FACTORS CAUSING SHRINKAGE OF BRINED CHERRIES

by

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TABLE OF CONTENTS

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INTRODUCTION

A few years ago nearly all of the brined cherries packed for manufacture in the United States into maraschino-type cherries were imported from France and Italy. Now the industry has developed in this country under the protection of a tariff until only a very small percentage is imported. The northwestern states, Oregon, Washington, and Idaho, packed only nineteen hundred and twenty-five (1925) barrels of brined cherries in 1925, and seventy-eight thousand two hundred (78,200) barrels in 1938.

The industry has been very valuable in the Northwest as an outlet for the surplus cherry crop, most of the cherries being shipped to the eastern part of the United States for the production of maraschino-type cherries.

In the practice of brining cherries, the brine is composed of sulfur dioxide and hydrated lime ($Ca(OH)_2$) or whiting ($CaCO_3$). The sulfur dioxide is used to preserve the cherries and to bleach their natural color to a uniform straw color, while hydrated lime or whiting is used to harden the tissue and prevent cracking of the cherries. The procedure usually involves filling approximately two hundred and forty pounds of the fresh fruit into fifty-two gallon, paraffin-lined, fir barrels, then covering the fruit with a solution containing about one and one-fourth per cent sulfur dioxide and approximately three-fourths of one per cent of hydrated lime or whiting. After the barrels are filled and closed, they are stored for at least thirty days before the cherries are stemmed and pitted. During the first few days of storage, the barrels are rolled each day to insure a uniform bleaching.

According to Bullis and Wiegand (1), one packer found that diffusion and shrinkage losses on three hundred-pound samples of Royal Ann cherries in bleach solution averaged eight and one-fourth per cent in 1930. Stemming and pitting averaged a further loss of twelve per cent. These cherries, after pitting and rebarreling in diluted sodium chloride brine, showed a further shrinkage of four and one-fourth per cent between the time of rebarreling and time of receipt in New York City (six to eight weeks). It is with the last loss by shrinkage that this report is mostly concerned. Losses as high as twenty-five per cent have been reported during such shipment. It is probable, however, that such losses are extreme. This thesis records a number of experiments, the object of which was to determine what specific factors cause shrinkage of cherries and to what extent it occurs. In all the experiments, the amount of shrinkage was determined by the loss in drained weight.

THE METHOD OF APPROACH TO THE PROBLEM

It was decided that the following factors might have an effect on the drained weight of the brined cherries:

I. The quality of fruit and its condition.

II. The ratio of the weight of cherries to the weight of brine covering the cherries.

III. The composition of the brine covering the cherries:

A. The concentration of the hardening agent used.

B. The metal ion responsible for the hardening effect.

C. The concentration of sulfur dioxide.

D. The pH of the brine.

E. The viscosity of the brine.

IV. The temperature at which the barrels of cherries were stored or transported and the temperature of the cherries at the time the drained weight was taken.

V. The length of the storage period and the length of time the cherries were in transit.

VI. The roughness of handling of the barrels of cherries.

VII. The method of taking the drained weight.

GENERAL PROCEDURE FOR MAKING WEIGHINGS

Jars. The cherries were weighed into glass-topped two-quart jars, the weight of each jar being subtracted from the weight of the cherries and jar. Standardized brine from a large container was added until the jars were full, and the jar rubbers and glass lids were sealed on. After keeping the jars at room temperature (always taken as a basis) for two days, the jars were opened, inverted on a screen having four meshes to the inch, and allowed to drain for five minutes, as shown in Plate I. All jars were wiped clean and dry before weighing. After weighing and resealing the jars were incubated at the given temperature (Plate II). A period of ten days was allowed for incubation; then the jars were removed, wiped clean and dry, and reweighed. The change in weight in each instance was noted, and it was divided by the initial weight of cherries to obtain the per cent change.

Barrels. The cherries were filled into five-gallon, paraffin-lined, fir barrels. Standardized brine from a large container was added until the barrels were full. After the sealed barrels were allowed to stand at sixty-five degrees Fahrenheit for one week, they were opened and weighed. Weighing consisted in dumping the entire contents of each barrel into a wicker bamboo basket, which was placed over a fifty-two gallon barrel for catching the

Plate I. Obtaining the Drained Weight of Two-Quart Jars

Plate II. Constant Temperature
Incubation

Plate III. Draining the
Five-Gallon Barrels

brine. (Plate 3) After four minutes and fifty seconds, the baskets were tipped to allow the brine to drain from the bottom of the basket for ten seconds. This made the total draining time five minutes. When drained, the cherries were dumped from the wicker basket into a tared container and weighed to one-eighth pound on a scale. This weight was recorded as the original or basic weight, and the cherries were replaced in the barrels, the brine poured back, and the barrels resealed. Then the barrels were incubated at constant temperatures for ten days. After the ten days' incubation, the cherries were reweighed as described above.

APPARATUS AND PROCEDURE FOR MAKING CHEMICAL TESTS ON BRINE

The pH was taken with a Coleman model 3A pH meter (glass electrode).

Per cent solids was taken with a Zeiss refractometer.

Relative viscosity was determined with an Ostwald viscosimeter.

Per cent sulfur dioxide was determined according to the method used by Bullis and Wiegand (1).

I. EFFECT OF QUALITY AND CONDITION OF THE FRUIT ON THE SHRINKAGE OF CHERRIES

Variety. Due to the lack of availability, very little has done to determine the shrinkage* in different varieties of cherries. Since Royal Ann (Napoleon) is the most important variety used for brining in the Northwest, it has been used almost exclusively as the basis for this work. A few tests were tried on Jones' Seedlings, however, and the results are shown in Table 1. As a comparison, Table 2 is considered here to indicate that Royal Ann cherries are probably affected more by a change in temperature than the Jones' Seedlings. It is difficult to obtain exactly comparable conditions with two different varieties, and definite conclusions are hard to obtain unless the average is taken from a great many tests over a period of several years, and from a large variety of growing conditions.

Growing Conditions and Maturity. Each season is different, and the altitude, soil, temperature, precipitation, and other climatic variations affect the composition of cherries. Cherries may contain more or less sugar and other constituents of the cells that would affect their shrinking or swelling in a brine solution. Also, as a cherry matures its cells loosen, starch changes to sugar,

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*Shrinkage is defined in this thesis as the loss in drained weight.

and the changed composition affects the amount of shrinking and swelling that the fruit will undergo. To determine this effect conclusively, however, would necessitate much study and probably several years of experimentation.

Methods of Handling the Fresh Fruit. The treatment that the cherries receive before being placed in the brine will affect the shrinkage or swelling that the cherries might undergo under certain conditions. Tables 3 and 4 show that there is a difference between the shrinking of pitted and non-pitted cherries, the greatest change being noted with pitted cherries. Since commercial practice is usually concerned with pitted cherries, they have been the subject of most concern in this work.

Table 1. Effect of Variety and Condition on Shrinkage

No.	Condition	Temperature Degrees F.	Change Per cent	Average change Per cent
1A	Pitted	100	- 2.7	(- 2.8)
1B	Pitted	100	- 2.9	
2A	Stemmed	100	- 1.3	(- 1.5)
2B	Stemmed	100	- 1.7	
3A	Unstemmed	100	- 0.5	(- 0.8)
3B	Unstemmed	100	- 1.1	
4A	Unstemmed	32	+ 2.0	(+ 2.3)
4B	Unstemmed	32	+ 2.6	

Constant conditions:

Jones' Seedlings cherries, 1000 grams.

Sulfur dioxide, 1.45 per cent.

Original temperature, 67½ degrees Fahrenheit.

Length of storage, 10 days.

Table 2. Effect of Variety and Condition on Shrinkage

No.	Condition	Temperature	Change
		Degrees F.	Per cent
5 -------	Pitted	100	- 3.50
6 -------	Stemmed	100	- 2.10
7 -------	Unstemmed	100	- 1.40
8 -------	Unstemmed	32	≁ 3.10

Constant conditions:

Same except Royal Ann cherries

Table 3. Difference in Shrinkage of Pitted and Unpitted Cherries as Effected by Temperature

Data in table represents the per-cent change in drained weight of different barrels incubated at the different temperatures.

