Bulletin No. 227 - Soft-Curd Milk

R. L. Hill

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Ormsby Skylark Marion No. 633914. A typical soft-curd cow averaging 16 grams' curd tension for a 6-year period. This cow's milk, when modified, was digested as readily by new-born infants as was their own mothers' milk.
Soft-Curd Milk

R. L. HILL

HISTORICAL

Data on the early studies on the curd character of milk are found in Utah Agricultural Experiment Station Bulletin 207 and, therefore, are not included here. The key to research in this field came to light with the development of the "Hill Test," the results of which were first published in 1923. This test furnished a means of quantitatively measuring the difference in curd character of various milks.

The term "soft-curd" milk originated with R. L. Hill to describe milk which on coagulation with pepsin or rennin forms a curd that is soft and clabbery in consistency, differing widely from the tough rubber-like curd obtained from most samples of cows' milk. In the earlier writings the term "soft-curded" milk was used, but since this sometimes gives the impression that the milk referred to as soft-curded has been coagulated, the term has been changed to "soft-curd" milk. It is by means of the Hill Test that the softness of the curd in milk can be determined.

APPARATUS USED IN THE TEST

The Curd Knife

For determining the hardness of the curd a star-shaped, 10-pronged curd knife is used. This knife has a 3/8-inch center which is tapered at 60° to fit over a 1/8-inch stem. The stem, which is used as a handle, is 6 1/4 inches long before it is bent to form the 1/4-inch loop at the end. The ten blades are soldered into the ten 1/8 by 1/20-inch slits in the center. The blades are cut from 1/20-inch sheet brass and are 1/8 inch wide. All are sharpened to a knife edge. Each blade is cut twice the necessary length. The blade is then placed in a bending jig and bent at an angle of 36°. Five blades thus bent are soldered into the center core to furnish the ten blades, the sharpened edge being placed on the upper side. When completed, the knives on the average weigh 18 grams and should not vary in weight more than one-half gram. The curd knife should not be more than 2 inches nor less than 15/16 inch in diameter.

Acknowledgments: The writer desires to express his appreciation to Director P. V. Cardon, for his cooperation, advice, and encouragement, and to Dr. Wilkie H. Blood, of Salt Lake City, for his contribution to the literature on the use of soft-curd milk in infant feeding. 1

1 Contribution from Department of Human Nutrition, Utah Agricultural Experiment Station. Progress report on Purnell Projects Nos. 103 and 103-a.

Publication authorized by Director, May 16, 1931.

This equipment is protected by patent and can now be obtained in testing units from Zion's Cooperative Mercantile Institution, Salt Lake City, Utah, at approximately the manufacturing and selling cost.
Fig. 1—Coagulation cylinder and curd knife used in Hill Test.

The Spring Balance

For measuring the pull required to draw the curd knife through the curd, a specially constructed spring balance with a capacity of 250 grams and a start of 18 grams to tare the curd knife is used.

The Coagulation Cylinder

Eight-ounce mayonnaise jars (No. 63 C. T. finish) are used as containers for the milk during coagulation. The jars should be examined for uniformity before use and should be about 2\(\frac{1}{4}\) inches inside the diameter and about 2 inches at the neck.

The Coagulant

For coagulating the milk a pepsin-calcium-chloride mixture is used. Marked difference can be obtained by the use of pepsin alone. The use of calcium chloride, however, increases the variation and decreases the coagulation time and gives a more uniform coagulation. The coagulant consists of a mixture of three parts of 0.6 per cent solution of 1-to-3000 dry scale pepsin to one part of a solution of calcium chloride containing 378 grams of dry granular calcium chloride per liter of solution. Porous mesh calcium-chloride used as a drying agent is not satisfactory for this test.
The milk should be tested as soon as possible after it is drawn from the cow, as a marked increase in acidity will alter the test. When comparative results are to be obtained it should be held at a constant temperature and tested the same length of time after milking. Duplicate 100 c.c. samples of thoroughly mixed milk are placed in the glass jars, previously described. The jars are then immersed in a waterbath and the temperature of the milk brought up to 35° Centigrade (95° Fahrenheit). The milk should be maintained at this temperature throughout the test. After placing the curd knives in the jars, 10 c.c. of freshly mixed coagulant are added by means of a rapidly flowing pipette. It is necessary to enlarge the opening in the pipette to allow a more rapid flow; the last of the coagulant is blown in from the pipette. The jars should be agitated to give the milk a circular motion while the coagulant is being added, thus assuring a more even mixture of the coagulant. The amount and uniformity of the agita-
tion given the jars during the addition of the coagulant is highly important. Too rapid or too prolonged agitation will agglutinate the curd, while little or no agitation will not adequately mix the coagulant with the milk, resulting in an uneven coagulation. The writer adds the coagulant with a pipette held in the left hand, while the jar is agitated with the right. By a little practice a uniform and smooth motion can be obtained.

