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SHRINKAGE OF COLD-CURED CHEESE DURING RIPENING.

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SHRINKAGE OF COLD-CURED CHEESE DURING RIPENING.[1]

S. M. BABCOCK, H. L. RUSSELL AND U. S. BAER.

INTRODUCTION.

In our previous studies on the cold curing of cheese[2] no determinations were made of the progressive shrinkage which occurred in the cheese when cured at low temperatures, for the reason that in the different series, most of the cheese were plugged more or less, and so rendered it impossible to secure any large number of accurate weighings.

During the last year an exceptional opportunity was offered for a series of studies on this point, in an experiment which we have been conducting under the auspices of the U. S. Dept. of Agriculture.

At our suggestion, the Department instituted a series of experiments on the cold-curing of cheese which was purchased under commercial conditions in the different cheese-producing sections of the country. The Eastern experiments were placed under the control of the New York Agricultural Experiment Station, and the Western experiments under the direction of this Station.[3]

For the purposes of this experiment, naturally Chicago would have been chosen as a curing station, but we found it difficult to make

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[1] NOTE.—This bulletin is one of a series that has been prepared with especial reference to the promotion of the cheese industry. For the information of parties who desire the earlier bulletins of this series, which can be secured upon application to the Wisconsin Agricultural Experiment Station at Madison, the numbers and subjects of those already issued are herewith appended:

Bulletin 60. The Cheese Industry: Its Development and Possibilities in Wisconsin—S. M. Babcock and H. L. Russell.
Bulletin 61. The Constitution of Milk with Especial Reference to Cheese Production—S. M. Babcock.
Bulletin 62. Tainted or Defective Milks: Their Causes and Methods of Prevention—H. L. Russell.
Bulletin 67. Factory Tests for Milk—S. M. Babcock, H. L. Russell and J. W. Decker.
Bulletin 70. Construction of Cheese-curing Rooms for Maintaining Temperatures of 58°—68° F.—F. H. King.
Bulletin 88. Dairy Industry in Wisconsin, with illustrated wall-map—H. L. Russell.
Bulletin 94. Curing of Cheddar Cheese, with especial reference to cool-curing—S. M. Babcock and H. L. Russell.

[2] Reported in detail in Bulletin No. 94 of this Station and also in 19th Annual Report for year 1902, p. 150.

[3] The full data relating to the influence which temperature exerts on the quality, as well as the shrinkage of cheddar cheese, will be found in Bulletin No. 49, Bureau of Animal Industry, U. S. Department of Agriculture.

arrangements for the range in temperature desired. Suitable arrangements, however, were made at the commercial cold storage warehouse of the Roach & Seeber Co., Waterloo, Wis., where rooms were fitted up and the desired temperatures secured.

SELECTION OF THE CHEESE.

As Wisconsin is the leading cheese-producing State of the west naturally the bulk of the product selected should represent the type of cheese manufactured in this state. In order, however, to more thoroughly cover the cheese-producing territory of the west, samples were also secured from a number of the neighboring states. In this way, all types of American cheese were obtained, ranging from the firm, export, typical cheddar cheese to the soft, open-bodied, moist cheese intended for early consumption.

For convenience we may group these various lots of cheese under three different types as follows:

I. Close-bodied, firm, long-keeping type suitable for export trade (typical cheddar).

II. Sweet curd type.

III. Soft, open-bodied, quick-curing type suitable for early consumption.

Type I represents the class of cheese that is especially manufactured in Wisconsin while as a rule Type III represents the kind of cheese that is chiefly made in Michigan. The representatives of the sweet curd type were taken from Iowa and Illinois, although this class is made to some extent in all sections.

Table I gives the location of the factories from which the different lots were secured, also the size and amount of cheese so purchased.

TABLE 1.— *Origin of cheese and amounts used in experiments.*

TYPE I (export type).	Size.	Amount (lbs.)
Wisconsin.		
Thos. Johnston, Boaz, Richland Co.	Flats.	600
H. J. Noyes, Muscoda, Grant Co.	Flats.	540
P. H. Kasper, Nicholson, Waupaca Co.	Flats.	540
La Crosse Cheese & Butter Co., Alma, Trempealeau Co.	Daisies.	1,200
	Prints.	400
TYPE II (sweet curd type).		
Iowa.		
E. G. Hodges, Union, Iowa.	Flats.	600
Illinois.		
J. B. Gilbert & Co., Sterling, Ill.	Flats.	600
TYPE III (soft home-trade type).		
Michigan.		
A. H. Barber & Co., Merrill, Mich.		
I	Flats.	270
II	Flats.	270
III	Flats.	870
IV	Flats.	390

In having the cheese made at these various factories, directions were given for the use of a uniform amount of rennet and salt. Color was left optional for each maker to follow his customary practice. The use of three and one-half ounces of Hansen's rennet extract and two and one-half pounds of salt per 1,000 lbs. of milk was recommended in each case with the exception of the smaller cheese (daisies and 10 lb prints), which were salted at the rate of two and one-fourth lbs. per 1,000 lbs. of milk. The cheese were made from September 26th to October 4th. The condition of the milk was influenced in several instances by the fact that severe frosts had occurred in some sections, which injured the quality of the product. This was particularly true in the case of the La Crosse cheese which were somewhat tainted. The milk from which the Iowa cheese were made was also reported as of inferior quality. The Michigan goods were too high acid, and were cooked low, making a soft cheese which was quick-curing, and kept poorly.

Where it was necessary to secure cheese from such a wide range of territory, it was manifestly impossible to expect that the curing could be carried out as satisfactorily as it would be if it had been done directly at the factories. The varying period of transit to which the cheese were subjected with no especial temperature control, affected of course the initial stage of curing, but the conditions of the experiment prevented the carrying out of immediate installation of the cheese in the cold curing room, especially in the case of those made outside of Wisconsin, although the shipments were made in October when the temperature range was moderate.

The cheese were weighed and put in the respective rooms as soon as received at Waterloo. They were stored in boxes during the curing as is the custom in the handling of cold storage goods. The temperatures at which we desired to hold the cheese for curing were 40°, 50° and 60° F. These points were selected for the following reasons. In our previous experiments we had found that the character of the cheese cured at the lower temperatures, 40° and 50°, was much better than that produced at 60°. Perhaps it would have been better for the purpose of the experiment if the cold-cured cheese could have been compared with the same make of cheese cured under the widely variable conditions which prevail in most factories, where often the maximum temperature is in the neighborhood of 80° F. and fluctuates 20° or more. But we have made this comparison with the very best conditions that obtain in factories provided with sub-earth ducts, and other means of temperature control. In such cases a temperature of 60° can be maintained with a fair degree of constancy. The experiments therefore compare the cold curing process with the best prevailing conditions.

The temperatures actually maintained varied only slightly from the

chosen points and in the two colder rooms were remarkably uniform The 60° room was subject to somewhat wider fluctuations, but was much more uniform than obtains in summer where no artificial refrigeration is practiced. The following table gives the average of all the observations made at regular intervals, and the maximum and minimum observed throughout.

TABLE 2.—*Temperature records.*

	Cold rooms.		Normal Temp.
	Low.	Medium.	
	Room I.	Room II.	Room III.
	°F.	°F.	°F.
Average	36.8	46.9	58.5
Maximum	37.0	47.5	61.0
Minimum	35.0	45.0	57.0

The daily fluctuations were inconsequential as can be seen by a series of diagrams taken from the registering instrument.