No.	110° F.	100° F.	90° F.	72° F.	65° F.	32° F.
Pitted --	-6.52	- 4.89	- 2.17	- 1.09	0.00	≁ 1.09
Unpitted -	-5.43	- 2.17	- 2.17	0.00	0.00	≁ 1.09

Constant conditions:

Royal Ann cherries, 25 pounds

Sulfur dioxide, 0.32 per cent

Original temperature, 57 degrees Fahrenheit

Length of storage, 10 days

Table 4. Difference in Shrinkage of Pitted, Unpitted, and Unstemmed Cherries

No.	Condition	Shrinkage	Average Shrinkage
		Per cent	Per cent
21A	--------- Pitted	3.50	(3.70)
21B	--------- Pitted	3.90	
22A	--------- Unpitted	2.10	(2.30)
22B	--------- Unpitted	2.50	
23A	--------- Unstemmed	1.40	(1.20)
23B	--------- Unstemmed	1.00	

Constant conditions:

Royal Ann cherries, 1000 grams

Sulfur dioxide, 1.45 per cent

Original temperature, $67\frac{1}{2}$ degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

II. THE EFFECT OF THE RATIO OF THE WEIGHT OF CHERRIES TO THE WEIGHT OF BRINE ON THE SHRINKAGE OF CHERRIES

When cherries are packed into a barrel they sink to the bottom, since they are heavier than the brine. Weighted by the cherries above them, the cherries below the top layer are pressed together and part of the cell sap and some of the absorbed brine that they contain is pressed from them. The exudation of this small amount of cell sap and brine from the fruit is proportional to the pressure exerted from above. This pressure increases as the depth increases below the surface layer of cherries. Therefore, when more cherries are filled into a container a greater percentage of cherries is affected by the weight of cherries above, and the bottom layer of cherries in a heavily filled container is pressed to the greatest extent. That this is true is illustrated by Table 5 and figure 1.

Referring to figure 1, a change of the ratio of cherries to brine from three-tenths to seven-tenths varied the shrinkage of the cherries from about one and three-fourths to six per cent under the conditions indicated. Such an extreme variation in commercial practice, however, would be impractical. In commercial practice, cherries are forty-five to fifty-eight per cent of the contents of a barrel, the balance being brine. This variation would have an effect representing one and nine-tenths to four and nine-tenths, or three per cent, according to figure 1.

The small-scale experiments were further corroborated by an experiment using five-gallon barrels as containers. In this experiment, the barrels were held at different temperatures; but the data obtained, which is shown in Table 6, were insufficient to determine whether the effect of varying the fill is more pronounced at a higher or at a lower temperature.

Table 5. Effect on Shrinkage of Varying the Fill

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Sulfur dioxide, 1.45 per cent*

pH, 1.56

Original temperature, 67 degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

No.	Weight Cherries	Weight Brine	Total weight	Cherries	Shrinkage	Shrinkage	Average Shrink.
	grams	grams	grams	per cent	grams	per cent	per cent
24A	1300	620	1920	67.7	79	6.07	(6.03)
24B	1300	620	1920	67.7	78	6.00	
25A	1200	730	1930	62.2	61	5.08	(5.24)
25B	1200	730	1930	62.2	65	5.41	
26A	1100	835	1935	56.9	53	4.82	(4.82)
26B	1100	835	1935	56.9	53	4.82	
27A	1000	960	1960	51.0	38	3.80	(3.50)
27B	1000	960	1960	51.0	32	3.20	
28A	900	1080	1980	45.4	17	1.89	(1.94)
28B	900	1080	1980	45.4	18	2.00	
29A	700	1310	2010	34.8	4	0.57	(1.00)
29B	700	1310	2010	34.8	10	1.43	

*Per cent in brine. The brine came from the barrels in which the cherries had been bleached.

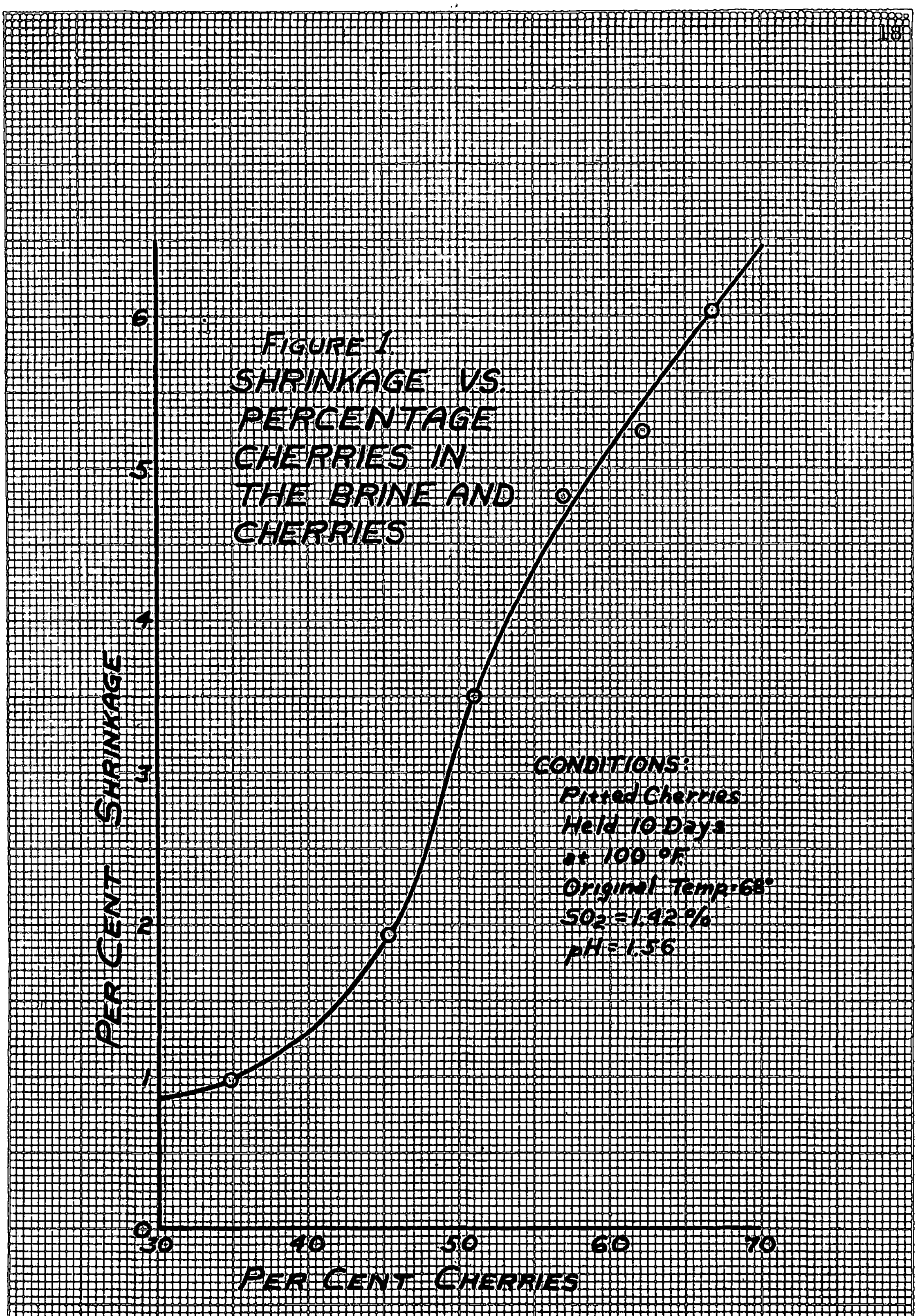
FIGURE 1.
SHRINKAGE VS. PERCENTAGE CHERRIES IN THE BRINE AND CHERRIES
CONDITIONS:
Pitted Cherries
Held 10 Days
at 100 °F
Original Temp. 68°
SO2 = 1.42 %
pH = 1.56
PER CENT SHRINKAGE
PER CENT CHERRIES
0
1
2
3
4
5
6
30
40
50
60
70

Table 6. Effect on Shrinkage of Varying the Fill

Data in the table represent the per cent change in drained weight.

	110°F.	100°F.	90° F.	72° F.	65° F.	32° F.
<u>Pitted cherries</u>:						
30 lbs.*	-7.50	-6.67	-4.38	-2.71	-0.83	+2.71
23 lbs.	-6.52	-4.89	-2.17	-1.09	-0.00	+1.09
<u>Stemmed, unpitted cherries</u>:						
30 lbs.*	-6.67	-5.83	-3.33	-2.50	-0.42	+1.67
23 lbs.	-5.43	-2.17	-2.17	0.00	0.00	+1.09

* 30 pound values are averages.