After adding the coagulant the jar should be returned to the waterbath, care being taken not to agitate it for a period of 10 minutes, when the spring balance is hooked through the loop in the curd knife; by a slow and even tension the knife is drawn through the curd. The amount of tension required can be read directly on the balance. (The balance in use now has the zero point at 18 grams, thus taring the curd knife.) It is essential that the spring balance be held perpendicularly and directly above the curd knife; otherwise, friction of the plunger on the side or back of the scales will render the test inaccurate.

By using a large number of knives one can run duplicate samples on from 15 to 20 cows at one time. It it is used immediately, coagulant for 40 or more samples can be mixed before beginning the test. The pepsin deteriorates, however, if violently agitated or if it is allowed to stand too long in the calcium-chloride solution. If one is working in a moist atmosphere the bottle containing the pepsin scales should be kept in a desiccator to prevent deterioration.
When one becomes experienced with the method, duplicate samples will check to within about 5 grams. Some may vary as much as 10 grams or more, while most samples check almost exactly. The variation between the hard and soft-curded milks is so great as to overcome slight variations in samples.

While it is important that the pepsin-calcium-chloride mixture be exactly right for the proper running of the test, yet if sufficient care is used the following departure from the method is permissible. This method has been used by the writer on his field trips with splendid success. The proportions of the reagents are approximately the same as given. The calcium-chloride solution is made by dissolving the contents of a one-pound bottle of dry granular calcium chloride in a quart of water. Anhydrous calcium chloride, especially prepared for drying tubes, is not satisfactory for this test. In making the pepsin solution, the scale pepsin is measured with measuring spoons. A level one-half teaspoonful of 1-to-3000 dry scale pepsin is dissolved in a measuring cup of water, preferably at a temperature of 35° Centigrade (95° Fahrenheit). Care should be taken to see that it is completely dissolved without agitation. It is more easily dissolved if added to the top of the water, since when the water is poured on the pepsin it often causes it to stick to the bottom of the beaker and to dissolve extremely slowly.

The coagulant is made by carefully mixing one-third cup of the calcium-chloride solution with 1 cup of the pepsin solution.

Figure 4 illustrates the method used in running the test. It is faulty in that the curd knife was not held perpendicularly; the coagulation cylinders have also been removed from the water-bath shown in the background. When a hot water-bath of this type is used and hot water is added to bring the temperature of the milk up to 35° Centigrade (95° Fahrenheit), care should be taken to see that the temperature of the water surrounding the coagulation cylinders is not more than 1° above the temperature of the milk at the time of coagulation.

NORMAL FREQUENCY OF THE SOFT-CURD CHARACTER IN DIFFERENT BREEDS OF DAIRY CATTLE

Insufficient work has been done to accurately predict the expectancy of soft-curded milk in each breed of dairy cows. Since there are varying degrees of curd hardness, it is difficult to state just how soft curded milk should be in order to be classed as "soft-curd" milk. Average mixed herd milk will usually test between 50 and 90 grams of curd tension. Milk that approaches this average should not be classed as soft-curd milk. If 20 grams of curd tension could be maintained as the upper limit for soft-curd milk, the health of infants using the milk would be greatly safeguarded. Since there are few cows with so low a curd tension in their milk, it may be necessary to use a higher standard. It is obvious that the higher the curd tension allowed for soft-curd milk, the greater the feeding problem when the milk is fed to delicate infants. Table 1 represents a compilation of tests on milk of different breeds of dairy cattle. Since there is a limited number of Ayrshires in the state and further since results recorded represent the tests from one herd only, the figures given are not an accurate index of what might be found in this breed. In all probability, if more Ayrshire cows
had been tested, definite results would have been obtained in the first (lower) and last six (higher) columns of Table 1. Moreover, tests were made on more Jersey and Holstein breeds than on Guernsey. A wider testing might have altered somewhat the distribution of curd tension.