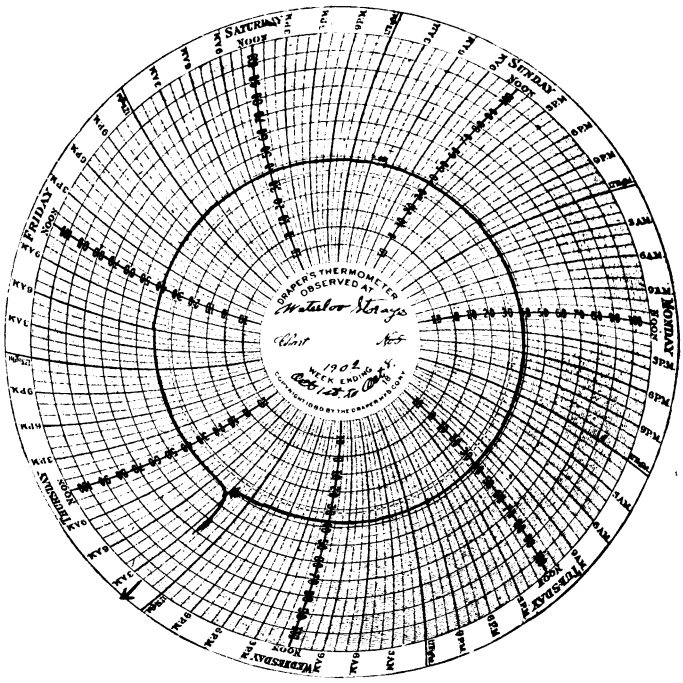

FIG. 1.—Thermometric record for one week in coldest room.

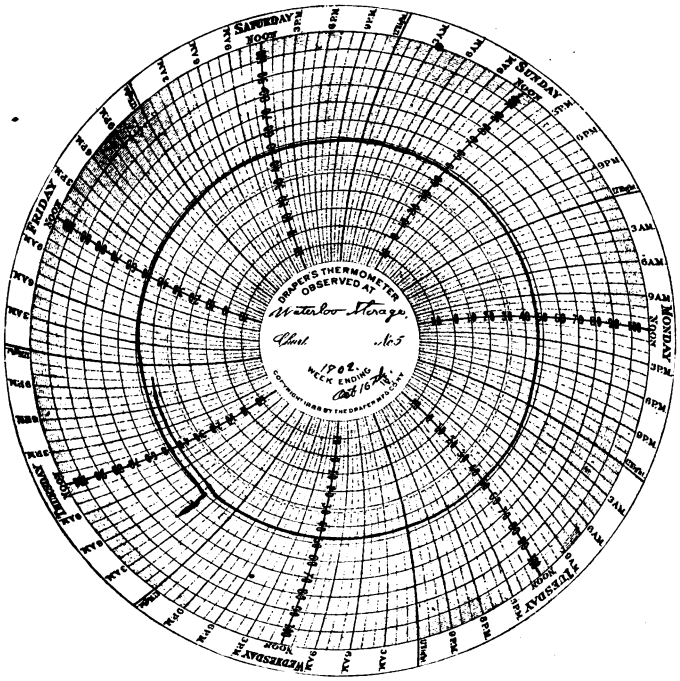

FIG. 2.—Thermometric record for one week in medium cold room.

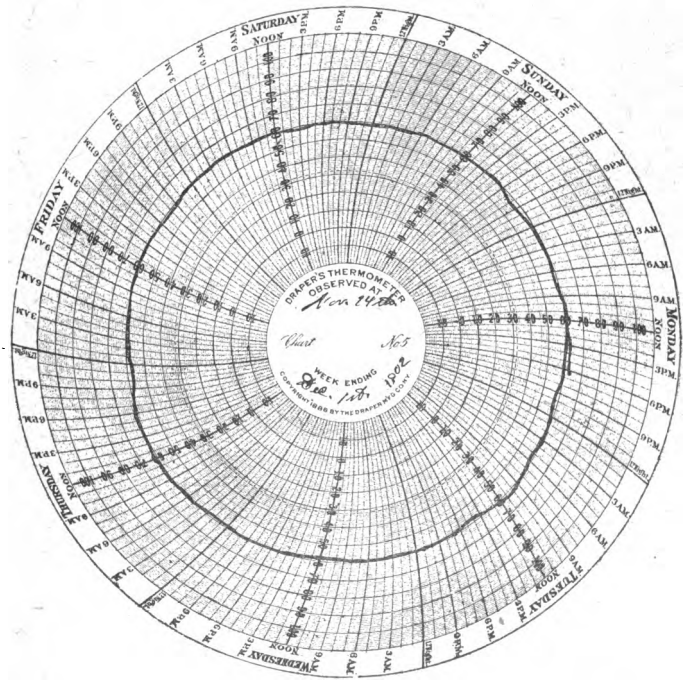

FIG. 3.—Thermometric record for one week in the 60° room.

FACTORS INFLUENCING RATE OF LOSS.

There are a number of factors which modify the rate at which a cheese loses its water content during the course of ripening. The following factors are known to exert a more or less marked influence, although it is impossible to arrange them in order of their relative importance, as they are always interdependent.

1. Temperature of curing room.
2. Relative humidity of air of curing room.
3. Size and form of cheese.
4. Moisture content of the cheese.
5. Protection to external surface of cheese.

The influence of temperature is closely connected with the relative humidity of the curing room, but in addition to the effect which the higher temperatures exert on this factor, it should be remembered that the [redacted] evaporation of water increased in warmer atmospheres even though the relative humidity remains the same. The more potent influence of temperature is however shown by the effect which varying degrees of heat exert on the relative humidity of the atmosphere. The relative humidity of the air is practically doubled when the temperature falls 20° F. As the average relative humidity of air is generally over 50%, it therefore follows in cold curing rooms supplied with outside air in which the temperature is from 30°-40° lower in summer than the outside temperature, that the air of these rooms is practically saturated, thus greatly reducing the loss of moisture from the cheese.

So far as the cheese itself is concerned the moisture of the room may be materially altered by the way in which the cheese is handled during the curing process. If the cheese are shelf-cured, as is the custom in most factories, the surrounding air more nearly approximates the average relative humidity of the entire room than is the case where the goods are box-cured. In the latter case the confined air is more nearly saturated, as is shown by the greater liability to mold and rind-rot.

This point is well shown in an experiment on the relative humidity of the air in a box containing cheese placed directly therein from the press.

To show this the following observations were made. Wet and dry bulb thermometers (Hydrodeik) were placed in a cheddar box with a 30 lb. flat. An opening was made in the cover which was covered with glass so that observations could be made directly without opening the box. The apparatus was placed for a period in rooms at different temperatures and the observations recorded as follows:

TABLE 3.—*Relative humidity of air surrounding box-cured versus shelf cured cheese.*

	Temp. Range.	Relative Humility.	
		Room.	Cheese box.
Room I	35°-40°	Per cent 85-92	Per cent. 100
Room II	50°-55°	55-75	94
Room III	60°-69°	50-70	84-90

A factor which is frequently overlooked is the varying moisture content of the cheese. The more moisture there is left in the cheese, the more rapid the evaporation. The varying moisture content of different types of cheese is determined by the temperature at which the curds are cooked, the time of exposure and the acidity of the curd. A cheese in which the acidity is developed is materially drier than a sweet curd cheese. Salt also has a tendency to diminish the water content. In the foregoing cases this diminution in moisture is due to the shrinking of the curd particles under the influence of these factors. An increase in fat lessens the drying of the curd. Much loss of moisture can also be prevented by coating the cheese with paraffin, a practice which is now coming into very general use for the prevention of mold, and the lessened shrinkage in weight.