Constant conditions:

Royal Ann cherries filled into 5-gallon, paraffin-lined fir barrels

Sulfur dioxide, 1.10 per cent

pH, 3.48

Original temperature, 60 degrees Fahrenheit

Length of storage, 10 days

III. THE EFFECT THAT THE COMPOSITION OF THE BRINE HAS ON THE SHRINKAGE OF CHERRIES

A. The concentration of the hardening agent used. To determine to what extent the concentration of the hardening agent used has an effect on the shrinkage of cherries, a solution of sulfur dioxide and water was prepared. Various amounts of calcium carbonate were added to aliquot portions for use on different samples of cherries. The results of the experiment are shown in Table 7 and figure 2. From these results, it has been concluded that the addition of calcium carbonate promotes the shrinkage of cherries to a pronounced degree. In figure 2, it is noted that changing the concentration of calcium carbonate in the brine from three-tenths per cent to one and two-tenths per cent increased the per cent shrinkage approximately three per cent. The per cent calcium carbonate used in commercial practice is usually approximately three-fourths of one per cent, which, according to figure 2, caused a shrinkage of two and one-tenth per cent when the temperature was raised from sixty-five to one hundred degrees Fahrenheit. Re-used brine, which contains in solution part of the constituents of the original cherries, usually causes a shrinkage under similar conditions of about four and nine-tenths per cent. This observation indicates that the cherry solutes that are exuded into the brine cause an increased shrinkage.

Table 7. Effect on Shrinkage of Varying the Amount of Whiting in the Brine

No.		$CaCO_3$ Per cent	Shrinkage grams	Shrinkage Per cent	Average Shrinkage
61A	------	1.2	44	4.00	(3.82)
61B	------	1.2	40	3.64	
62A	------	1.0	36	3.27	(3.45)
62B	------	1.0	40	3.64	
63A	------	0.9	32	2.91	(3.04)
63B	------	0.9	35	3.18	
64A	------	0.8	27	2.45	(2.36)
64B	------	0.8	25	2.27	
65A	------	0.6	20	1.82	(1.59)
65B	------	0.6	15	1.36	
66A	------	0.3	11	1.00	(0.91)
66B	------	0.3	9	0.82	

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Brine, 740 grams

Sulfur dioxide, 1.45 per cent

Original temperature, 65 degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

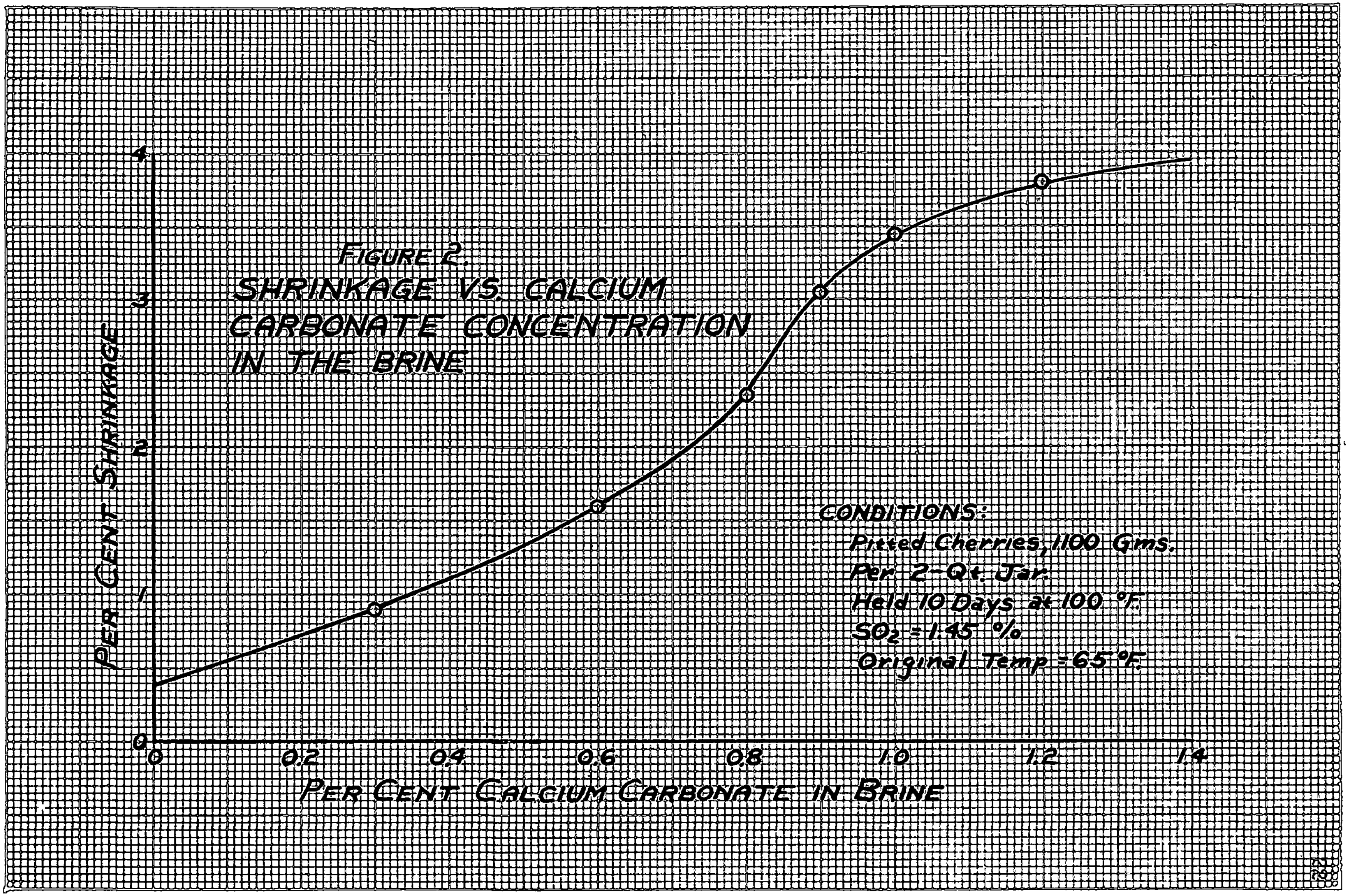

FIGURE 2.
SHRINKAGE VS. CALCIUM CARBONATE CONCENTRATION IN THE BRINE
PER CENT SHRINKAGE
PER CENT CALCIUM CARBONATE IN BRINE
0
1
2
3
4
0.2
0.4
0.6
0.8
1.0
1.2
1.4
CONDITIONS:
Pitted Cherries, 1100 Gms.
Per. 2-Qt. Jar.
Held 10 Days at 100 °F.
SO2 = 1.45 %
Original Temp = 65 °F.

B. <u>The effect of the metal ion used in the brine.</u> The nature of the solutes in the brine have an effect on the amount of shrinkage that occurs in the cherries. Table 8 indicates that sodium chloride probably inhibits shrinkage. Calcium and sodium ions are antagonistic toward each other. According to Miller, et al (4), sodium ions tend to decrease the permeability. Miller also gives data that indicate that plasmolysis, or shrinking, occurs to a greater extent when a very small amount of calcium salt exists in the presence of sodium salt than when calcium salt alone is present. This work may be an explanation of the observance of the smaller shrinkage that occurred when no sodium chloride was added to the brine. (Table 8) Also, it would make it difficult to state definitely if any significance can be attached to the observation of an optimum shrinkage at a sodium chloride concentration of approximately 2.5 per cent. The cherries that were used in the test were drained but not leached from calcium salt before the sodium salt was added to them. It is more probable that sodium salt had an inhibiting effect toward shrinkage at any concentration, but that the residual calcium opposed that effect at the smaller concentrations.

Taking cherries from a brine containing calcium ions, however, and placing them in a brine containing sodium ions appears to be impractical, since all of the samples treated with sodium chloride instead of lime were discolored badly when incubated at one hundred degrees Fahrenheit. Notwithstanding, the effect of using sodium salt in lieu of calcium salt, in the brine surrounding the cherries, has an interesting effect that might be of significance for future work.