From Table 1 the wide variation in the curd character of milk from different cows of the same breed and also breed differences is indicated. It is also evident that there is a relatively small percentage of cows tested that test between 10 to 20 or 20 to 30 grams. While it will be observed that there is a greater preponderance of soft-curd cows in some breeds than is found in others, it is possible to select soft and hard-curd cows in practically all breeds. The results indicated in Table 1 were obtained from tests made on typical dairy herds in thirteen different counties in Utah and in the aggregate represent the results of several thousand tests. These results are graphically shown in Figure 5.
| BREED   | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 |
|---------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Jersey  | 0.9 | 1.8 | 4.2 | 12.0 | 9.6 | 11 | 12.3 | 10.8 | 7.3 | 6.0 | 5.4 | 4.8 | 5.7 | 2.1 | 2.1 | 3.6 | 3.51 |
| Early   | 0.15 | 0.6 | 1.36 | 6.07 | 10.01 | 9.86 | 10.19 | 13.81 | 9.56 | 9.86 | 10.32 | 5.92 | 4.4 | 3.04 | 1.52 |
| Results | 0.53 | 1.2 | 2.78 | 9.04 | 9.8 | 10.48 | 11.25 | 12.3 | 8.68 | 7.93 | 7.86 | 5.35 | 5.65 | 2.57 | 1.81 | 2.47 |
| Holstein| 1.5 | 8.0 | 15.0 | 14.0 | 20.0 | 15.0 | 7.5 | 7.7 | 1.1 | 3.4 | 1.9 | 1.1 | 0.8 | 0.0 | 0.8 | 0.4 |
| Early   | 0.87 | 5.21 | 10.06 | 16.35 | 14.78 | 15.65 | 10.56 | 9.19 | 5.59 | 4.35 | 2.61 | 1.24 | 0.62 | 0.25 | 0.12 | 0.0 |
| Results | 1.18 | 6.6 | 12.53 | 15.17 | 17.39 | 15.33 | 9.03 | 8.45 | 3.3 | 3.87 | 2.25 | 1.17 | 0.71 | 1.25 | 0.46 | 0.2 |
| Durham  | 0.0 | 2.53 | 3.80 | 21.52 | 10.13 | 13.92 | 17.59 | 10.13 | 7.59 | 7.59 | 3.80 | 1.26 | 0.0 | 0.0 | 0.0 | 0.0 |
| (Shorthorn) | | | | | | | | | | | | | | | | |
| Grade   | 1.7 | 5.3 | 10.6 | 14.2 | 15.8 | 11.1 | 8.2 | 8.7 | 6.9 | 5.5 | 3.2 | 2.9 | 3.4 | 0.79 | 0.79 | 2.05 |
| Early   | 0.44 | 3.54 | 7.52 | 12.83 | 17.26 | 16.18 | 11.5 | 9.29 | 8.0 | 7.05 | 3.54 | 2.65 | 0.88 | 0.88 | 0.0 | 0.0 |
| Results | 1.07 | 4.42 | 9.08 | 13.61 | 15.94 | 13.64 | 9.85 | 9.0 | 7.43 | 6.28 | 3.38 | 2.77 | 2.14 | 0.84 | 0.40 |
| Guernseys| | | | | | | | | | | | | | | | |
| Later   | 0.65 | 2.6 | 7.16 | 5.2 | 15.58 | 11.69 | 7.80 | 14.93 | 10.4 | 7.16 | 5.19 | 2.6 | 3.95 | 1.95 | 0.65 | 2.6 |
| Ayrshires| | | | | | | | | | | | | | | | |

Table 1—Average Percentage of Curd Tension with Different Breeds of Utah Dairy Cows (grams)
Fig. 5—Percentage distribution of soft-curd character of milk in dairy breeds.