EXPERIMENTS IN THE SHRINKAGE OF COLD-CURED CHEESE.

In these experiments the first careful weighings were made when the cheese were received at the cold storage plant in Waterloo. The cheese were shipped from the factories directly after they were removed from the press but were in every case several days upon the road. In no instance was the interval between making and installation in cold curing rooms less than five days, and it ranged from this up to seventeen days with one lot from Michigan which was delayed in transit. During this period which was in early October the cheese were subjected to varying conditions of temperature and exposure. In a few cases boxes were broken, and in other instances, the cheese were delayed at points of transfer. It was impossible to obviate these difficulties as the cheese were purchased from distant points, in order to secure representation from a wide range of territory, and from different types of cheese. This variation in initial drying changed, of course, the rate of loss when cheese were placed in cold curing rooms, so that this factor must be taken into consideration in studying the data presented below.

The losses reported in this bulletin only cover those which took place in the cheese after they had reached the cold curing rooms, but careful records have been kept for the entire curing period and these data we believe are of sufficient importance to warrant full consideration in this connection.

DETAILS OF WEIGHING.

The cheese were all weighed on counter scales, weighing accurately to fractions of an ounce. In order to check the accuracy of the weights, each cheese was weighed separately and the weight recorded; then the whole lot was weighed collectively. As these weights agreed within a few ounces they show the accuracy of the weighing. For practical purposes it is desirable to know the losses which occur for stated periods. It was however impracticable for all of the cheese to be weighed at exactly the same intervals, as they were put in storage at different dates, but it was designed to secure at least three weighings for the first month of storage, two weighings for the second, and at about monthly intervals thereafter. If these data are charted, it is possible to deduce an estimated loss for any stated period, and in doing so, we have selected the following intervals as being those concerning which data would be most frequently desired. For this purpose, 10, 20, 30, 60, 90 days, etc., have been selected.

CONDITION UNDER WHICH THE CHEESE WERE STORED.

In this work the attempt was made to hold the cheese at 40°, 50° and 60° F. The actual temperatures secured averaged 36.8, 46.9° and 58.5° F.

The variation in temperature in the two lower rooms was practically negligable as it was only 2–2½ degrees. The temperature of the 60° room oscillated somewhat more (4° F.) but was very much more uniform than ordinary factory curing rooms. (See figs. 1, 2 and 3 for thermometric data.)

Hygrometric data were not secured during the whole period as it was at first thought that a saturated atmosphere would prevail where the cheese were box-cured, but during the course of the experiments it was noted that the 50° cheese were not molding as much as were those at 40° and 60°. This fact could only be explained by the assumption that a less humid atmosphere was present in the case of the 50° room. Observations at the end of the experiment showed a relative humidity in the different curing rooms as follows:

	Temp. degrees Fahrenheit.	Relative humidity. per cent.
Room I	37	92
II	48	73
III	59	72

It will be observed in the figures later presented (fig. 5) that the difference in rate of loss at 50° and 60° was higher toward the end of the experiment than in the earlier stages. This probably means that the relative humidity of Room III was diminished at this time, bringing it down from a moister state to approximately the same humidity as the 50° room. If this was so, this would account for the lessened development of mold at 50° as mold is very sensitive to hygrometric conditions.

DISCUSSION OF RESULTS.

As there are several factors which affect the rate of shrinkage which the cheese suffers in curing, it will be desirable to discuss the data collected under several heads. The conditions of the experiment were such as to temperature that an especially favorable opportunity was had for the study of the influence which this factor exerts on the cheese. It is of course necessary in a study of this sort to have the cheese uniform in size. The moisture content of the cheese cannot be made alike, but we have grouped in this study the cheese of the same type together, i. e., firm cheddars suitable for export or softer moister cheese intended for home trade.

A. INFLUENCE OF TEMPERATURE ON SHRINKAGE.

To study the rate of loss of cheddar cheese when kept at different temperatures, 129 flats were selected from nine lots of cheese made by six makers. These were exposed at three different temperatures which averaged as follows: 36.8°, 46.9°, and 58.5° F. In each of the following tables is given the number of cheese which were subjected to stated weighing. It will be observed that much more data were collected on the lower temperatures than on the 60° lot. This was regarded necessary as up to this time we have no published data on cheese cured at so low a temperature. The following tables give the actual loss in ounces of each lot of cheese together with the percentage loss for each period observed.

In arranging these tables the lots of cheese that were similar in type are placed together. This fact gives much more weight to these figures than those secured on the smaller lots.

For purposes of convenience the different lots of cheese are divided into three types, depending upon their character.

I. Firm bodied cheese (export type) made by Johnston, Noyes and Kasper of Wisconsin.

II. Sweet curd type as represented by the Iowa and Illinois makes.

III. A very moist, soft type suitable for home trade (Michigan).

TABLE 4.—*Shrinkage of firm typical cheddar cheese (Type I), cured at different temperatures.*

LOT 1.—Thos. Johnston, Boaz, Richland Co., Wisconsin.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
10	.....	.....	.....	.....	17	1.26
17	.....	.....	31	1.16	28	1.86
21	17	.365	.....	.....	.....	.....
26	.....	.....	50	1.88	.....	.....
51	37	.796	68	2.55	44	2.83
88	51	1 09	92	3.45	58	3.73
112	54	1.16	100	3.76	65	4.19
160	58	1.18	123	4.55	96	6.13
Weights of cheese when received	299 lbs. 6 ozs.		166 lbs. 4 ozs.		97 lbs. 1 oz.	
Number of cheese weighed	9		5		3	

LOT 2.—H. J. Noyes, Muscoda, Grant Co., Wisconsin.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent	Ozs.	Per cent.
10	.....	.....	.....	.....	14	.912
16	.....	.....	16	1 07	26	1.69
19	17	.374	.....	.....	.....	.....
24	.....	.....	28	1.87	.....	.....
50	35	.77	39	2.61	41	2.67
86	44	.994	63	4.22	49	3.13
110	44	.994	71	4.75	56	3 65
158	50	1 12	82	5.49	78	5.09
Weights of cheese when received	279 lbs. 12 ozs.		93 lbs. 5 ozs.		95 lbs. 14 ozs.	
Number of cheese weighed.	9		3		3	

LOT 3.—P. H. Kasper, Nicholson, Waupaca, Co., Wisconsin.

