have been due to the use of less moisture utilized for the inoculation of the fruit, or the decrease of moisture content of the figs. It is evident that when dehydrated fruits commence to dry below the minimum moisture content that will support the growth of microorganisms, the infection period is supposed to be passed and the high concentration of sugar in the fruit makes them no longer favorable media for the growth of microorga-nisms, or for insects which attack the green fruits.

During the progress of this experiment, Clague (10) did some experimental work on the numbers of microorganisms on dried figs. The results as shown below, reveal a great variation in the numbers of microorganisms on dried figs. This was the result obtained from two experiments on the four varieties of figs used.

Figs	Organisms per Gram		
	Bacteria	Molds	Yeasts
Adriatic	2600	-----	20
Calimyrna	20	20	------
Mission	-------	-----	20
Smyrna	1300	200	380,000

The average counts of samples is not always a safe rule to use in estimating the numbers of microorganisms present. Thus some foods might have an average count of 1000,000 organisms per gram, while others might show as low as 20 or none at all, as in the case of the Mission figs. Again bacterialcounts depend to some extent on the way the product is handled, and the portion of the container it is taken from. Fruit in the middle or the bottom of the container not being exposed as the fruit at the surface, might have a decidedly low count. The greatest benefit of the plate count method is not in the number of organisms that may be isolated, but the kind of organisms that may exist on the product. As far as pasteurization is concerned, the destruction of pathogenic organisms, yeasts, molds and insects that might grow on the fruit and render it harmful or unfit for consumption is of major importance.

Insects Injurious to Dehydrated Figs

Many insecticides have been invented and used for the extermination of pests that destroy figs and other fruits, but so far no efficient insecticide has been discovered which would render dry fruits absolutely unsusceptible to further infestation. Washburn (36) in 1890 estimated the annual loss of crops by insects as $300,000,000 in the United States. Many of the injurious insects were imported into this country from other lands, and have thrived better in their new home than in the old. More damage is done to figs before drying and while they are still on trees, than after drying.

Cyanide, carbon bisulphide, sulphur, mixtures of ethylene oxide with carbon dioxide, ethyl dichloride, carbon tetrachloride, and propylene dichloride with carbon tetrachloride is extensively used to-day to fumigate foodstuffs for the destruction of pests. Some of these fumigants as hydrocyanic-acid are extremely poisonous, affect the flavor, and possibly leave a poisonous residue on the material treated. Carbon disulphide affects the flavor, is highly inflammable and explosive in the gaseous state. The other compounds named above, although not poisonous to higher animals will affect the flavor and to some extent the color of the products if not used with great care, and would there-fore involve more labor and expense than the use of heat and humidity. Furthermore, it is not known that any of these fumigants has a bactericidal action.

Although sulphuring of white figs results in some insect destruction, it cannot be relied upon to rid figs of all insects. Sulphured white figs may retain 500-1500 parts per million of sulphur dioxide, though this amount gradually grows less during storage. It is also believed that the sulphuring process destroys many yeasts on the figs.

Washburn (1890) mentions the use of varying temperatures for the destruction of insects on wheat. Fumigation with carbon disulphide, kerosene vapor, camphor and tobacco was also used. Although these were effective in a limited way to ckeck the growth of fruit and grain beetles, they were not found very efficient.

Dry heat-treatment has also been used for the control of food pests in many food plants. It was found suitable for products such as cereals, flour, etc., that are not damaged by any loss in moisture. But dehydrated fruits need a high humidity with the heat applied to insure the retention of their moisture content. For extermination of insects, Stiner (31) recommends a maximum temperature of 140°F. for half an hour. Dry heat, and even heat of 140°F. with very low humidity for 40 to 70 minutes has been found to cause the fruit to lose much moisture and assume a caramelized flavor, with a decided change in color. In fact, steam alone used for the figs, gives better results than when a combination of dry and moist heat was used.

Of the insects injurious to dried fruits, there are several species that were not available for use during the the time of this experiment. However a carton of dates was obtained which was swarming with saw-toothed grain beetles, and some Indian meal-moths from a sack of flour. The dates were so infected that nothing of the fruit remained but the skin filled with the excrement, eggs and larvae.