Table 8. Effect on Shrinkage of Varying Brine Concentrations using Sodium Chloride

No.	NaCl	Shrinkage	Shrinkage	Aver. Shrink.
	Per cent	grams	Per cent	Per cent
71A	12	28	2.55	(2.59)
71B	12	29	2.64	
72A	6	35	3.18	(3.54)
72B	6	43	3.91	
73A	3	55	5.00	(4.91)
73B	3	53	4.82	
74A	1.5	45	4.09	(4.13)
74B	1.5	46	4.18	
75A	0.75	25	2.27	(2.18)
75B	0.75	23	2.09	
76A	0	10	0.91	(1.13)
76B	0	15	1.36	

Constant conditions:

Royal Ann cherries, 1100 grams, pitted

Sulfur dioxide, 1.45 per cent

Original temperature, 65½ degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

A change in permeability appears to have an effect on the amount of shrinkage that the cherries undergo in the brine, but to foretell what the effect would be and in what direction it would go brings up a very complicated problem. In the first place, there is reason to believe that the harsh action of sulfur dioxide and calcium-acid-sulfite on the cells of the cherries would destroy their semipermeability by making them completely permeable. From a consideration of the results of this experiment, however, and the experiments following that involve changing the concentration of the brine constituents, it would appear that all of the semipermeable nature of the cherry cells is not destroyed. The problem of determining the effect of changed permeability would also involve a consideration of the molecular or ionic constituents within the cells of the cherries, the ability of the molecular or ionic constituents to pass through the cell cytoplasm, and the concentration of the various constituents. In addition, the problem would involve a consideration of the concentration and penetrability of the molecules and ions in the brine.

If shrinkage can be attributed to osmotic action, sodium ions must be able to penetrate the cell membrane, whereas calcium ions must be withheld or penetrate more slowly. It is well to point out in this connection that the amount of osmotic action may be greatly influenced by the difference in rate of penetrability of particles (mole ecular, ionic, or colloidal) through a membrane. Theoretically, of course, such an osmotic action would tend to vanish if the particles are all actually penetrable and are eventually able to get through the membrane. Practically, however, such an osmotic action is very common and significant.

Whatever the effect of sodium in the brine may be, whether it increases the permeability in order that more molecules or ions can pass through the membrane or whether it is able to pass through while calcium is withheld, the shrinkage of cherries is less in a sodium chloride brine than in a calcium hydroxide brine.

C. <u>The effect of the concentration of sulfur dioxide.</u> The concentration of sulfur dioxide in the brine proved to be a very important factor affecting the shrinkage of cherries. To study its effect, strained, re-used brine was separated into eleven containers and sulfur dioxide was bubbled through the brine in the containers for different lengths of time. Samples of the different solutions were then titrated with iodine to determine the per cent sulfur dioxide that each contained. The various concentrations of brine were then used to fill jars containing weighed samples of cherries, the jars sealed, and incubated at one hundred degrees Fahrenheit. Reweighing in ten days showed the effect of per cent sulfur dioxide as indicated by Table 9 and figure 3. As shown in figure 3, changing

Table 9. Effect on Shrinkage of Varying the Sulfur Dioxide Content in Brine

No.	SO_2 Per cent	pH	Shrinkage grams	Shrinkage Per cent
81	9.10	0.87	61	6.1
82	6.34	1.04	60	6.0
83	4.40	1.18	60	6.0
84	3.15	1.26	54	5.4
85	2.42	1.32	50	5.0
86	1.44	1.55	38	3.8
87	0.92	1.90	27	2.7
88	0.67	2.14	20	2.0
89	0.45	2.58	14	1.4
90	0.28	3.38	0	0.0
91	0.12	4.04	1	0.1

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Brine contained 6.5 pounds hydrated lime per 100 gallons of water

Original temperature, 72 degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

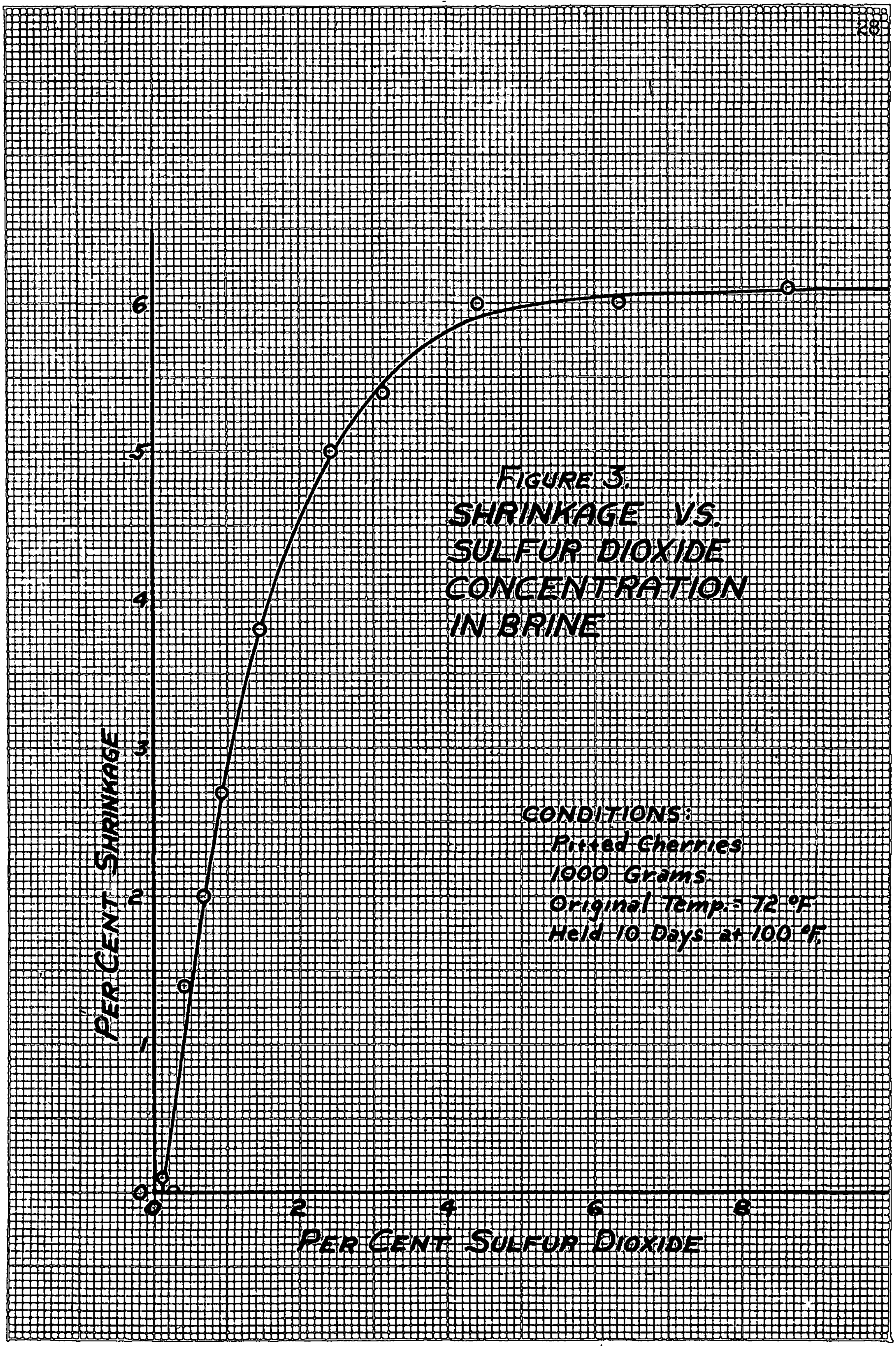
FIGURE 3.
SHRINKAGE VS.
SULFUR DIOXIDE
CONCENTRATION
IN BRINE
CONDITIONS:
Pitted Cherries
1000 Grams
Original Temp. = 72 °F
Held 10 Days at 100 °F.
PER CENT SHRINKAGE
PER CENT SULFUR DIOXIDE
0
1
2
3
4
5
6
0
2
4
6
8

the concentration of sulfur dioxide from one-tenth to five per cent caused an increased shrinkage from zero to six per cent, but increasing the sulfur dioxide concentration above five per cent had very little effect on shrinkage. In commercial packs, the per cent sulfur dioxide is quite variable. For instance, one barrel that was opened for this work contained one and twenty-two-hundredths per cent (1.22%) sulfur dioxide. Another contained one and one-tenth per cent (1.10%), and two others contained thirty-eight-hundredths per cent (0.38%). Figure 3 shows that the probable difference in shrinkage caused by different concentrations of sulfur dioxide in these four barrels when heated from seventy-two to one hundred degrees Fahrenheit varied approximately two and one-half per cent.