CURING PERIOD Days)	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
10	18	.383	13	.845	11	.716
20	.....	.....	25	1.62	22	1.43
26	34	.724	.....	.....	.....	.....
37	.....	.....	34	2 21	.....	.....
41	.....	.....	.....	.....	38	2.47
74	40	.852	50	3 25	.....	.....
87	.....	.....	.....	.....	56	3.64
97	45	.951	52	3 38	.....	.....
100	.....	.....	.....	.....	60	3 90
145	.....	.....	68	4.42	78	5.07
163	70	1 46	78	5 06	84	5.46
Weight of cheese when received	293 lbs. 8 ozs.		96 lbs 2 ozs.		96 lbs. 1 oz.	
Number of cheese weighed.	9		3		3	

As these three makes of cheese agree quite closely in type, a composite diagram made from the data collected will indicate more nearly the average results which may be expected than where they are considered separately. The actual losses observed in the three foregoing lots of Wisconsin cheese were first charted individually and from these an average curve constructed which is represented in Fig. 4. In this and following figures, the losses are only shown for a period of ninety days so that the figures would be on tne same scale.

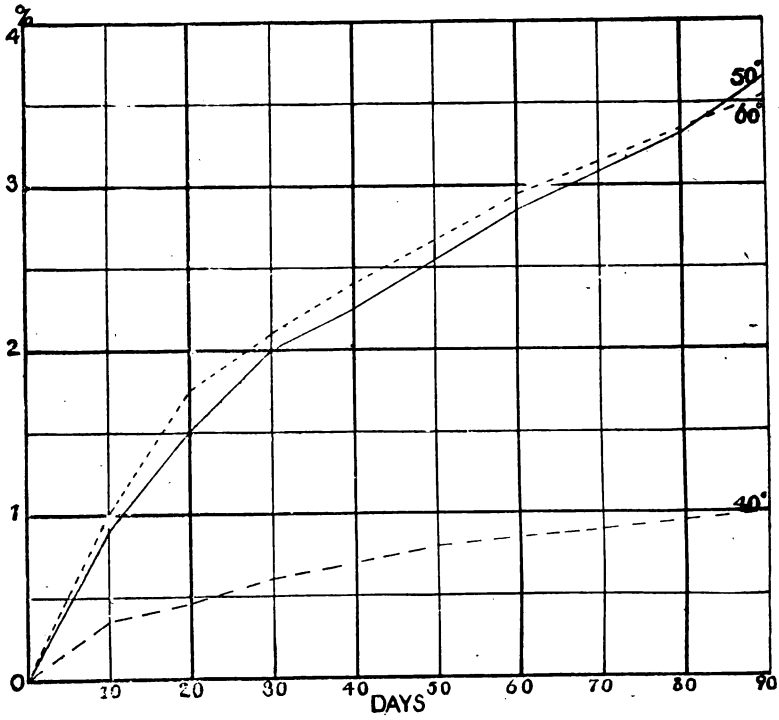

FIG. 4.—Rate of loss of typical cheddar type of cheese cured at different temperatures (40°—60° F.).

TABLE 5.—*Shrinkage of sweet curd cheese (Type II), cured at different temperatures.*

LOT 1.—E. G. Hodges, Union, Iowa.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
7	35	.774	23	.933	12	.852
17					22	1.56
20			35	1.42		
34	51	1.13			32	2.27
37			63	2.55		
71	55	1.21			61	4.33
74			76	3.07		
94	69	1.59				
97			86	3.47	66	4.68
145			103	4.16	78	5.54
163	85	1.88				
Weight of cheese when received	282 lbs. 7 ozs.		154 lbs. 7 ozs.		88 lbs. 1 oz.	
Number of cheese weighed	9		5		3	

LOT 2.—J. B. Gilbert & Co., Sterling, Ill.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
10	22	.583	26	1.11	15	1.08
20			42	1.80	26	1.88
26	34	.821				
37			58	2.41	40	2.89
74	50	1.21	83	3.56	56	4.13
97	62	1.50	92	3.94		
100					63	4.56
145			110	4.71	73	5.29
163	74	1.79				
Weight of cheese when received	258 lbs.		145 lbs. 13 ozs.		86 lbs. 4 ozs.	
Number of cheese weighed	9		5		3	

A composite curve of this type of cheese was made in a similar manner to that noted in Type 1 and is represented in Fig. 5.

In Figure 5 is reproduced in pictorial form the data which is given in Table 5. This curve is made by charting the above data, and from these curves so constructed, the curve as given is produced. It must be remembered that in this type of cheese there is more difference to be noted in the different lots than obtains in those represented by Type I as would be expected where cheese was made in different sections of the country.

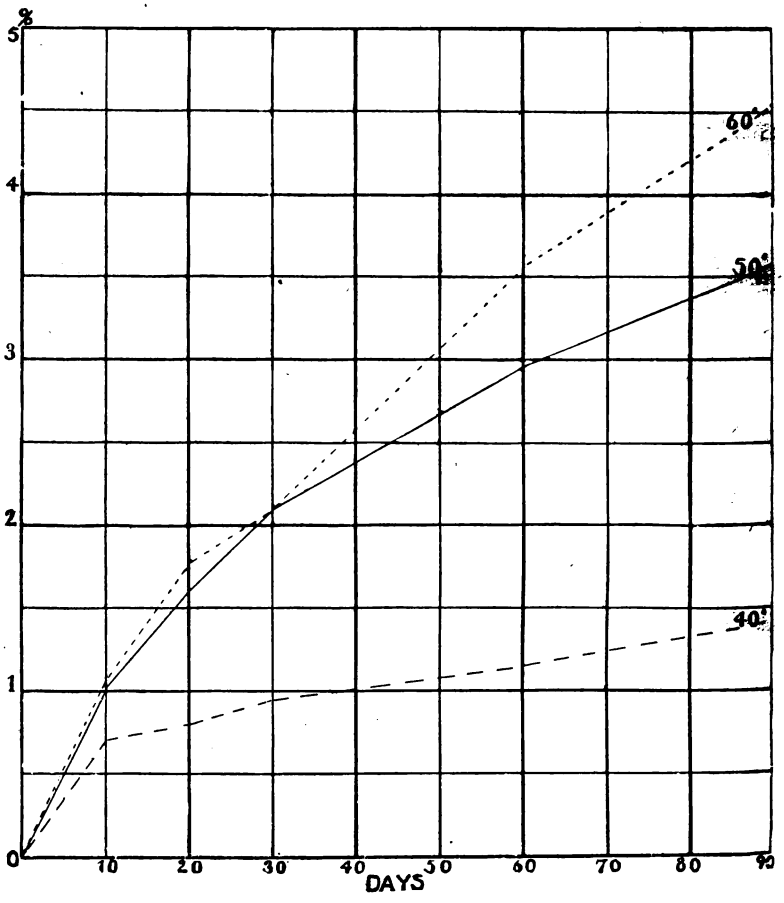

FIG. 5.--Rate of loss of sweet curd cheese cured at different temperatures (40°—60° F.).

TABLE 6.—*Shrinkage of soft, moist home-trade cheese (Type III), cured at different temperatures.*

LOT 1.—A. H. Barber & Co., Merrill, Mich.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
10	6	.30	6	1.15	5	1.05
20			10	1.92	7	1.47
26	10	.50				
37			12	2.30		
41					10	2.10
74	14	.70	16	3.07	15	3.15
100	20	1.00	18	3.46	19	3.99
145			21	4.38	28	5.88
Weights of cheese when received	125 lbs. 6 ozs.		32 lbs. 8 ozs.		29 lbs. 12 ozs.	
Number of cheese weighed.	4		1		1	

LOT 2.—A. H. Barber & Co., Merrill, Mich.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
4	2	.10				
10			4	.837	4	.84
20			8	1.67	7	1.47
26	13	.65				
37			11	2.30		
41					10	2.10
74	17	.85	14	2.92	16	3 36
100	28	1.40	18	3.76	20	4.20
145			21	4.38	30	6.30
Weights of cheese when received	121 lbs. 11 ozs.		29 lbs. 14 ozs.		29 lbs. 12 ozs.	
Number of cheese weighed	4		1		1	

LOT 3.—A. H. Barber & Co., Merrill, Mich.