Seven pounds of the four varieties of the figs were infested with the insects. A two gallon glass container with a wide mouth was used to hold the figs, where oviposition and hatching took place. A piece of cheese-cloth held in place by a rubber band was used to cover the top of the jar. The container was then left at room temperature for six weeks to allow ample time for the insects to thoroughly infest the

fruit. The infestation was fairly successful as the parasites were of sufficient numbers so as not to limit their parasitization.

As seen from the surface, the insects did not appear to have multiplied rapidly, nor did the figs seem to have been much damaged. But on closer examination, it was observed that many of the figs were bored through, or crevices were made by the insects on the skin wherein their eggs were laid, while, when a few figs were taken out, opened and examined, they were found to be well overrun on the inside by insects and their larvae. Undoubtedly the majority of the beetles made their entrance through the eye of the figs.

The number of beetles, eggs, and larvae found within the figs varied, depending on the kind of the fruit. The Adriatic, Calimyrna and Smyrna were found to be more infested than the mission figs. Owing to the smaller size of the eye in the Mission variety, it was probably not as convenient for the parasites to make their entrance. Figs that were pasteurized were also included in the jar with the unpasteurized ones. These being relatively moist and soft, formed a somewhat compact mass and were only attacked upon the exterior in small crevices between individual figs. For pasteurization, the infested figs were packed in similar cartons as previously described. Care was taken to include all the insects on and within the figs and prevent their escape. The cartons were arranged on the wire trays, and steam admitted into the cabinet. A thermometer was also inserted into one of the packets as was done with the

normal figs. When the temperature inside the packets reached 100°F., the packets were drawn for examination at intervals indicating a rise of ten degrees in temperature on the inserted thermometer. When the figs were examined at temperatures of 100° to 130°F. with humidities ranging from 60 to 80 per cent, very few of the insects or their larvae were destroyed in the figs tested. Twenty minutes after the temperature inside the fruit reached 145°F. with a humidity of 80 per cent, a carton of figs was drawn, which on examination revealed the destruction of all the pests that were present in every fig tested.

The figs were then taken out from the pasteurizer after the temperature had reached 150°F. cooled and stored. A week after, every fig was opened and examined carefully. It was observed that other insects besides the insects utilized had been living in the figs also. Worms and cocoons were discovered, which could not be identified owing to their change of color and shrivelling. No living insects of any kind were encountered. It is obvious from the above results that temperatures from 140°-150°F. with humidities of 60 to 80 percent are sufficient to destroy all insects that attack dehydrated figs within thirty minutes.

Canning of Dehydrated Figs

Usually for canning, figs are picked when ripe enough to hold their shape. They are sometimes peeled, or cooked unpeeled with the stems on, just as they come from the tree. One of the processes of canning figs consists of boiling the

fruit at first in a light syrup, allowing it to cool and then transferring it with successive heating and coòling to syrups of gradually increasing density. (14)

Figs are canned extensively in Texas and California, and small quantities are canned in other southern states, particularly Louisiana. The two varieties used in California are the Calimyrna and the Kadota. In Texas the Magnolia fig is most commonly used, and in Louisiana the Celeste.

The method used in this study for canning dehydrated figs was to wash the figs in cold water to eliminate all dust or other foreign matter that might be present on the figs. The stalks were then trimmed off and the figs transferred to a steam jacketed kettle, well covered with water and boiled for thirty-five to forty minutes. This boiling caused the figs to swell by absorbing water and become soft and tender. By assuming a light brown to yellow color instead of the common dark brown color characteristic of dehydrated figs, the appearance of the fruit was greatly enhanced.

At the end of the thirty-five minutes boiling, the fruit was drained and packed into pint glass jars or tin cans. The water used for the boiling was strained, measured and poured back into the kettle. Enough sugar was then added to make a syrup of 55 per cent sugar concentration. The syrup was added while still hot to the fruit in sufficient amounts to cover the fruit in the container. The containers were then sealed and processed at 190°F. for 40 minutes. When tested, the vacuum in the containers showed 6 to 10 inches, and a

constant syrup concentration of 55 per cent sugar.

