The Effect of Different Percentages of Butterfat on the Physical Properties of Ice Cream

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The Effect of Different Percentages of Butterfat on the Physical Properties of Ice Cream

D. H. Nelson and Wm. H. E. Reid

Abstract.—A study of the effect of different percentages of butterfat on the physical properties of ice cream showed that with each additional increment of 2 per cent of fat to the mixture the specific gravity was uniformly decreased and the viscosity was increased. The overrun increased up to 10 per cent of fat. Above 10 per cent of fat, the overrun decreased although the viscosity continued to increase. No direct relation was found between the fat content of the different mixtures and the hardness of the ice cream. An increase in the fat retarded the melting of the ice cream by increasing the resistance offered to summer temperatures. Variation in the overrun had a decided effect on the stability of the finished product.

Holdaway and Reynolds¹, in making determinations of the effect of binders upon the melting and hardness of ice cream, found that the hardness of different kinds of eight and nineteen per cent creams ranked in the following order from hard to soft: first, cream containing one ounce of gelatin per gallon of cream; second, four ounces of gelatin; third, corn starch; fourth, gum tragacanth; fifth, control cream. The eight per cent creams ranked in the same order in melting resistance. The power to resist melting increased as the percentage of fat was increased.

DESCRIPTION OF APPARATUS USED IN EXPERIMENTAL WORK

The Westphal Balance was used for determining the specific gravity of the various ice cream mixtures. All mixtures were tempered to 15° C.

A "viscosity determinator" was used to study the heaviness or lightness of the ice cream mixture. The determinator was a glass funnel tapered to a $\frac{3}{16}$ inch outlet below which was placed a 500-cubic centimeter graduate. In making all determinations equal pressure was applied by maintaining a constant depth of mixture. A constant temperature of 4.5° C. was used in making all determinations.

The freezer used by Reid² in studying the effect of sugar on the physical properties of ice cream was used in this investigation. This freezer furnished a convenient means of obtaining duplicate freezings.

The overrun was determined by a difference in weight. A given volume of the mixture was weighed before it was placed in the freezer and the same volume of frozen cream was weighed when the freezing of the mixture was complete. From the difference of these weights, the overrun or swell was calculated.

The "hardness determinator" used was the same as used by Holdaway and Reynolds and later by Reid. This piece of equipment made it possible to measure the degree of hardness of ice cream with such accuracy that the tests made at various times would be comparable.

**METHOD OF PROCEDURE**

The object of this investigation was to determine the effect of different percentages of butterfat on the physical properties of ice cream. The mixtures used in each freezing were the same except for the fat content. All factors which enter into the manufacturing process such as type of freezer used, temperature of brine, speed of dasher, and amount of mixture used in each freezing were maintained at a constant.

Each mixture was standardized for fat and total solids content, cooled to a temperature of 15° C., the specific gravity determined, then further cooled to a temperature of 4.5° C. and the viscosity determined.

Two freezings were frozen at one time. When the maximum overrun had been reached and the mixture frozen to a desirable consistency, it was removed from the freezer, the overrun determined, and three bricks were hardened for one day after which the various tests were made.

The fat content of the mixtures used in the investigation varied from 4 per cent to 20 per cent increasing the fat 2 per cent for each new mixture. One mixture containing 25 per cent fat was frozen out as a check upon ice cream with an extremely high fat content.

**RESULTS OF THE INVESTIGATIONS**

**The Relation of the Butterfat Content to the Specific Gravity of Ice Cream Mixtures.**—When the mixture had aged four hours at a temperature of 10° F. it was warmed to 15° C. and the specific gravity determined. The results are presented in Tables 1 and 2.

**The Relation of Different Percentages of Butterfat to the Viscosity of Ice Cream Mixtures.**—To determine the effect of additional increments of butterfat on the viscosity of the ice cream mixture, each mixture was cooled to 4.5° C. and run through the "viscosity determinator" and the viscosity expressed in time.

Table 1 shows a gradual increase in the viscosity as the fat content is increased. This indicates that the butterfat content of the ice cream
mixture bears a definite relation to the viscosity of the mixture. Each additional increment of 2 per cent fat increases the absolute viscosity 5½ seconds. However, from the 20 per cent mixture to the 25 per cent mixture, the viscosity increases more rapidly. This is undoubtedly due to the very high fat content.