CURING PERIOD. (Days.)	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
10	42	.538	32	.88	17	.814
20	.....	.....	76	2.08	28	1.34
37	73	.935	102	2.79	44	2.10
74	82	1.05	124	3 39	68	3.25
100	95	1.21	133	3.67	73	3.49
Weight of cheese when received	487 lbs. 14 ozs.		228 lbs.		130 lbs. 7 ozs.	
Number of cheese weighed	15		7		4	

LOT 4.—A. H. Barber & Co., Merrill, Michigan.

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent.	Ozs.	Per cent.
7	23	.676	9	.928	6	1.24
17	.....	.....	.....	.....	11	2.28
20	.....	.....	17	1.75	.....	.....
34	39	1.14	23	2.37	18	3.73
71	47	1.37	28	2.88	29	6.02
97	55	1.62	38	3.92	32	6 64
145	.....	.....	.....	.....	39	8.09
Weight of cheese when received	219 lbs. 7 ozs.		60 lbs. 9 ozs.		30 lbs 9 ozs.	
Number of cheese weighed.	7		2		1	

In the four preceding lots of cheese considerable difference in rate of loss will be noticed. This is explained when it is considered that these lots were exposed during transit period to higher temperatures for varying periods of time as follows: Lot 1, 17 days, lot 2, 14, lot 3, 12 and lot 4, 7 days.

Fig. 6 shows a composite curve of the Michigan cheese, which was constructed in a similar manner to Figs. 4 and 5.

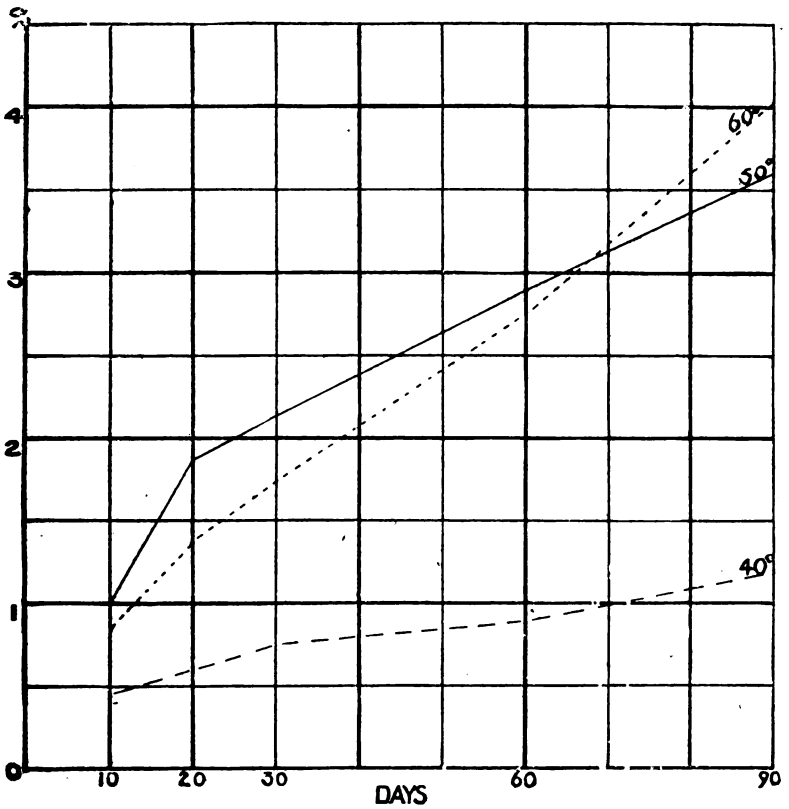

FIG. 6.—Rate of loss of soft, quick-curing cheese cured at different temperatures (40°—60° F.).

GENERAL SUMMARY OF LOSSES AT DIFFERENT TEMPERATURES.

In Figs. 4, 5 and 6 the average curves showing losses of the different types of cheddar cheese are shown. Frequently the cheesemaker wishes to know what these losses would be for stated intervals at different temperatures. With the data at our command, it is impossible to answer definitely this question, because of the varying conditions which surrounded the cheese during the transit period, but in Table 7 the losses which occurred after the cheese were installed in the respective curing rooms are presented for consideration. In this table the average losses for 10 days or mulples thereof are given. In constructing this table the data for each lot of cheese were first charted. From the curves so obtained the losses of each lot for the periods of 10, 20, 30, 60 and 90 days were taken from the above charts by observation. An average of these losses for each type of cheese is given in the following table.

TABLE 7.—*Losses at different periods in cheese cured at different temperatures.*

	Type I. (Typical cheddar.)			Type II. (Sweet curd.)			Type III. (Soft.)		
No. cheese tested.....	27	11	9	9	5	5	30	11	7
	40°	50°	60°	40°	50°	60°	40°	50°	60°
Days.	Per ct.	Per ct	Per ct.	Per ct.	Per ct.	Per ct	Per ct	Per ct.	Per ct.
10.....	.38	.92	.96	.69	1.02	1.05	.49	.92	.85
20.....	.44	1.48	1.74	.82	1.60	1 77	.64	1.89	1.39
30.....	.58	2.00	2 05	.96	2.10	2.10	.84	2.35	1.75
60.....	.83	2.87	2.93	1.15	2.97	3.57	.98	2 98	2.77
90.....	1.00	3.64	3.57	1.42	3.60	4.55	1.21	3.44	4.02

As the number of cheese of the different types cured at the various temperatures were not the same, the percentage losses given in the above table for the varying periods noted are therefore not entitled to equal weight. The smallest number of cheese were those exposed at 60° while nearly 60% of the entire lot were kept at 40°. This gives much greater weight to the figures presented in the 40° series.

In the table it will be observed that there are some apparent discrepancies, especially in the case of the 50° and 60° lots of Type III. These discrepancies are undoubtedly explained by the fact that this type of cheese which was the moistest of the whole lot in the beginning lost more during the longer transit period, and hence the evaporation was less than in other types after being placed in cold storage.

GENERAL DISCUSSION OF EFFECT OF TEMPERATURE.

1. The losses sustained by the different lots were very much less at 40° than at either of the other two temperatures. For a ninety day period, the losses of the 40° cheese ranged from 1-1.4%, while the 50° and 60° product shrunk from 3.4–4.5% for the same time. In other words by the use of the lower temperature for curing, practically two-thirds of the losses which occurred at the temperatures of 50° and 60° were prevented. If these results are compared with what occurs under ordinary factory conditions, the loss at these low temperatures for a period of ninety days (the minimum curing period) will not be more than one-fourth of that which obtains under average factory conditions when the cheese are held for a period of about twenty days. The saving for any such factory making 500 pounds of cheese daily would amount to at least 15 pounds (or $1.50) per day as an

average for the season, or considerably more for cheese made in hot weather. This saving in itself would go far toward meeting the extra expense of lower temperature curing, even if the product was no better than that cured at higher temperatures.