The readiness with which cherries shrink in a concentrated sulfur dioxide solution seems to prove that either the increased total concentration of the solution surrounding the cherries or the increased hydrogen ion concentration is responsible for the increased shrinkage. Either the film of solution adhering to the cherries has been reduced by the hydrogen ions or the increased total solids of the solution has caused an increased plasmolysis of the cherry cells. In the opinion of the writer, osmotic effect causing plasmolysis is the more logical conclusion. To hold the pH constant and vary the per cent sulfur dioxide was impossible in this experiment. Increasing the sulfur dioxide concentration from twelve-hundredths per cent to nine per cent varied the pH from four (4.0) to nine-tenths (0.9).

D. <u>The pH of the brine</u>. Due to the buffer action of calcium bisulfite and sulfur dioxide, the addition of strong acids and alkalis has little effect on the pH of a solution. Wiegand, Norton, and Pentzer (5) studied the effect of pH on the cracking of cherries during the bleaching process. They found that increasing <u>or</u> decreasing the hydrogen ion concentration from a pH of approximately two (2.) would increase the cracking of the cherries. After the cherry tissue has been hardened in the brine, however, the cherries are very resistant to cracking. Since cracking would be expected to be due to conditions that are the reverse of those that would normally cause shrinkage, it follows that more shrinkage might be expected to occur at a pH of two than at any other pH value.

A solution containing one and twenty-five-hundredths per cent (1.25%) sulfur dioxide and six and one-half pounds of hydrated lime was used as a basis for experiments to determine the effect of pH on the shrinkage of cherries. To portions of this solution various amounts of five-normal hydrochloric acid and five-normal sodium hydroxide were added. These brines were added to separate samples of cherries and brine which had been held at sixty-seven and one hundred degrees Fahrenheit, respectively, for ten days, and weighed. After the treated brines had been added, the

Table 10. Effect on Shrinkage of Varying the pH With NaOH and HCL

No.	Temperature	Relative Viscosity	Treatment	pH	Shrinkage
	degrees F.				per cent
101A	67	1.202	10 cc HCl	1.99	0.0
101B	67	1.202	10 cc HCl	1.99	0.0
102A	67	1.174	5 cc HCl	2.18	0.2
102B	67	1.184	5 cc HCl	2.17	0.4
103A	67	1.162	$2\frac{1}{2}$ cc HCl	2.24	0.4
103B	67	1.202	$2\frac{1}{2}$ cc HCl	2.24	0.4
104A	67	1.188	control	2.28	0.0
104B	67	1.178	control	2.28	1.3
105A	67	1.172	5 cc NaOH	2.63	1.0
105B	67	1.178	5 cc NaOH	2.60	1.1
106A	67	1.194	10 cc NaOH	2.71	2.1
106B	67	1.190	10 cc NaOH	2.71	1.1
107	100	1.164	5 cc HCl	3.18	0.1
108	100	1.170	control	3.23	0.0
109	100	1.178	5 cc NaOH	3.58	1.1

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Brine, 960 grams

Sulfur dioxide, 0.67 per cent

Length of storage, 10 days

Viscosity of water taken as 1.00 at 70° F.

NaOH and HCL, 5-normal

samples were incubated at the original temperature for another ten days and reweighed. The results are shown in Table 10. Although these results are insufficient in number to give conclusive evidence, they indicate that hydrochloric acid probably has very little effect on shrinkage, whereas, sodium hydroxide increases shrinkage slightly. According to Miller (4), sodium hydroxide increases permeability while hydrochloric acid produces a rapid decrease followed by a rapid increase. The results recorded in Table 10 show that it is probably not advantageous to add either hydrochloric acid or sodium hydroxide to the solution surrounding the cherries for the purpose of preventing shrinkage, since no inhibiting effect was produced by altering the pH.

E. The viscosity of the brine. Judged from an uncontrolled preliminary experiment, it was believed that the addition of a viscous substance, or one that would increase the viscosity of the solution, would prevent shrinkage by increasing the amount of solution that would adhere to the outside of the cherries. When a controlled experiment was made, however, the belief was not substantiated. Several samples were held at sixty-seven and at one hundred degrees Fahrenheit for ten days, and the drained weight was taken. After adding glycerine and sugar in various amounts to the brine, these samples were replaced at the original incubating temperature for another ten days. The drained weight was again taken, and the results are shown in Table 11. All that can be ascertained from these results is that the addition of either sugar or glycerine does not prevent shrinkage.

Table 11. Effect on Shrinkage of Varying the Viscosity of the Brine

No.	Temperature Degrees F.	pH	Relative Viscosity	Treatment	Shrinkage Per cent
111A	67	1.164	3.00	10 cc glycerine	1.3
111B	67	1.164	2.97	10 cc glycerine	1.0
112A	67	1.148	2.73	control	0.1
112B	67	1.148	2.73	control	0.6
113A	100	1.180	3.08	10 cc glycerine	0.6
113B	100	1.688	3.02	10 cc glycerine	0.9
114A	100	1.184	3.04	control	0.9
114B	100	1.170	3.23	control	0.0

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Brine, 960 grams, from commercial barrel

Sulfur dioxide, 0.56 per cent

Viscosity of water taken as 1.00 at 70° F.

Length of storage, 10 days

Table 12. Effect on Shrinkage of Varying the Viscosity of the Brine

No.	Temperature	pH	Relative Viscosity	Treatment	Shrinkage
	Degrees F.				Per cent
115A	67	2.46	1.294	100 grams sugar	2.3
115B	67	2.43	1.300	100 grams sugar	1.3
116A	67	2.48	1.212	50 grams sugar	0.6
116B	67	2.52	1.226	50 grams sugar	0.0
117A	67	2.52	1.164	25 grams sugar	0.8
117B	67	2.62	1.184	25 grams sugar	0.4
118A	67	2.64	1.150	10 grams sugar	1.1
119B	67	2.61	1.152	10 grams sugar	0.1
120A	67	2.73	1.148	control	0.1
120B	67	2.73	1.148	control	0.6
121A	100	3.00	1.216	50 grams sugar	1.2
121B	100	3.06	1.200	50 grams sugar	1.3
122A	100	3.02	1.200	25 grams sugar	0.8
122B	100	3.08	1.190	25 grams sugar	1.3
123A	100	3.04	1.134	control	0.9
123B	100	3.23	1.170	control	0.0

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Brine, 960 grams, from commercial barrel

Sulfur dioxide, 0.56 per cent

Viscosity of water taken as 1.00 at 70° F.

Length of storage 10 days

IV. THE EFFECT THAT STORAGE-TEMPERATURE AND DRAINING-TEMPERATURE HAS ON THE SHRINKAGE OF CHERRIES

According to Miller (4), it has been found that the permeability of certain plant tissues increases with an increase in temperature up to one hundred and eight degrees Fahrenheit, the highest temperature investigated. The rate of shrinking or swelling of tissue in any particular solution would be expected, therefore, to increase unless the increased permeability affects the direction which the flow would take. Considering that a semipermeable membrane separates the brine and the cell sap, a change in the permeability of the membrane toward the solvents of either the cell sap or the brine would affect the shrinkage. Whether or not this is true of cherries in brine has not been proved. Another hypothesis might be that a temporary coagulation or change occurs within the cells of the cherry when it is heated to a higher temperature, and this reduces the osmotic pressure value of the cell sap. Such a cell sap pressure reduction might cause an increased flow of water out of the cells. Temperature also affects the thickness of the film of solution that adheres to the cherries, and higher temperatures of draining would naturally cause a decrease in drained weight. It will be apparent, however, from the results of experiment V that there is some effect other than the temperature of draining the cherries. No direct method was developed to study the effect of draining temperature on shrinkage.

Whatever the cause, temperature has a pronounced effect on the shrinkage of cherries. Several experiments were performed and the results are indicated in Tables 13, 14, 15, 16, 17, 18, and 19, and in figures 4 and 5.

Six different barrels containing thirty pounds of non-pitted cherries were drained at fifty-seven degrees Fahrenheit. After returning the cherries to the barrels, they were incubated at various temperatures between thirty-two and one hundred degrees Fahrenheit. After ten days the drained weight was taken again. The cherries that had been raised in temperature showed a loss in drained weight, while the cherries that had been lowered in temperature had effected a gain. As shown in Table 13, the results indicated that the drained weight had been effected through a range of more than eight per cent by changing the storage temperature. Table 14 shows the results of a similar experiment using twenty-three pounds of cherries in each barrel. Changing the temperature affected the drained weight of these samples in a similar manner but to a lesser extent.