**Table 1.—Showing the Effect of Different Percentages of Butterfat on the Viscosity and Acidity of the Ice Cream Mixture**

<table>
<thead>
<tr>
<th>Fat content</th>
<th>Specific gravity at 15° C.</th>
<th>Age of mixture (Hrs.)</th>
<th>Per cent mixture</th>
<th>Temperature of mixture centigrade</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>1.104</td>
<td>4</td>
<td>0.25</td>
<td>4.5°</td>
<td>1.24</td>
</tr>
<tr>
<td>6%</td>
<td>1.102</td>
<td>4</td>
<td>0.25</td>
<td>4.5°</td>
<td>1.29</td>
</tr>
<tr>
<td>8%</td>
<td>1.098</td>
<td>4</td>
<td>0.23</td>
<td>4.5°</td>
<td>1.33</td>
</tr>
<tr>
<td>10%</td>
<td>1.093</td>
<td>4</td>
<td>0.25</td>
<td>4.5°</td>
<td>1.40</td>
</tr>
<tr>
<td>12%</td>
<td>1.088</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>1.47</td>
</tr>
<tr>
<td>14%</td>
<td>1.085</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>1.54</td>
</tr>
<tr>
<td>16%</td>
<td>1.081</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>2.02</td>
</tr>
<tr>
<td>18%</td>
<td>1.076</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>2.15</td>
</tr>
<tr>
<td>20%</td>
<td>1.071</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>2.30</td>
</tr>
<tr>
<td>25%</td>
<td>1.066</td>
<td>4</td>
<td>0.24</td>
<td>4.5°</td>
<td>3.50</td>
</tr>
</tbody>
</table>

The Effect of Different Percentages of Butterfat on the Resulting Overrun.—The objective was to obtain the greatest possible overrun on each freezing and at the same time to maintain the same consistency in all the batches when drawn from the freezer. Considerable difficulty was encountered and it was not always possible to get the maximum overrun within a range of one per cent.

As soon as each batch was drawn, the overrun was determined and recorded, giving an opportunity to compare the results obtained in different freezings of the same mixture.

A study of Table 2 shows that an increase in the fat content of the

**Table 2.—Showing the Effect of Different Percentages of Butterfat on the Specific Gravity and the Overrun of the Ice Cream Mixture**

<table>
<thead>
<tr>
<th>Fat content</th>
<th>Specific gravity at 15° C.</th>
<th>Weight of mixture</th>
<th>Weight of ice cream</th>
<th>Per cent overrun</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>1.104</td>
<td>1432</td>
<td>755</td>
<td>89.7</td>
</tr>
<tr>
<td>6%</td>
<td>1.102</td>
<td>1437</td>
<td>757</td>
<td>89.8</td>
</tr>
<tr>
<td>8%</td>
<td>1.098</td>
<td>1440</td>
<td>755</td>
<td>90.7</td>
</tr>
<tr>
<td>10%</td>
<td>1.093</td>
<td>1436</td>
<td>748</td>
<td>92.0</td>
</tr>
<tr>
<td>12%</td>
<td>1.088</td>
<td>1434</td>
<td>749</td>
<td>91.5</td>
</tr>
<tr>
<td>14%</td>
<td>1.085</td>
<td>1428</td>
<td>747</td>
<td>91.2</td>
</tr>
<tr>
<td>16%</td>
<td>1.081</td>
<td>1422</td>
<td>744</td>
<td>91.1</td>
</tr>
<tr>
<td>18%</td>
<td>1.076</td>
<td>1414</td>
<td>741</td>
<td>90.8</td>
</tr>
<tr>
<td>20%</td>
<td>1.071</td>
<td>1387</td>
<td>735</td>
<td>88.7</td>
</tr>
<tr>
<td>25%</td>
<td>1.066</td>
<td>1372</td>
<td>740</td>
<td>85.4</td>
</tr>
</tbody>
</table>
mixture reduces its specific gravity. This was expected since the specific gravity of butterfat is less than that of the water which it replaces.

The overrun has a total variation of only 6.6 per cent. This variation occurs when freezing the mixtures with fat contents ranging from 10 per cent to 25 per cent. Considering the overrun of the mixture with butterfat tests from 4 per cent to 10 per cent it will be noted that an increase of 2.3 per cent overrun was obtained with an increase of 6 per cent fat. The maximum overrun was obtained when freezing the 10 per cent mixture indicating that less than 10 per cent fat will give a lower overrun as is also true of mixtures containing a fat content in excess of 10 per cent fat. A variation of each one per cent in fat content from 10 per cent decreases the overrun slightly more than 0.4 per cent.

It is known that the viscosity of the mixture has a marked influence on the percentage of overrun that can be obtained, that is, when the mixture is aged to increase its viscosity, a greater overrun is obtainable. The mixtures frozen in this particular part of the investigation were not aged. The increased viscosity is due to increasing the fat content which does not increase the overrun except as stated in the freezing of 4, 6, 8, and 10 per cent mixtures. As the fat content increases above 10 per cent the effect of the additional fat appears to overcome the effect of the increased viscosity resulting in a lower overrun. When the fat content of a mixture is 10 per cent or less, the effect of the viscosity of the mixture is greater than the effect of the fat in determining the overrun.