EFFECT OF PERIOD OF LACTATION ON SOFT-CURD CHARACTER OF MILK

Random tests on dairy herds are not a reliable index of the curd character of the individual cow's milk unless the period of lactation of each cow is carefully checked. Results to date indicate that after the cow freshens the milk immediately has an abnormally hard curd. This characteristic, however, does not apply to the colostrum milk. This characteristic is usually
SOFT-CURD MILK

retained from a month to six weeks. It should not be implied, however, that a soft-curd cow necessarily gives hard-curd milk during this period. The milk secreted by this cow, however, will be much higher than normal in curd tension for the rest of the lactation period. During this period, a cow with a normal curd test of 20 grams will often test as high as 40 grams. In supplying soft-curd milk for infants, that from a soft-curd cow should not be sold as soft-curd milk unless milk has been given sufficiently long and has been tested as soft-curded.

Toward the end of the lactation period the curd of milk usually becomes harder; in some instances, however, the curd may become softer. Usually when the curd becomes softer at this time, the milk is abnormal and should not be used as so-called "baby milk." In some instances cows have been purchased solely on a curd test of their milk run in this abnormal period. Such cows are usually a disappointment during the following lactation periods as they often give hard-curd milk.

PERMANENCY OF THE SOFT-CURD CHARACTER

Much concern has been expressed as to the permanency of the soft-curd character in dairy cattle. To test this point, the curd test has been run on dairy cows in the Station dairy herd at rather frequent intervals for the past ten years. In all cases the curd test proved to be a permanent and individual characteristic of the cow. When those tests taken at the beginning and at the end of the lactation period are discarded, the tests show a remarkable uniformity from year to year. It is possible that some disease or injury to the udder might permanently affect the curd character of the milk, but no case is on record of an effect of this type. There is, however, some variation in the curd test from day to day as well as some differences between the night and morning milkings, but these differences are comparatively slight.

VISUAL DIFFERENCE IN THE CURD CHARACTER OF COWS' MILK

In order to determine accurately the curd character of cows' milk it is necessary to employ the Hill Test. It is possible, however, to roughly determine the hardness of the curd of the milk by the cheesecloth method or by a careful examination of the curd of the milk obtained by coagulation of the milk as described in the Hill Test. Figure 6 shows the characteristic appearance of soft and hard-curd milk after it has been coagulated at 35° Centigrade (95° Fahrenheit) using the pepsin-calcium mixture used in the test. The curd from the hard-curd milk (shown on the left) when slightly agitated with a circular motion coalesced in a rubber-like mass, while that from the soft-curd milk retained its clabbery consistency and was distributed equally throughout the whey. If these two samples of coagulated milk are placed in a fine-meshed cheesecloth and then wrung in the cheesecloth, as illustrated in Figures 7 and 8, practically all of the curd from the soft-curd milk will pass through the meshes of the cheesecloth, while the curd from the hard-curd milk will remain behind as a rubbery mass. This test, known as the cheesecloth test, is not an absolutely accurate or reliable test.

Fig. 6—View showing hard and soft-curd milk in a petri dish, as seen from above. The figure on the right is a more correct representation of the original photograph. The curd in the figure on the left is a compact, rubbery mass.

and should be used only in picking out extremes. It does present, however, an effective demonstration of the difference between the two milks and can be used to advantage when demonstrating these differences to others.

Fig. 7—Curd from soft-curd milk being wrung through fine-mesh cheesecloth. Compare with Figure 8.

EFFECT OF FEED, EXTERNAL TEMPERATURE, OR OTHER EXTERNAL CONDITIONS ON SOFT-CURD CHARACTER OF MILK

Sufficient work has not been done at this Station to justify any final definite statement regarding the effect of the feed the cow receives on the
curd character of the milk. However, results to date indicate that except for sudden changes in the diet, the curd character of the milk is independent of the nature of the feed given. A sudden change in ration will cause a fluctuation in the curd test similar to the change in the fat content. This change, however, is only temporary. Pasture and rations with a high water content result in a more dilute milk and a slightly lower curd test. Conversely, when the animal is on dry feed and the water consumption is decreased (because of extremely cold weather or other external conditions), the curd test is usually higher; under these conditions, the milk usually has a harder curd.

**SOFT-CURD CHARACTER OF MILK AS IT IS AFFECTED BY FAT CONTENT**

Infants have so often had difficulty in digesting milk with a high fat content that doctors have come to associate a high fat milk with digestive troubles in the infant. While it is true that milk with a high fat content is more likely to be hard-curded than that with a low fat content, yet some soft-curd cows are high-fat cows; similarly, some low-fat cows give milk that is decidedly hard-curded. Milk with a curd test below 20 grams is usually decidedly low in fat content. Often it is so low that it comes below the standard set for market milk. On the contrary, however, some cows testing as high as 6 per cent have had a curd test below 20 grams.