In Table 15, the change in drained weight is shown for a fifty-two-gallon barrel that was subjected to various storage temperatures. The results indicate that a critical temperature was reached somewhere between one hundred and one hundred and eighty-two degrees Fahrenheit, where the shrinkage of cherries became somewhat permanent, since it was found that the cherries did not regain the loss in

Table 13. Effect on Shrinkage of Varying Temperature

No.	Temperature Fahrenheit	Change in weight	Refractometer solids	pH	Sulfur dioxide
	Degrees	Per cent	Per cent		Percent
131	110	- 6.67	10.3	3.50	0.31
132	100	- 5.83	10.3	3.48	0.31
133	90	- 3.33	10.2	3.49	0.31
134	72	- 2.50	10.2	3.47	0.31
135	65	+ 0.42	10.3	3.47	0.32
136	32	+ 1.67	10.0	3.47	0.33

Constant conditions;

Royal Ann cherries, 30 pounds, non-pitted

Same initial re-used brine for all barrels

Original temperature, 57 degrees Fahrenheit

Length of storage, 10 days

Table 14. Effect on Shrinkage of Varying Temperature

No.	Temperature Fahrenheit	Change in weight	Refractometer solids	pH	Sulfur dioxide
	Degrees	Per cent	Per cent		Percent
141	110	- 5.43	10.3	3.50	0.30
142	100	- 2.17	10.2	3.48	0.30
143	90	- 2.17	10.2	3.48	0.31
144	72	0.00	10.5	3.48	0.31
145	65	0.00	10.5	3.47	0.32
146	32	+ 1.09	10.2	3.47	0.33

Constant conditions;

Same as above, except 23 pounds were used instead of 30 pounds

Table 15. Effect on Shrinkage of Varying Temperature

No.	Temperature Fahrenheit	Refractometer solids	pH	Sulfur dioxide	Change in weight
	Degrees	Per cent		Percent	Per cent
151	110	10.3	3.49	0.30	- 6.52
152	100	10.2	3.48	0.31	- 4.89
153	90	10.2	3.48	0.31	- 2.17
154	72	10.0	3.48	0.32	- 1.09
155	65	10.0	3.47	0.33	0.00
156	32	10.2	3.47	0.33	+ 1.09

Constant conditions:

Royal Ann cherries, 23 pounds, pitted

Same re-used brine for all barrels

Original temperature, 57 degrees Fahrenheit

Table 16. Effect on Shrinkage of Varying Temperature

Date	Temperature Fahrenheit	Weight	Change in weight
	Degrees	Pounds	Per cent
12/14/38	51	230.0	0.00
12/21/38	32	232.5	+ 1.09
12/30/38	182 (held at 130 before weighing)	209.0	- 9.13
1/20/39	100	209.5	- 8.92
2/12/39	62	210.0	- 8.69

Constant conditions:

Fifty-two-gallon barrel of unstemmed Royal Ann cherries as received
Sulfur dioxide in brine, 0.385 per cent

Weights were taken by pouring contents of barrel in 9 approximately equal portions into wicker baskets. Each basket was drained five minutes, as with five-gallon barrels.

drained weight by lowering the temperature. Perhaps coagulation or rupture of the cells occurred at a high temperature.

In obtaining results for Table 17, the storage temperature of four samples was alternated between thirty-two and one hundred degrees Fahrenheit. The results indicate that loss in drained weight occurs more rapidly at a high temperature than gain in drained weight occurs at a low temperature.

Table 18 and figure 4 show the effect of temperature on samples of pitted Royal Ann cherries in two-quart jars, while Table 19 and figure 5 show the effect of storage temperature on samples in five-gallon barrels. Some of the difference between the two sets of data can be attributed to the difference in the initial temperature that was used. Slower heat penetration to the center of a barrel may be the cause of the rest of the difference.

Table 17. Effect on Shrinkage of Varying Temperature

Figures record changes after storage for four days at temperature at head of each column.

No.	100° F	32° F	100° F	32° F	100° F	32° F	100° F
171	- 4.1	+0.5	- 3.1	+ 2.2	- 3.8	+ 2.0	- 4.1
172	- 4.0	+1.1	- 2.9	+ 2.1	- 3.1	+ 1.8	- 4.4
173	- 3.1	+2.0	- 2.7	+ 2.5	- 2.9	+ 2.2	- 3.2
174	- 4.9	+1.0	- 2.6	+ 2.6	- 3.7	+ 1.6	- 4.9
Average	- 4.0	+1.15	- 2.82	+ 2.32	- 3.12	+ 1.90	- 4.15

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Re-used brine originally containing 5 pounds unslacked lime per 100 gallons

Sulfur dioxide, 0.385 per cent

Original temperature, 67 degrees Fahrenheit

Table 18. Effect on Shrinkage of Varying Temperature

No.	Temperature Fahrenheit	Change in Weight	Change in Weight	Average Change
	Degrees	Grams	Per cent	Per cent
181A	100	lost 53	- 4.82	
181B	100	lost 55	- 5.00	
181C	100	lost 59	- 5.36	
181D	100	lost 51	- 4.63	
181E	100	lost 49	- 4.45	(- 4.85)
182A	90	lost 34	- 3.09	
182B	90	lost 39	- 3.54	(- 3.31)
183A	80	lost 22	- 2.00	
183B	80	lost 26	- 2.36	(- 2.18)
184A	72	lost 8	- 0.73	
184B	72	lost 10	- 0.91	(- 0.82)
185A	65	gain 4	+ 0.36	
185B	65	gain 4	+ 0.36	(+ 0.36)
186A	32	gain 67	+ 6.09	
186B	32	gain 65	+ 5.91	
186C	32	gain 62	+ 5.63	
186D	32	gain 69	+ 6.27	
186E	32	gain 65	+ 5.91	(+ 5.96)

Constant conditions:

Royal Ann cherries, 1100 grams, pitted

Sulfur dioxide, 1.42 per cent

pH 1.56

Original temperature, 68 degrees Fahrenheit

Length of storage, 10 days

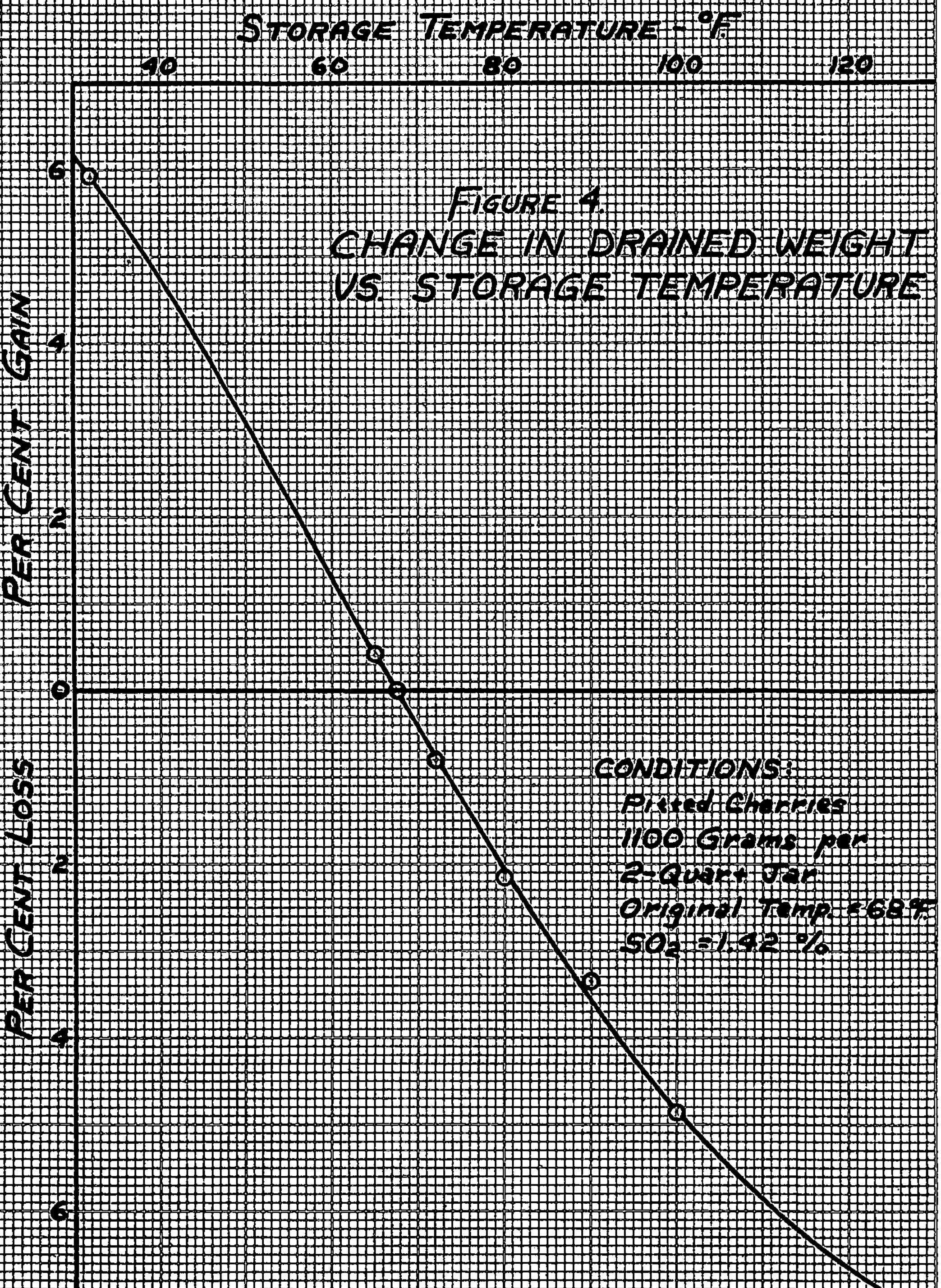
STORAGE TEMPERATURE - °F.
40
60
80
100
120
FIGURE 4.
CHANGE IN DRAINED WEIGHT
VS. STORAGE TEMPERATURE
PER CENT GAIN
6
4
2
0
PER CENT LOSS
2
4
6
CONDITIONS:
Pitted Cherries
1100 Grams per
2-Quart Jar
Original Temp. = 68°F.
SO2 = 1.42 %
40
60
80
100
120
STORAGE TEMPERATURE - °F.

Table 19. Effect on Shrinkage of Varying Temperature

No.	Temperature Fahrenheit	Change in Weight	Per Cent Change	Per Cent Change	Refractometer after incubation	pH after incubation
		Pounds			Per cent solids	
191A	130	-2.75	-9.17		11.7	3.47
191B	130	-2.50	-8.33	-8.75	11.8	3.47
192A	110	-2.25	-7.50		11.3	3.48
192B	110	-2.25	-7.50	-7.50	11.6	3.47
193A	100	-2.125	-7.08		11.1	3.48
193B	100	-1.875	-6.25	-6.67	11.1	3.48
194A	90	-1.25	-4.17		10.4	3.47
194B	90	-1.375	-4.58	-4.38	10.2	3.48
195A	72	-1.00	-3.33		10.3	3.49
195B	72	-1.00	-3.33	-3.33	10.3	3.49
196A	72	-0.75	-2.50		10.2	3.47
196B	72	-0.875	-2.92	-2.71	10.4	3.48
197A	65	0.00	0.00		10.4	3.50
197B	65	-0.75	-1.67	-0.83	10.2	3.48
198A	32	+2.75	+2.50		10.2	3.50
198B	32	+2.50	+2.90	+2.71	10.2	3.51

Constant conditions:

Royal Ann cherries, 30 pounds, pitted

Sulfur dioxide, 1.1 per cent

Original temperature, 60 degrees Fahrenheit

Length of storage, 10 days

Re-used brine, originally containing 6.5 pounds of hydrated lime per 100 gallons

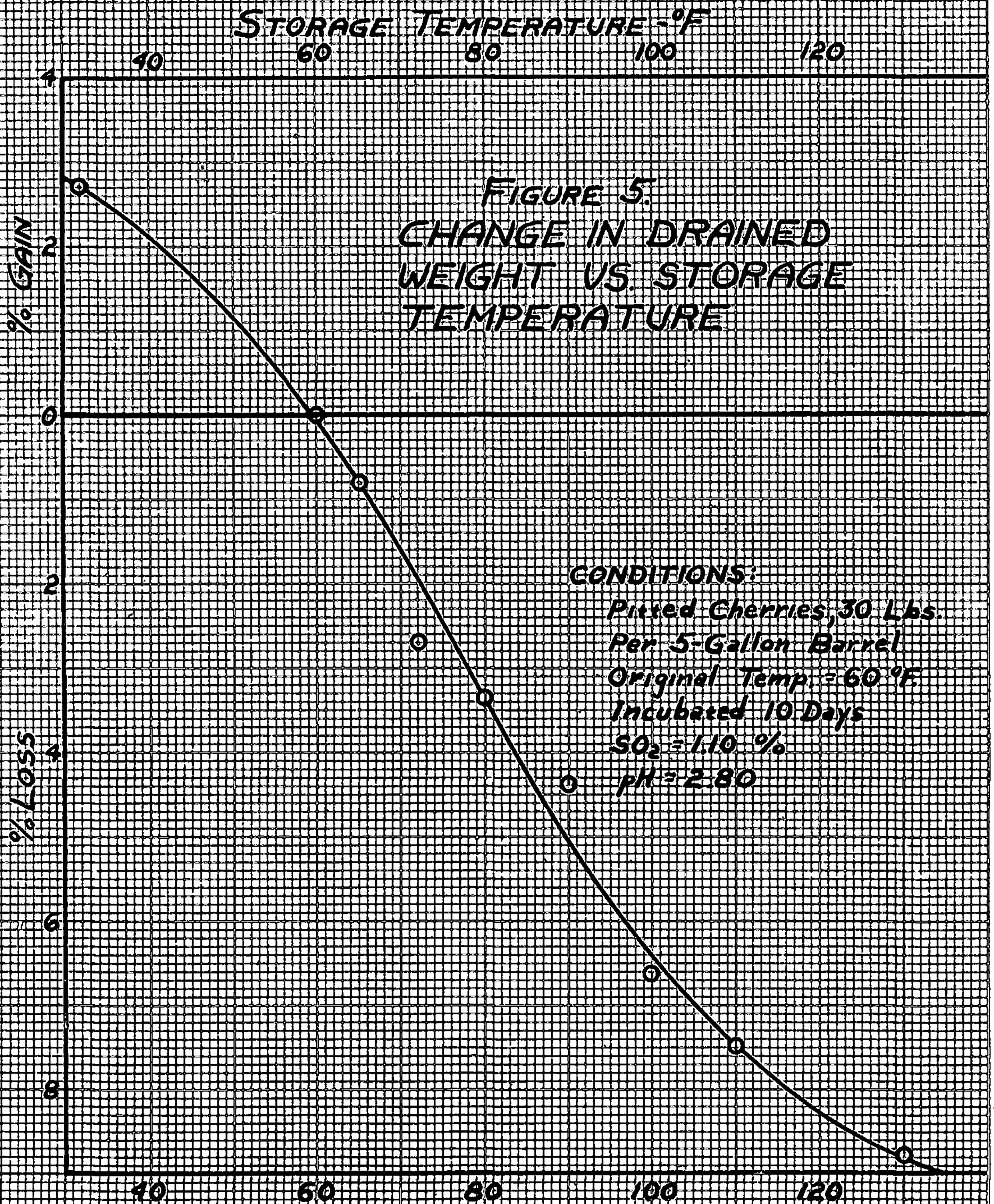

FIGURE 5.
CHANGE IN DRAINED WEIGHT VS. STORAGE TEMPERATURE

V. THE EFFECT THAT LENGTH OF STORAGE AT A PARTICULAR TEMPERATURE HAS ON THE SHRINKAGE OF CHERRIES

It was found that raising the storage temperature to one hundred degrees Fahrenheit caused an increasing loss for approximately four days, but continued incubation after four days at that temperature caused very little further change. Tables 20 and 21 show the experimental data from which this conclusion was reached. Table 20 also shows that changing the incubation temperature from sixty-six to thirty-two degrees Fahrenheit caused an increasing gain for thirty-two days, the longest time for which readings were obtained.