The Effect of Different Percentages of Butterfat on the Hardness of Ice Cream.—In preparing the different creams for this test, it was desirable that each brick of a particular mixture have a uniform temperature. Four bricks of each mixture were hardened for 7½ hours. The hardness of each brick was determined by making six penetrations, two in each end and two in the center, thus giving a check upon the uniformity of the hardness of the cream. Making six penetrations on each brick and using four bricks from each mixture gave a total of 24 determinations for each change in the fat content of the mixture and would eliminate any effect which the overrun might have upon the hardness of the cream.

Table 3 shows a direct relation of the uniform penetration to the temperature which indicates that the temperature of the cream has an appreciable effect upon the hardness. Since there is no uniform variation in the depth of penetration, it is evident the fat content of ice cream has no influence on its hardness. The result of this investigation corroborates the investigation completed at the Virginia Station1 in which it was

shown that fat content had no apparent effect on the hardness of the ice cream.

**Table 3.—Showing the Effect of Different Percentages of Butterfat on the Hardness of Ice Cream**

<table>
<thead>
<tr>
<th>Fat content</th>
<th>Hours tempted</th>
<th>Temp. of ice cream (°C)</th>
<th>Size of needle (mm.)</th>
<th>Penetration in millimeters</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>7 1/2</td>
<td>-10.4</td>
<td>6.35</td>
<td>23.0 24.0 25.0 24.0</td>
</tr>
<tr>
<td>6%</td>
<td>7 1/2</td>
<td>-10.5</td>
<td>6.35</td>
<td>25.0 26.0 26.0 25.7</td>
</tr>
<tr>
<td>8%</td>
<td>7 1/2</td>
<td>-10.0</td>
<td>6.35</td>
<td>25.0 26.0 26.0 25.7</td>
</tr>
<tr>
<td>10%</td>
<td>7 1/2</td>
<td>-10.2</td>
<td>6.35</td>
<td>24.0 25.0 25.0 24.7</td>
</tr>
<tr>
<td>12%</td>
<td>7 1/2</td>
<td>-10.2</td>
<td>6.35</td>
<td>23.5 23.5 23.5 23.5</td>
</tr>
<tr>
<td>14%</td>
<td>7 1/2</td>
<td>-9.7</td>
<td>6.35</td>
<td>26.0 25.0 25.0 25.3</td>
</tr>
<tr>
<td>16%</td>
<td>7 1/2</td>
<td>-10.1</td>
<td>6.35</td>
<td>25.2 24.2 24.0 24.5</td>
</tr>
<tr>
<td>18%</td>
<td>7 1/2</td>
<td>-10.0</td>
<td>6.35</td>
<td>22.5 23.0 23.5 23.4</td>
</tr>
<tr>
<td>20%</td>
<td>7 1/2</td>
<td>-10.3</td>
<td>6.35</td>
<td>23.0 23.7 23.7 23.5</td>
</tr>
<tr>
<td>25%</td>
<td>7 1/2</td>
<td>-9.0</td>
<td>6.35</td>
<td>24.5 26.0 25.7 25.4</td>
</tr>
</tbody>
</table>

Determination of the Time Required for Ice Cream with Different Percentages of Butterfat to Melt Under Summer Temperatures.—The stability of ice cream may be defined as the power or ability to withstand exposure to high temperature and retain a salable form and attractive appearance. This is one of the most important properties of ice cream, since it is the property that determines the length of time required for ice cream to lose its original form when exposed to average summer conditions.

Several factors such as the temperature of the ice cream, the percentage overrun, the use of binders and fillers, and different ingredients

**Table 4.—Stability of Ice Cream when Exposed to Summer Temperatures**

(Temperatures recorded in Centigrade and Weights in grams)