2. The difference between the cheese cured at 50° and 60° is not as marked as between 50° and 40°. It is quite probable, as before mentioned, that the 50° room was somewhat drier than the 60° (as shown by the lessened mold growth); and hence, the rate of loss was abnormally increased in this room. This would tend to bring the two curves nearer together.

3. If the firm Wisconsin type is compared with the softer varieties as shown in Type II and III, it appears that the losses are considerably less, especially at the higher temperatures, although this difference is not so observable at the 40°.

4. The above data presented show a marked saving in losses where the cheese were cold-cured, but in these experiments it must be remembered that they were subjected to higher temperatures during transit, and hence dried out somewhat more than they would have done if they had been put in storage as soon as they were removed from the press. Also, these cheese were box-cured, and therefore under conditions which prevented rapid evaporation. Under these conditions, the losses would have been greater than represented here, and the difference in rate of loss between the different lots wider than reported above. This would still further increase the saving.

B. INFLUENCE OF SIZE AND FORM OF CHEESE ON SHRINKAGE.

In order to study the influence of size of cheese on shrinkage during curing, lots of two different sizes were purchased from the same source. These two sizes were the customary Daisy type 13 inches in diameter and 3½ inches high, weighing about 20 lbs. apiece and the newer type of print cheese put up in 10 lb. blocks (10x10x2⅝ inches high). These cheese were of the usual Wisconsin cheddar type although a little firmer than the Wisconsin flats used in these experiments. On account of this difference in type it is impossible to compare these cheese directly with the larger thirty pound size.

In the following tables are presented the actual and percentage losses which were noted in two lots of cheese (daisies and prints) which were purchased from the La Crosse Cheese and Butter Co., of La Crosse, Wis.

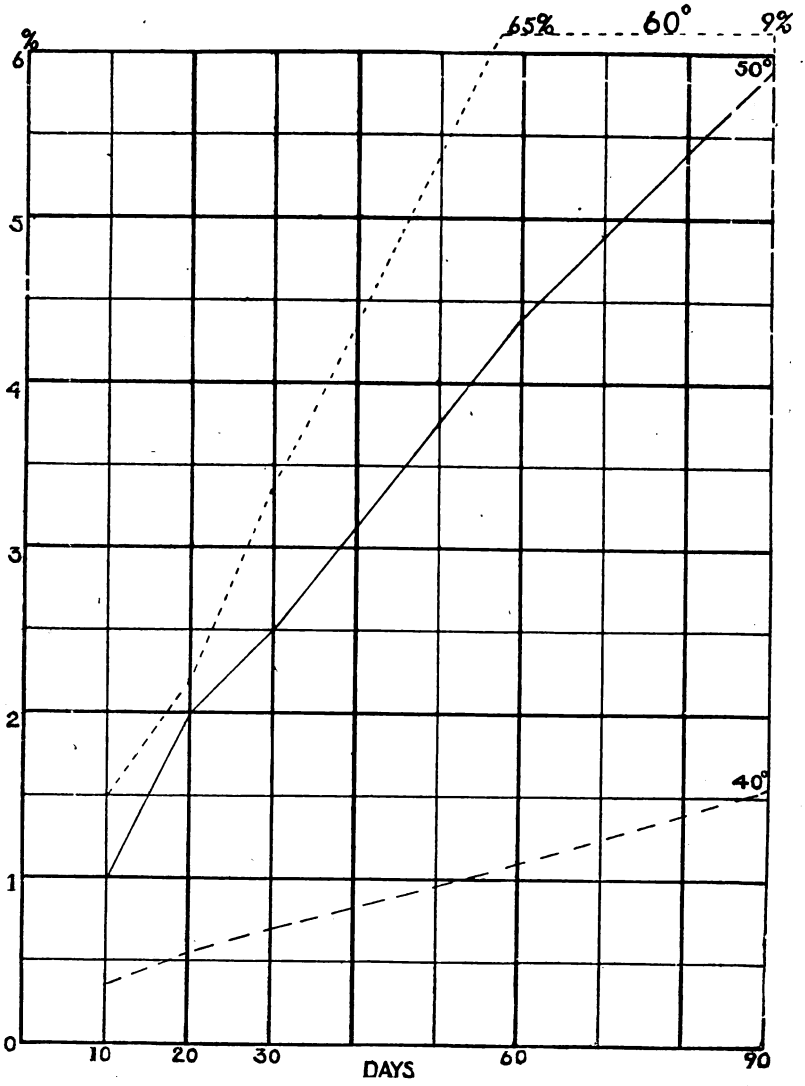

FIG. 7.—Rate of loss of 10 lb. print cheese cured at different temperatures.

TABLE 8. – *Shrinkage of different sized cheese cured at different temperatures.*

LOT 1.—Prints (10 pounds).

CURING PERIOD (Days.)	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F		50° F.		60° F.	
	Ozs.	Per cent.	Ozs.	Per cent	Ozs.	Per cent.
7	.....	.....	1	.62	2	1.23
10	3	.371	.....	.....	.....	.....
16	.....	.....	3	1.82	.....	.....
24	.....	.....	.....	.....	4	2.46
41	7	.835	5	3.1	8	4.92
78	11	1 35	9	5 59	14	8 64
109	14	1 73	10	6 2	16	9 88
167	21	2 61	12	7.45	18	11.11
Weights of cheese when received	50 lbs. 8 ozs.		10 lbs. 1 oz.		10 lbs. 2 ozs.	
Number of cheese weighed.	5		1		1	

LOT 2.—Daisies (20 pounds).

CURING PERIOD (Days).	LOSS IN WEIGHT AT DIFFERENT PERIODS OF STORAGE.					
	40° F.		50° F.		60° F.	
	Ozs.	Per cent	Ozs.	Per cent	Ozs.	Per cent.
7	.....	.....	35	.673	25	1.14
16	38	.627	72	1.38	.....	.....
24	.....	.....	.....	.....	41	1.96
30	66	.916	.....	.....	.....	.....
41	.....	.....	103	1.98	65	3.11
78	90	1 25	128	2 46	89	4.26
100	101	1.40	134	2.58	97	4.64
149	136	1 89	148	2.85	118	5.65
Weights of cheese when received	419 lbs. 15 ozs		325 lbs. 8 ozs.		130 lbs. 9 ozs.	
Number of cheese weighed.	24		17		7	