Table 20. Effect on Shrinkage of Length of Storage

No.	Days Held	Temperature Fahrenheit Degrees	Change in Weight Per cent	Average Change Per cent
201A	2	100	- 2.55	
201B	2	100	- 1.36	(- 1.95)
202A	4	100	- 2.64	
202B	4	100	- 2.82	(- 2.73)
203A	8	100	- 2.00	
203B	8	100	- 3.18	(- 2.59)
204A	16	100	- 2.73	
204B	16	100	- 3.09	(- 2.91)
205A	32	100	- 2.82	
205B	32	100	- 3.00	(- 2.91)
206A	2	32	+ 2.55	
206B	2	32	+ 2.00	(+ 2.27)
207A	4	32	+ 5.27	
207B	4	32	+ 3.91	(+ 4.59)
208A	8	32	+ 4.37	
208B	8	32	+ 3.36	(+ 3.86)
209A	16	32	+ 5.46	
209B	16	32	+ 5.09	(+ 5.27)
210A	32	32	+ 6.55	
210B	32	32	+ 5.46	(+ 6.00)

Constant conditions:

Royal Ann cherries, 1100 grams, pitted

Sulfur dioxide, 0.385 per cent

Original temperature, 66 degrees Fahrenheit

Table 21. Effect on Shrinkage of Length of Storage

No.	½	1	1½	2	2½	3	3½	4	4½	5	8	10
211	1.7	1.9	4.6	4.6	4.9	4.8	5.2	5.4	5.2	5.0	4.7	4.3
212	1.8	1.8	3.2	4.1	4.6	4.6	4.6	4.8	4.8	3.7	4.2	4.6
213	1.6	2.1	3.0	3.8	4.4	4.4	4.6	4.6	4.6	3.7	4.2	4.6
214	1.7	1.5	3.1	4.2	4.6	4.6	4.8	5.0	4.6	4.1	4.5	5.0
215	1.2	1.8	2.9	3.6	4.0	4.2	4.2	4.4	4.2	3.6	4.0	4.2
Ave.	1.60	1.82	2.96	4.06	4.48	4.52	4.68	4.84	4.68	4.11	4.32	4.54

Numbers at top indicate the days held; numbers in table indicate the percentage of shrinkage.

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Sulfur dioxide, 1.45 per cent

Original temperature, 67½ degrees Fahrenheit

Storage temperature, 100 degrees Fahrenheit

VI. THE EFFECT OF HANDLING THE BARRELS OR JARS CONTAINING THE CHERRIES ON THE SHRINKAGE OF THE FRUIT

Agitation of the container of cherries was shown by experiment to be an important factor of shrinkage, but no controlled method was developed to enable duplication of experiments. Table 22, however, shows that the effect is substantial and is noticeable at the time that the agitation occurs. The explanation, of course, is simple. Agitation presses solution from the cherries, ruptures some of the cells, and causes some of the cell solutes to go into the brine. Since an increased concentration in the brine causes a greater shrinkage of the cherries, and since the cherries would be able to hold less solution when some of the cells are ruptured, a lowering of the drained weight would be expected.

Table 22. Effect on Shrinkage of Roughness of Handling

No.	Treatment	Shrinkage	Average Shrinkage
		Per cent	Per cent
221A	Given 10 shakes each day for the first five days	1.6	
221B		1.8	
221C		0.9	
221D		2.6	(1.7)
222A	Given 10 shakes, vigorously, only just before taking the drained weight	2.2	
222B		3.4	
222C		3.9	
222D		4.1	(3.4)
223A	Handled carefully with no shaking	0.2	
223B		0.1	
223C		0.0	
223D		0.6	

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Sulfur dioxide, 1.25 per cent

Original temperature, 100 degrees Fahrenheit for 10 days before initial draining

Storage temperature, 100 degrees Fahrenheit

Length of storage, 10 days

VII. THE EFFECT THAT THE METHOD OF TAKING DRAINED WEIGHT HAS ON THE SHRINKAGE OF CHERRIES

Naturally, the type of sieve that holds the cherries while they are draining would have an effect on how much solution drains from them. Also, if the cherries or sieve is agitated while the solution is draining off, there would be an increased amount of solution drain from the cherries. Some evidence of how agitation affects the drained weight is illustrated by the results tabulated in Table 23. In the experiment, ten jars of cherries were allowed to set for two hours at room temperature, then they were drained. Five of the jars were drained by the usual method, while the other five were allowed to drain for four minutes, inverted to right-side-up for five seconds, then allowed to drain one minute longer. The results show that more brine drained from the cherries when the jars were inverted for the five-second interval during the draining period. The five-second inversion caused the drained weight to be four per cent less than obtained by the ordinary method. The slight agitation and rearrangement of the cherries while being inverted probably opened new channels for the brine to flow out. Some of the solution may have been pressed from the pit cavities when the cherries fell back and forth in the jar with little brine to cushion their fall.

Table 23. Effect on Shrinkage of the Method of Draining

No.	Treatment	Shrinkage*	Average Shrinkage
		Per cent	Per cent
231A	Jars 1 to 5 were drained 4 minutes horizontally, inverted to right-side-up for 5 seconds, then allowed to drain horizontally for an additional minute.	4.4	
231B		5.2	
231C		6.1	
231D		5.3	
231E		5.3	(5.5)
232A	Jars 6 to 10 were drained 5 minutes horizontally.	1.2	
232B		0.8	
232C		1.0	
232D		1.2	
232E		1.2	(1.1)

*Shrinkage between drainings two hours apart.

Constant conditions:

Royal Ann cherries, 1000 grams, pitted

Sulfur dioxide, 1.25 per cent

Cherries used had been sitting for one week at room temperature

They were drained (67°F.), rebrined, let stand for 2 hours, then redrained

SUMMARY OF CONCLUSIONS

I. The variety, growing conditions, maturity, and methods of handling cherries have an undetermined effect on shrinkage.

II. The more cherries that are packed into a container, the greater the per cent shrinkage. In ten days, the cherries in a container having thirty-four and eight-tenths (34.8) per cent cherries and sixty-five and two-tenths (65.2) per cent brine shrank one per cent when the temperature of incubation was raised from sixty-seven to one hundred degrees Fahrenheit; and under the same conditions, a container with sixty-seven and seven-tenths per cent cherries shrank six per cent of the weight of the cherries.

III. The composition of the brine covering the cherries has a marked effect on the shrinkage of cherries.

A. Increasing calcium carbonate in the brine from three-tenths to one and three-tenths caused an increased shrinkage of three per cent when the temperature was raised from sixty-five to one hundred degrees Fahrenheit.

B. The metal ions in the brine have an effect on shrinkage. Sodium chloride was found to inhibit the shrinkage of cherries; but it was found impractical to change the brine from calcium carbonate to sodium chloride, since the cherries discolored when placed in sodium chloride brine and incubated for ten days at one hundred degrees Fahrenheit.

C. The concentration of sulfur dioxide affects shrinkage. It was found that increasing sulfur dioxide from two-tenths to five per cent caused an increased shrinkage from zero to five per cent in ten days' incubation. Increasing the sulfur dioxide concentration above five per cent, however, had little effect on shrinkage.

D. The pH of the brine had little effect on shrinkage over the range studied. Sodium hydroxide added to the brine probably caused increased shrinkage.

E. Effecting small changes in viscosity by adding sugar or glycerine to the brine did not inhibit shrinkage.

IV. Temperature has a pronounced effect on the shrinkage of cherries. Cherries raised from sixty-seven to one hundred degrees lost five per cent of their weight by shrinkage in ten days under controlled conditions, while cherries lowered from sixty-seven to thirty-two degrees Fahrenheit gained six per cent in weight.

V. The length of time that cherries are stored at a particular temperature is important. After four days there was little change when the temperature was raised to one hundred degrees Fahrenheit. Lowering the temperature to thirty-two degrees, however, caused an increase in drained weight, which continued for four weeks.

VI. The roughness of handling of brined cherries had a pronounced effect on shrinkage. The more roughly they were handled, the more loss by shrinkage. When shaken just before weighing, the shrinkage was greater.

VII. The method of taking the drained weight was a very important factor affecting shrinkage. Important things to be standardized are:

1. Agitation during draining.
2. Type of draining equipment.
3. Depth of cherries in the equipment.
4. Temperature at which cherries are drained.

Time of draining had little effect on shrinkage. All but a very small percentage of the brine drained off in one-fourth minute.

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