<table>
<thead>
<tr>
<th>Percentage fat</th>
<th>4%</th>
<th>6%</th>
<th>8%</th>
<th>10%</th>
<th>12%</th>
<th>14%</th>
<th>16%</th>
<th>18%</th>
<th>20%</th>
<th>25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of ice cream</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
</tr>
<tr>
<td>Temperature after melting</td>
<td>-10.4</td>
<td>-10.5</td>
<td>-10.0</td>
<td>-10.2</td>
<td>-10.1</td>
<td>-10.6</td>
<td>-10.3</td>
<td>-10.0</td>
<td>-10.3</td>
<td>-9.0</td>
</tr>
<tr>
<td>Orig. weight of brick</td>
<td>525.0</td>
<td>531.0</td>
<td>510.0</td>
<td>502.0</td>
<td>555.75</td>
<td>531.25</td>
<td>570.25</td>
<td>525.75</td>
<td>529.00</td>
<td>528.25</td>
</tr>
<tr>
<td>Loss in weight 1 hr.</td>
<td>326.0</td>
<td>323.0</td>
<td>291.0</td>
<td>259.0</td>
<td>266.75</td>
<td>233.25</td>
<td>203.50</td>
<td>158.50</td>
<td>132.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2 hrs.</td>
<td>490.0</td>
<td>486.0</td>
<td>454.0</td>
<td>416.0</td>
<td>428.75</td>
<td>404.50</td>
<td>372.00</td>
<td>316.00</td>
<td>292.25</td>
<td>61.25</td>
</tr>
<tr>
<td>3 hrs.</td>
<td>515.0</td>
<td>515.0</td>
<td>485.0</td>
<td>462.0</td>
<td>496.00</td>
<td>459.00</td>
<td>466.50</td>
<td>391.00</td>
<td>350.25</td>
<td>211.00</td>
</tr>
<tr>
<td>Loss in percentage 1 hr.</td>
<td>62.1</td>
<td>60.8</td>
<td>57.1</td>
<td>51.6</td>
<td>48.00</td>
<td>43.90</td>
<td>35.70</td>
<td>30.10</td>
<td>25.00</td>
<td>0.19</td>
</tr>
<tr>
<td>2 hrs.</td>
<td>93.3</td>
<td>91.5</td>
<td>89.0</td>
<td>82.9</td>
<td>77.10</td>
<td>76.10</td>
<td>65.20</td>
<td>60.10</td>
<td>55.20</td>
<td>11.50</td>
</tr>
<tr>
<td>3 hrs.</td>
<td>98.1</td>
<td>97.0</td>
<td>95.1</td>
<td>92.0</td>
<td>89.20</td>
<td>86.40</td>
<td>81.80</td>
<td>74.40</td>
<td>66.20</td>
<td>39.90</td>
</tr>
</tbody>
</table>
influence this property, increasing or decreasing the length of time required to melt the cream.

In this investigation the ice cream was exposed to a constant temperature of 30° C. which was assumed to be the average summer temperature at which commercial ice cream is exposed while being consumed.

In securing the data presented in Table 4, four bricks of ice cream containing the same percentage of fat were melted and the results averaged. One brick from each of the four freezings, representing one mixture, was selected for this determination. The original weight of the bricks varied, but it is believed that this variation had little effect on the stability of the ice cream.

The loss in weight represents in each case the total loss in weight during the specified period of time. The loss in percentage is computed on the same basis.

It should be noted that there is a direct relation between the increased fat content and the ability of the ice cream to resist summer temperatures. The 4 per cent creams lost 98.1 per cent of their total weight during three hours melting as compared with ice cream containing 25 per cent butterfat which lost only 39.9 per cent.

A Study of the Appearance of Ice Cream Containing Different Percentages of Butterfat when Exposed to Summer Temperature.—The results of melting ice creams with butterfat contents of 4, 6, and 8 per cent indicate that the bricks had lost their definite form and appeared to be entirely melted at the end of the second hour, although the ice cream continued to soften and run from the form until only a small amount was left. The difference in percentage loss at the end of the third hour represents the difference in the residue left on the form which was due primarily to an increase in the viscosity caused by an increase in the fat content.

As the fat content of the mixture was increased, the cream had a tendency to retain its original form over a longer period of time. The bricks containing the higher percentages of fat, such as those of the 18 and 20 per cent creams, softened with a rise in temperature but retained their original shape while the cream low in fat dripped off as rapidly as melted.

The difference in weight lost at the end of the first hour between the ice cream containing 4 and 6 per cent fat was marked although the appearance of the bricks, in size and shape, was similar. The corners of the bricks had melted and fallen, giving the appearance of an oval covered with a thin layer of honeycombed cream. An exposure of two

(Discussion continued on page 17.)
Fig. 1.—Bricks containing 6 per cent fat before exposure to summer temperature of 30°C.

Fig. 2.—Bricks containing 6 per cent fat after one hour exposure to a summer temperature of 30°C.

Fig. 3.—Bricks containing 6 per cent fat after three hours exposure to a summer temperature of 30°C.
Fig. 4.—Bricks containing 10 per cent fat before exposure to a summer temperature of 30°C.

Fig. 5.—Bricks containing 10 per cent fat after one hour exposure to a summer temperature of 30°C.

Fig. 6.—Bricks containing 10 per cent fat after two hours exposure to a summer temperature of 30°C.
Fig. 7.—Bricks containing 10 per cent fat after three hours exposure to a summer temperature of 30°C.

Fig. 8.—Bricks containing 18 per cent fat before exposure to a summer temperature of 30°C.