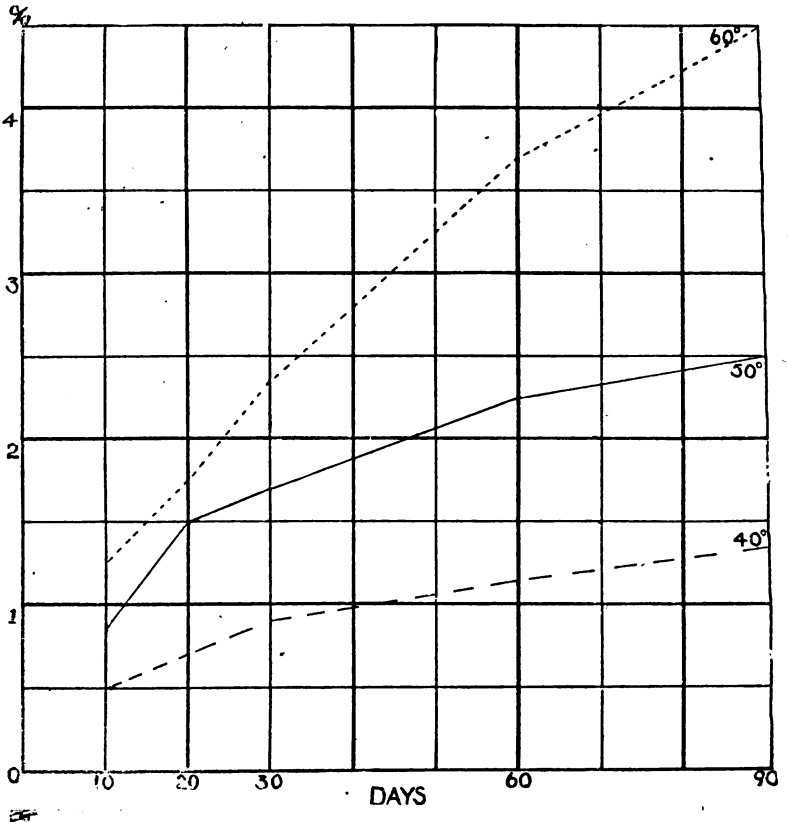

FIG. 8.—Rate of loss of 20 lb. daisies cured at different temperatures.

In Figs. 7 and 8 are represented graphically the losses observed in the smaller sizes of cheese (10 and 20 lb. varieties). It will be noted that these losses at the different temperatures are greater as the temperature increases, and that the differences between the various temperatures are more marked as the relative size of the cheese diminishes.

In order that a comparison may be made between different sizes of cheese at the same temperatures, and the losses at these respective temperatures compared with each other, the foregoing data are rearranged in Figs. 9, 10 and 11 so as to show the rate of losses of the different sizes of cheese at the different temperatures.

From these curves it is evident that at 40° (Fig. 9) the loss was practically the same in both sizes of the cheese. This is probably because the relative humidity at this temperature was practically 100%, and, therefore, in a saturated atmosphere the rate of evaporation would be reduced to a minimum, regardless of the size of the cheese.

It must be remembered that the entire loss in weight during the curing of cheese is not due to evaporation. A cheese in curing is constantly breathing out carbon dioxide the same as any living organism, due to the development of microörganisms (bacterial growth within the cheese as well as molds on surface). Aside from these biological factors, it has recently been shown by Van Slyke and Hart[1] that profound proteolytic decompositions also give rise to an appreciable amount of CO_2. With cheese at 60° F. in which external mold growth was suppressed, they found a loss of approximately one-fourth per cent. in ninety days. In our cold-cured cheese, copious mold development occurred, and hence the losses of carbon from the cheese due to this growth would be considerably greater than if no such growth occurred. With the nearly uniform rate of shrinkage shown in these cold-cured cheese, (Fig. 9), regardless of size, it is quite problematical whether this loss in weight may not be chiefly due to the operation of the foregoing factors. If this is so, we may consider such losses as absolutely unavoidable under normal conditions, for the action of microörganisms which cannot be suppressed will inevitably result in the production of some volatile products.

At the temperatures of 50° and 60° where the relative humidity was below saturation, the factor of evaporation is apparent and is inversely related to the size of the cheese. From a practical point of view, it is worth noting that the losses in both sizes of cheese cured at 60° are approximately fifty per cent. more than they are in the cheese ripened at 50° F.

C. INFLUENCE OF PARAFFINING CHEESE ON SHRINKAGE DURING CURING.

Within the last few years the custom of coating the cheese with an impervious layer has been suggested, mainly for the purpose of preventing the development of mold. For this purpose paraffin has been found to be the most suitable agent. The application of such a layer to the cheese not only prevents the growth of mold spores, by excluding the air, but materially retards the rate at which the cheese loses its moisture. Paraffined cheese then dry out much more slowly than the untreated product, and the application of this method is of particular service in the handling of the smaller types of cheese which have a relatively larger superficial area exposed to the air.

[1] Bul. No. 231, N. Y. Agricultural Expt. Station, p. 36.

To study the effect of this method of treatment at different temperatures, a number of the smaller sizes of cheese (daisies and 10 lb. prints) were taken from the same make and part of them covered with paraffin. These were divided into three lots and placed in the different curing rooms where they were held for a period of several months.

In table 9 are recorded the data as to the percentage loss in both the paraffined and unparaffined (control) lots.

TABLE 9.—*Shrinkage in paraffined and unparaffined 10 lb. prints and 20 lb. daisies cured at different temperatures.*

Ten pound print cheese.

Curing Period (Days).	Percentage Loss in Weight for Different Periods of Storage.					
	40° F.		50° F.		60° F.	
	Unpar.	Paraf.	Unpar.	Paraf.	Unpar.	Paraf.
7			.62	.24	1.23	.603
10	.37	.495				
16			1.82	.84		
24					2.46	1.8
41	.865	1.06	3.1	1.45	4.92	2.77
77	1.35	1.48	5 6	2.9	8.64	3 01
100	1.73	1.88	6.2	3.5	9.88	3.62
Number cheese tested	5	17	1	5	1	5

Twenty pound daisies.

Curing Period (Days).	Percentage Loss in Weight for Different Periods of Storage.					
	40° F.		50° F.		60° F.	
	Unpar.	Paraf.	Unpar.	Paraf.	Unpar.	Paraf.
7			.673		1 14	.317
14	.527	.466				
16			1.38	.609		
24					1.96	1.58
30	.916	1 10				
41			1.98	.914	3.11	2.54
77	1.25	1.71	2.46	1.65	4.26	3.17
100	1.40		2.58	2 0	4.64	3.49
Number cheese tested	24	4	17	1	7	1

In order to permit of a more ready comparison of the above data, the same are presented in graphical form in Figs. 12 and 13. At 60° F., the application of paraffin resulted in reducing the losses to less than one-half of that which occurred in the unparaffined lot. This difference is naturally more observable in the smaller sized cheese (prints).