Summarizing the above canning data it seems entirely practical to can dried figs in either glass jars or tin cans. The dried figs are preferably stewed or boiled before canning so as to soften and plump the fruit. Syrups of 55 to 65 per cent sugar concentration may be used . The figs are either boiled with the sugar or the hot syrup is added after the figs are packed into the cans or jars. Figs thus prepared are very suitable for breakfast food or dessert. The product takes much less time to prepare than fresh figs, and is not inferior to the fresh-canned fruit either in color, flavor or attractiveness. Dried figs are easier to handly than fresh figs; they hold their shape better, and, like the fresh fruit, they become partially transparent. The final syrup is clear and free from sediment, which adds to the quality of the pack.

Plate VII.

Canned dehydrated figs

Summary

1. The scientific literature on dried figs, fig spoilage, chemical composition and fig by-products is reviewed.
2. The production, drying and distribution of figs is one of the important food industries of the world. The 1933 production for the United States was approximately 25,000 tons of which 19,000 were dried. The imports were 2,928 tons of which 72 per cent otiginated in Turkey.
3. There are hundreds of commercially important varieties of figs, but those studied in this investigation were Calimyrna, Adriatic, Mission and Smyrna. The latter is the common Turkish fig; the others are California varieties.
4. Dried figs have a high nutritive value largely because of their high sugar and mineral contents. They also possess a laxative and regulatory effect on the body. Commercial dried figs have a moisture content of about 19 per cent and a sugar content close to 65 per cent. The total ash content is about 2.4 per cent.
5. Figs are subject to attack by insects, molds and yeasts. Injury may occur either on the tree during maturation, during the drying process or in storage. Important defects are endosepsis, smut, souring and insect infestations.
6. The white to gray powdery coating on the surface of figs consists of fruit sugar (dextrose.) This does not affect the nutritive value of the figs, but it is unsightly. Sugaring occurs when the moisture content is reduced to much below 22 per cent. This coating may be dissolved by

treatment with steam or heated humidified air. The treatments also improve the texture of the fruit and make it softer and more palateable.

7. Pasteurization of figs, by exposing them in small paper cartons to the action of humidified air and steam, is a feasible commercial treatment for the improvement in sanitary quality, physical appearance and palatability of the fruit.

 Experimental equipment for the pasteurization of figs is described. Essentially this consists of a metal cabinet with shelves, with steam (for humidity) and temperature controls. The relative humidity is determined by a wet and dry bulb thermometer. Variations in time temperature ahd humidity are thus made possible for control.

8. Using this pasteurizer, figs in ten ounce paper cartons were exposed to many different humidity and temperature variations in attempt to determine the optimum treatment for improving the quality of dried figs.

 While each of the four varieties requires a slightly different pasteurization treatment, for practical purposes, an exposure of dried figs for sixty to seventy minutes in steam (water vapor) at 90 to 95 per cent humidity and a temperature of 165^{o} to 170^{o}F. gave uniformly satisfactory results.

9. As demonstrated by heat penetration determination, the above treatment produced a temperature of 150^{o}F. or higher for at least 30 minutes. This heat treatment is believedto fully pasteurize the figs and destroy any insects, insect eggs or

insect larvae, yeasts or nonsporulating pathogenic bacteria.

10. Dried figs in cartons inoculated with Esch. coli, when subjected to the pasteurization treatment, were uniformly rendered free from the colon bacillus. Since Esch. coli is usually considered more heat-resistant than Mycobacterium tuberculosis or Bact. typhi, it is believed that the figs are truly pasteurized.

11. The adults, larvae, and eggs of the saw-toothed grain beetle (Silvanus surinamensis Linn.), and the Indian meal moth Plodia interpunctella and some unidentified insects from various infested cereal products were uniformly destroyed by the pasteurization process.

12. Pasteurization added 2 to 4 per cent moisture to the figs, tendered the skin, dissolved the crystallized sugars and generally improved the appearance and eating qualities of the figs. The color was not injured appreciably until temperatures of 180°F. were reached, unless the relative humidity was low,

13. Escherichia coli, inoculated on the surface of dried Adriatic, Calimyrna, Mission and Smyrna figs survived for seven weeks at 36-40°F. (cold storage), and for 5 weeks at 70°F. (room temperature). This indicates that figs may be accidentally infected with pathogenic organisms while repacking in retail cartons or packages, and the bacteria may survive lon enough on them to constitute a potential health hazard.

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