Fig. 9.—Bricks containing 18 per cent fat after one hour exposure to a summer temperature of 30°C.
Fig. 10.—Bricks containing 18 per cent fat after two hours exposure to a summer temperature of 30°C.

Fig. 11.—Bricks containing 18 per cent fat after three hours exposure to a summer temperature of 30°C.

Fig. 12.—Bricks containing 25 per cent fat before exposure to a summer temperature of 30°C.
EFFECT OF PERCENTAGE OF BUTTERFAT ON ICE CREAM

Fig. 13.—Bricks containing 25 per cent fat after one hour exposure to a summer temperature of 30°C.

Fig. 14.—Bricks containing 25 per cent fat after two hours exposure to a summer temperature of 30°C.

Fig. 15.—Bricks containing 25 per cent fat after three hours exposure to a summer temperature of 30°C.
Fig. 16.—The relation of the overrun to the stability of the ice cream.
EFFECT OF PERCENTAGE OF BUTTERFAT ON ICE CREAM

Fig. 17. — A close-up view of the texture of 4 per cent ice cream.

Fig. 18. — A close-up view of the texture of 10 per cent ice cream.
Fig. 19.—A close-up view of the texture of 18 per cent ice cream.

Fig. 20.—A close-up view of the texture of 25 per cent ice cream.
hours left the form covered with a coating of syrupy, sticky substance comprised principally of sugar and butterfat. The small percentage of fat present and the correspondingly large amount of water accounts for the heat quickly breaking down the small ice crystals and liberating the air. As soon as the ice cream with low fat content had softened, the air pockets lost their form, due to the absence of sufficient viscosity which would reduce adequate surface tension on the air pocket.

The low percentage of solids weakened the body, making it difficult for the ice cream to retain a definite shape. With an increased fat content, a change in the appearance of the bricks exposed to the summer temperature was observed. The ice cream containing 8 or 10 per cent butterfat has less of the honeycombed appearance after two hours exposure, and at the end of the third hour’s exposure the residue on the paraffined form resembled whipped cream in appearance.

With the 12 per cent ice cream, it was noticed that the cream softened more uniformly, retaining a shape resembling that of the original brick. The melted portion remained intact giving the brick a thick covering of soft cream resembling whipped cream in appearance. The air bubbles in this cream were small, closely arranged, and had a shape which was uniform and easily retained. The honeycombed appearance observed in creams with a lower percentage of fat had practically disappeared, and at the end of the third hour a considerable portion of the residue was left on the form. This residue had the undesirable sickening flavor of whipped butterfat, due to the excess fat content and its temperature. This undesirable taste became more pronounced as the fat content was increased above 12 per cent, but the bricks continued to retain their shape and structure much longer, and the honeycombed appearance entirely disappeared. These differences can be observed by a study of figures 10, 11, 14, and 15.

The ice cream with 20 per cent butterfat content retained 75 per cent of its original weight when exposed one hour. The bricks had sagged, the corners were weakening and breaking away, but the original structure was still retained in fine condition. Exposure of two hours completely softened the bricks and much of the melted portion sloughed off. The structure was still well retained, indicating that the structure of the ice cream is an important factor in the stability test and that an increase in fat content tends to bring about this desirable structure. The exposure of the 20 per cent cream for a period of three hours reduced the original weight 66.2 per cent. The cream had slumped in shape, spreading at the bottom, and a small portion had sloughed off. The flavor of the residue, which was principally fat, was sickening, flat and undesirable due to the absence of sugar which had settled out.
The cream containing 25 per cent fat gave practically no change in weight or appearance during the first hour. At the end of the second hour, the cream had softened to the extent that spreading at the base was apparent. This would suggest that the loss in weight was due to evaporation of moisture as none of the cream had sloughed off. At the end of the third hour, a small portion had broken over the sides and each brick was sagging. The outward appearance of the bricks was of a yellowish tint, while the texture was brittle. The viscosity of the mixture together with the structural shape of the air pockets caused the residue to retain its original structure and resist the extreme temperatures. Figures 13, 14, and 15 clearly indicate the condition of this cream at the end of the first, second, and third hours, respectively.

A study of the data presented in figures 1 to 15 points to three conclusions. (1) There is a direct relation between the fat content of ice cream and its stability or the resistance offered to summer temperatures. Each additional increment of butterfat strengthens the ability of the ice cream to resist summer temperatures. (2) The ability of an ice cream to resist summer temperatures is closely allied to the structure of the frozen cream. (3) The higher the percentage of butterfat in the mixture, the more resistant the structure becomes when exposed to summer temperatures for a given period of time.

The Relation of Different Percentages of Overrun to the Stability of Ice Cream.—To determine the relation of the overrun to the stability of different ice creams, the same apparatus and methods were employed as when determining the relation of fat and stability. Mixtures varying in fat content from 8 to 16 per cent were prepared in duplicate. Eight freezings of each mixture were made. The overruns obtained were such as would give four freezings with a low overrun and four with a high overrun of the same mixture. One brick from each freezing was exposed to summer temperature for three hours and the results recorded.