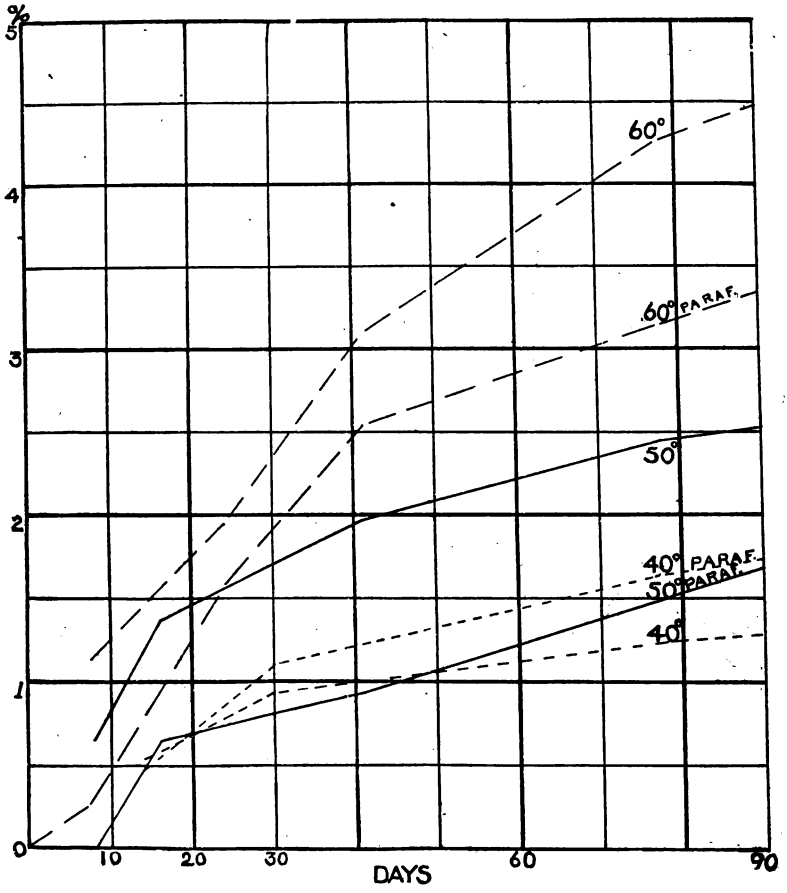

FIG. 12.—Influence of paraffining 20 lb. daisy cheese on shrinkage in weight.

At 50° this ratio was slightly diminished but was in the same general direction.

At 40°, a peculiarity was observable in both the print and the daisy size, in that the paraffined cheese lost a trifle more than the unparaffined lot. We do not think this apparent paradox can be explained on the basis of errors in weighing as there were five unparaffined and

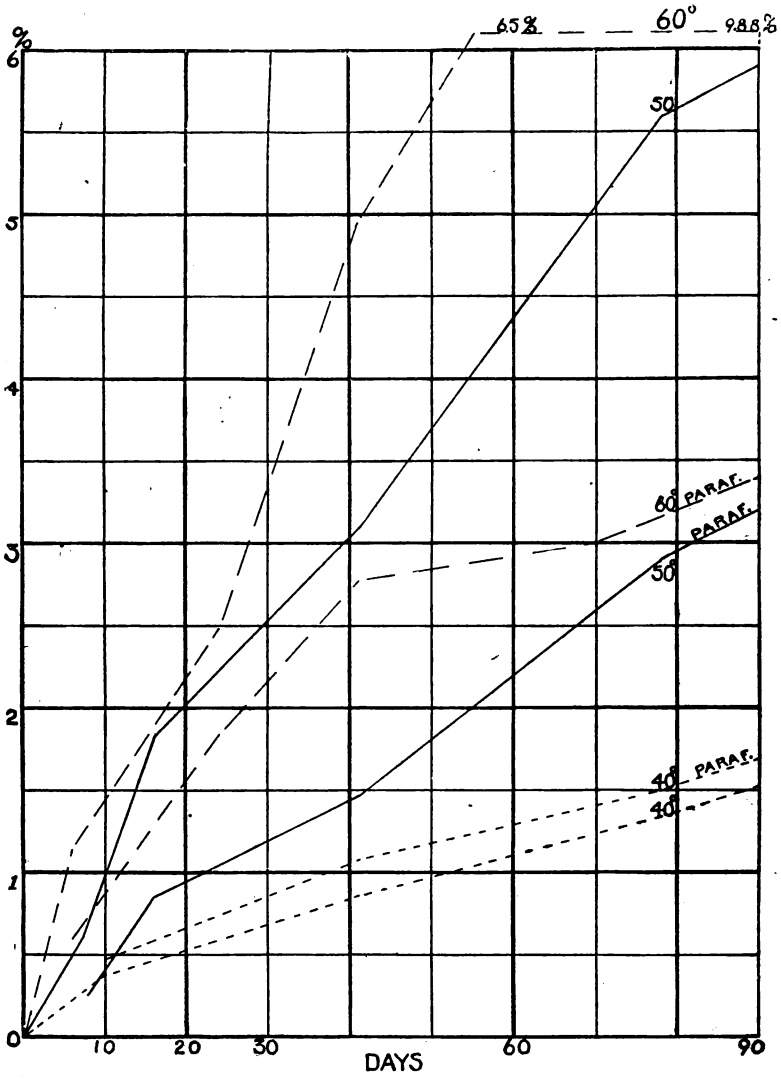

FIG. 13.—Influence of paraffining 10 lb. print cheese on shrinkage in weight.

seventeen paraffined print cheese, and twenty-four unparaffined and four paraffined 20 lb. cheese in these experiments. Also the weighing of these cheese was made at frequent intervals and in every case the same relation was observed.[1]

[1] A new series of experiments with paraffined and unparaffined cheese has since been made in which the losses in the unparaffined were found to be slightly more than the paraffined, even at 40°.

In the paraffined cheese at 40° the losses were reduced practically to a minimum as was also the case with those unparaffined at this temperature. As evaporation would certainly be lessened in the paraffined lot, the uniformity of loss between these and the unparaffined, still further substantiates the view advanced earlier that these losses are not so much due to shrinkage from evaporation, as they are to metabolic activities of organisms, and possibly chemical transformations within the cheese.

CONCLUSION.

1. *Influence of temperature.* When cheese are cold-cured, the losses due to shrinkage in weight are greatly reduced over what occurs under ordinary factory conditions. In these experiments the actual temperatures employed were on the average as follows: 36.8°, 46.9° and 58.5° F. Cheese cured at the lowest temperature decreased in weight in ninety days from 1–1.4%, while that cured at the intermediate and higher temperatures lost fully three times as much. This amount would be still further increased if comparison was made between the results of cold curing and existing factory conditions. Under prevailing factory practice cheese are sold at a much earlier date than is advisable with cold cured goods, but the loss under present conditions, for even as brief a curing period as twenty days, is fully four times as great as has occurred in these experiments in a ninety day period (the minimum curing period recommended) under cold-curing conditions (40 deg. F.). This saving in a factory making 500 pounds of cheese daily would average not less than fifteen pounds of cheese per day for the entire season, or considerably more than this if only summer-made cheese were cold-cured.

2. *Influence of type of cheese.* In these experiments, different types of cheese were used, ranging from the firm, typical cheddar to the soft, moist, quick-curing cheese made for the home-trade. The losses with the firmer type were considerably reduced in comparison with the others, but the conditions to which the softer type of cheese were subjected were not as favorable (because of initial delays), and hence, the losses with these types cannot be relied upon with such definiteness. As they were exceedingly moist cheese the total losses from the press were undoubtedly greater than here reported.

3. *Influence of size of cheese.* The size of package exerts a marked effect on the rate of loss. At ordinary temperatures, the smaller the cheese, the more rapidly it dries out. This difference in loss diminishes as the temperature is lowered and in our experiments at approximately 40 deg. F. was practically independent of the size. This condition, however, was undoubtedly attributable to the relative humidity of the curing room, which at this low temperature was 100%.

4. *Influence of paraffin.* By coating the cheese with melted paraffin the losses at 60 deg. were reduced more than one-half. At the intermediate temperature the saving was somewhat less and at the lowest temperature the difference was practically negligable.

5. As some loss occurs even in a saturated atmosphere where evaporation is presumed not to take place, it implies that the shrinkage in weight of cheese under these conditions is not wholly due to desiccation, but is affected by the production of volatile products that are formed by processes inherent to the curing of cheese.