A study of Table 5 shows that in each set of duplicate freezings, those freezings with the greatest overrun proved the more stable. This indicates that an increase in the percentage overrun will retard the melting of the ice cream.

Close-up Views Showing the Structure and Texture of Ice Creams Containing Different Percentages of Butterfat.—In making a study of the effect of fat on the body, texture, and appearance of the cream it was realized that any description would be inadequate. It is very difficult to describe the body, texture, or appearance of any particular cream and give a definite and clear mental picture of the cream.
For this reason, the preceding description has been mainly a comparison applied in comparing the qualities of ice cream. As a means of conveying a clear mental picture of the difference in the structure and texture of the ice cream, photographs of the broken creams are presented.

The 4 per cent ice creams showed a coarse, open granular texture. The porous condition of the cream and the size of the particles as they project from the broken surface are discernible.

Table 5.—Showing the Effect of the Percentage overrun on the Stability of Ice Cream when Exposed to a Summer Temperature of 30° C.
(Temperatures recorded in Centigrade and Weights in grams)

<table>
<thead>
<tr>
<th>Percentage butterfat</th>
<th>8%</th>
<th>10%</th>
<th>12%</th>
<th>16%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage overrun</td>
<td>83.1</td>
<td>87.6</td>
<td>87.6</td>
<td>81.7</td>
</tr>
<tr>
<td>Temperature of vat</td>
<td>88.5</td>
<td>91.7</td>
<td>91.5</td>
<td>92.7</td>
</tr>
<tr>
<td>Temperature</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
<td>30°</td>
</tr>
<tr>
<td>of ice cream</td>
<td>-9.70°</td>
<td>-10.2°</td>
<td>-10.2°</td>
<td>-9.9°</td>
</tr>
<tr>
<td>Original weight of brick</td>
<td>519</td>
<td>502</td>
<td>521</td>
<td>541</td>
</tr>
<tr>
<td>hr.</td>
<td>510</td>
<td>511</td>
<td>555.75</td>
<td>516</td>
</tr>
<tr>
<td>weight</td>
<td>291</td>
<td>259</td>
<td>291</td>
<td>329</td>
</tr>
<tr>
<td>after</td>
<td>242.5</td>
<td>266.75</td>
<td>178</td>
<td></td>
</tr>
<tr>
<td>after</td>
<td>416</td>
<td>425.5</td>
<td>468</td>
<td></td>
</tr>
<tr>
<td>before melting</td>
<td>420</td>
<td>428.75</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>hurs.</td>
<td>454</td>
<td>487</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>hrs.</td>
<td>485</td>
<td>478</td>
<td>496</td>
<td>420.8</td>
</tr>
<tr>
<td>Loss in weight</td>
<td>69.2</td>
<td>51.6</td>
<td>55.9</td>
<td>60.8</td>
</tr>
<tr>
<td>percentage</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hr.</td>
<td>57.1</td>
<td>47.4</td>
<td>48.0</td>
<td>34.5</td>
</tr>
<tr>
<td>hrs.</td>
<td>94.0</td>
<td>82.9</td>
<td>81.7</td>
<td>86.5</td>
</tr>
<tr>
<td>hrs.</td>
<td>89.0</td>
<td>82.2</td>
<td>77.1</td>
<td>67.8</td>
</tr>
<tr>
<td>hrs.</td>
<td>92.0</td>
<td>93.5</td>
<td>92.4</td>
<td></td>
</tr>
<tr>
<td>hrs.</td>
<td>95.1</td>
<td>93.5</td>
<td>89.2</td>
<td>81.5</td>
</tr>
</tbody>
</table>

In the 8 per cent mixture, the structure of the granules is much finer, the body less porous, and the texture closer than in the 4 and 6 per cent creams. The influence of the fat content on the body and texture is evident. The 10 per cent ice cream, when compared with the 8 per cent cream, showed a much closer texture. The broken portion of the 10 per cent ice cream closely resembles the appearance of broken steel indicating a texture that is desirable and typical of a good ice cream.

The 12 per cent ice cream, when compared with the 4, 6, 8, and 10 per cent creams, indicates that a higher fat content produces an ice cream that is closer in texture and firmer in body.

There is a very decided change in the appearance of the structure and texture of the 16 per cent ice cream and that of the 10 per cent cream. The 16 per cent cream shows a much closer texture and a more solid body.

The 18 per cent ice cream shows increasing adhesiveness. The texture is too close for a desirable ice cream. The 20 per cent ice cream
shows more marked closeness of the texture, the surface of the broken portion of this cream resembling the appearance of broken jelly. An even closer texture is observed in the 25 per cent ice cream.

A comparison of figures 17, 18, 19, and 20 demonstrates the complete changes in the structure and texture of the ice cream. This change in a large measure accounts for the ability of different ice creams to withstand summer temperatures. A gradual increase in the closeness of the cream shows the direct relation of the butterfat content of the ice cream to its body, texture, structure, and appearance.

The Effect of Different Percentages of Butterfat on the Flavor, Body, Texture, Richness, and Appearance of Ice Cream.—The hardened ice cream was judged, special attention being given to any noticeable difference in the flavor, body, texture, richness and appearance of the ice cream from the different mixtures at the age of one day. The ice cream was then held in storage for five days and again scored to determine the influence of the fat content when ice cream was stored. Two bricks from each of the four freezings of each mixture were hardened under the same conditions as the bricks used in determining the hardness and stability.

Judging the ice cream for flavor.—The ice creams aged one day were judged on flavor as follows: The four per cent ice cream possessed an undesirable flavor, was flat and very cold. The coldness of the cream was attributed to the low percentage of fat and solids. The six per cent ice cream had a flavor which was not entirely desirable and was colder than an ice cream should be. The cream melted rapidly in the mouth due to the low solid content which also accounts for the coldness. The eight per cent ice cream had a flavor more closely resembling that of a typical ice cream than did the 4 and 6 per cent ice creams. This cream did not, however, have the delicate flavor typical of ice cream containing higher percentages of fat. The ten per cent ice cream gave a delicate, desirable and typical ice cream flavor. The coldness was moderate, and it was free from an undesirable aftertaste. The twelve per cent ice cream had a typical ice cream flavor and was free from any excessive sweetness and undesirable coldness. The fourteen per cent ice cream produced a slight butterfat flavor giving the product somewhat of a flat flavor and leaving a thin coating inside the mouth. An aftertaste of butterfat was noticeable. The flavor of the sixteen per cent cream was so rich as to give an undesirable taste and coating of the mouth. The aftertaste was more noticeable than that of the ice cream with lower percentages of fat. The eighteen per cent ice cream had a clean, somewhat sweet flavor but was so rich in butterfat as to be somewhat sickening, and a small quantity satisfied the appetite. The butterfat aftertaste was very objectionable.
The twenty and twenty-five per cent ice creams had so pronounced a butterfat flavor and aftertaste that the flavoring used was overshadowed. The coldness had disappeared and this ice cream would be described as being warm. The butterfat coating in the mouth was very perceptible.

The ice creams aged five days gave the following results: The four per cent and six per cent ice creams possessed an insipid, flat, and old-butterfat taste. The undesirable flavor appeared principally in the aftertaste. The coldness due to the low fat and total solids content, was sufficient to cause an unpleasant sensation. The eight per cent showed an improvement over the four per cent and six per cent ice creams but did not possess a particularly desirable flavor. The coldness and the old-butterfat taste were less pronounced. The ten per cent ice cream was clean of flavor, being free from any undesirable butterfat taste, coldness or excessive sweetness. The twelve and fourteen per cent ice creams had all of the desirable qualities of the 10 per cent ice cream except for a slightly more pronounced coating left in the mouth and an old-butterfat taste in the melted portion. The sixteen per cent ice creams possessed a sickening flavor if any quantity was consumed. The butterfat flavor was pronounced and the coating of the mouth was so noticeable as to be objectionable. The eighteen and twenty per cent ice creams had a clean flavor but not desirable or typical, due to the pronounced butterfat taste. The old taste appeared very pronounced, especially in the partially melted portion and there was a slightly rancid taste suggesting a breaking down of the fats. The twenty-five per cent ice cream had a rich butterfat flavor which together with the sweetness produced by the sugar, gave a flavor which resembled the flavor of syrup candy. The coating of the mouth with butterfat was the most pronounced of all ice creams judged.

Judging the ice cream for body and texture.—The body and texture of ice cream is second in importance only to flavor. They have a decided influence on the firmness of the cream and the desirable feeling in the mouth when eating ice cream. The most desirable body in ice cream is a firm and mellow one which, when combined with a smooth velvety texture that is entirely free from graininess or lumpiness, gives a perfect product in regard to body and texture.

The ice creams aged one day were judged for body and texture as follows: The ice creams containing four per cent and six per cent fat, while firm in appearance, were watery, melting rapidly in the mouth. The texture in each cream was open, porous and coarse giving a rough, granular feeling resembling that of dry bread crumbs on the tongue. The eight per cent cream had a firmer body, and less wateriness was
observed than in the 4 and 6 per cent creams. The texture was somewhat open, rough, and was termed coarse. There was a noticeable improvement in both body and texture over the 4 and 6 per cent ice creams. The body of the ten per cent ice cream was free from wateriness and retained its stability a desirable length of time. The texture was smooth, desirable and medium close. The twelve per cent ice cream was mellow and firm of body and was entirely free from wateriness. The stability was very desirable. The texture was smooth and velvety but appeared somewhat close. Compared with the 10 per cent ice cream the body was improved but the texture was too close. The fourteen and sixteen per cent ice creams had lost some of the mellowness present in the 10 and 12 per cent creams. The texture was close and smooth but not velvety. The increased fat content impaired both the body and texture. This indicates that the ice creams with the most desirable fat content were the 10 and 12 per cent creams. The eighteen per cent ice cream was mellow, somewhat tough and rubbery, melting away very slowly in the mouth. The texture was very close, smooth, and velvety, due to the high fat content. The twenty and twenty-five per cent ice creams required considerable effort to swallow, indicating that they were firm and stable. The texture was too close, although smooth and quite velvety, giving the ice cream a doughy texture, the evidence of which appeared when the product was scraped with a spoon.

The ice cream aged five days was judged as follows: Both the four per cent and six per cent ice creams were similar to the product when one day old, each having a firm body and being watery, lacking stability in the mouth. The texture was coarse and open, feeling rough on the tongue. The eight per cent ice cream proved more stable than the 4 and 6 per cent creams, melting with less rapidity when in the mouth. The ten and twelve per cent ice creams had a texture that was smooth, desirable and medium close, and the body proved very satisfactory. The fourteen, sixteen, and eighteen per cent ice creams showed no noticeable difference at five days compared with its condition at one day. The excessive firmness and the rubbery feeling were the principal defects. The twenty and twenty-five per cent ice creams had a body that was very firm, with a marked doughy consistency and, due to the adhesiveness of the fat, appeared in rolls when the surface of the ice cream was scraped with a spoon. The texture was very close, appearing almost as a solid mass.

Judging ice cream for richness.—The richness of the different ice creams studied increased in direct proportion to the fat content. Ice creams containing less than 10 per cent fat cannot be classified as being rich enough to gain the approval of the average consumer. The 10 and 12 per cent ice creams proved most desirable in richness. With each ad-
ditional increment of fat, the richness became less desirable. The quantity of ice cream required to satisfy the appetite was directly proportionate to the fat content. The richness of the ice cream was not affected by holding the ice cream in storage for a period of five days.

**SUMMARY**

The object of this investigation was to determine the effect of butterfat on the physical properties of ice cream including a determination of the relation of the fat content to the following properties of the mixture: the specific gravity and the viscosity. The physical properties of the finished product are as follows: body, texture, hardness, overrun, and stability.

The results show that the addition of different amounts of these ingredients in the manufacture of an ice cream will increase or decrease the maximum overrun, vary an ice cream as to its hardness and its ability to retain its original form when exposed to summer temperature.

The ice creams studied ranged in fat content from 4 to 25 per cent inclusive.

Experimenting with these different percentages of fat, it was found that with each additional increment of 2 per cent of fat, there was caused a uniform decrease of 0.004 in the specific gravity of the mixture. The viscosity of the mixture showed a gradual increase with each additional increment of fat. This increase in viscosity was more apparent when the mixture contained larger percentages of fat. Butterfat was found to have a decided influence on the viscosity of the mixture because the fat was more viscous than the water which it replaced.

It was shown that the fat content of the mixture has a greater influence on the percentage of overrun than does the viscosity of the mixture. The overrun increased slightly with increased viscosity until the mixture contained 10 per cent fat. When the fat content increased above 10 per cent, the overrun decreased although the viscosity continued to increase.

No direct relation between the fat content of the different mixtures and the hardness of the ice cream was found to exist. The slight variation in the penetrations recorded were due entirely to variations in the temperatures of the hardened product. The fact that these variations were not uniform and that the average of all determinations found checked with results obtained by Reid in his work with sugar showed that fat had no effect on the hardness of the ice cream. The temperature of the ice cream has a much greater influence on the hardness.

The determination of the rapidity with which the ice cream containing different percentages of fat melted when exposed to summer
temperatures demonstrated the effect of fat upon the stability of ice cream. The ability to resist melting when exposed to summer temperature is increased with each additional increment of fat.

The percentage of fat in the ice cream has no effect on the temperature of the frozen cream when the temperature reading is obtained from the freezer.

There is a direct relation between the fat content of the ice cream and the desirability of the flavor, body, texture, richness, appearance, and the keeping qualities of the cream.

A mixture containing 10 per cent fat appears to result in the most desirable ice cream. This cream has the most desirable and typical flavor, body, texture, appearance, and richness; and it will not develop defects during a five day storage period.