It has been definitely shown that the mere presence of fat in milk does not have a hardening effect on the curd formed when it is coagulated. On the contrary, it has a softening effect. The following experiment clearly demonstrates this point: The milks from a number of cows of different breeds and with a wide range in fat content were tested with the curd test. Each cow's milk was then separated and the skim milk from each tested
with the curd test. Cream was then added to the separated milk in sufficient quantities to restore the original fat content and the curd test run again. Tables 2 and 3 give the results of these tests.

Table 2—Curd tension of milk before and after removal of its fat content.

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>Average Percentage Fat in Milk</th>
<th>Curd Tension on April 10</th>
<th>Curd Tension on April 21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole Milk</td>
<td>Skim Milk</td>
<td>Whole Milk</td>
</tr>
<tr>
<td>108</td>
<td>3.5</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>135</td>
<td>2.7</td>
<td>19</td>
<td>23</td>
</tr>
<tr>
<td>28</td>
<td>6.1</td>
<td>109</td>
<td>132</td>
</tr>
<tr>
<td>137</td>
<td>3.8</td>
<td>67</td>
<td>98</td>
</tr>
<tr>
<td>47</td>
<td>6.2</td>
<td>87</td>
<td>103</td>
</tr>
<tr>
<td>36</td>
<td>5.0</td>
<td>65</td>
<td>68</td>
</tr>
<tr>
<td>136</td>
<td>3.2</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>5.9</td>
<td>88</td>
<td>111</td>
</tr>
<tr>
<td>141</td>
<td>3.8</td>
<td>54</td>
<td>57</td>
</tr>
<tr>
<td>41</td>
<td>3.3</td>
<td>118</td>
<td>140</td>
</tr>
<tr>
<td>143</td>
<td>3.5</td>
<td>51</td>
<td>64</td>
</tr>
<tr>
<td>44</td>
<td>4.5</td>
<td>62</td>
<td>67</td>
</tr>
</tbody>
</table>

From these results it is evident that the removal of the fat from milk renders the curd harder, the fat globules tending to prevent the curd particles from coalescing together with the same degree of toughness as is found in the separated milk. The fact that the addition of cream to the skim milk restored its normal curd shows that the hardening of the curd was not due to removal of some ingredient in the separator slime. In general, the higher the fat content the greater will be the effect of its removal on curd test. Figure 7 shows graphically the effect of removal of fat on the curd test of the milk.

Table 3—Curd tension of milk before and after removal of fat content as well as on remixed fat and milk.

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>Whole Milk</th>
<th>Prepared Milk</th>
<th>Skim Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>135</td>
<td>24</td>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>28</td>
<td>118</td>
<td>106</td>
<td>139</td>
</tr>
<tr>
<td>137</td>
<td>87</td>
<td>87</td>
<td>122</td>
</tr>
<tr>
<td>36</td>
<td>61</td>
<td>66</td>
<td>88</td>
</tr>
<tr>
<td>136</td>
<td>48</td>
<td>50</td>
<td>62</td>
</tr>
<tr>
<td>44</td>
<td>62</td>
<td>56</td>
<td>73</td>
</tr>
</tbody>
</table>

From these results it is evident that the removal of the fat from milk renders the curd harder, the fat globules tending to prevent the curd particles from coalescing together with the same degree of toughness as is found in the separated milk. The fact that the addition of cream to the skim milk restored its normal curd shows that the hardening of the curd was not due to removal of some ingredient in the separator slime. In general, the higher the fat content the greater will be the effect of its removal on curd test. Figure 7 shows graphically the effect of removal of fat on the curd test of the milk.

EFFECT OF HEAT TREATMENTS AND EVAPORATION OF MILK ON ITS SOFT-CURD CHARACTER

It has been well demonstrated by clinicians that boiling milk renders it more digestible by infants. The literature on this subject is reviewed in an earlier publication (see Footnote 4). However, since the publication of this bulletin in 1928 considerable data have been assembled on the effect of heat treatments of milk on its soft-curd character. Since it has been believed that evaporated milk forms a soft curd on coagulation, it was decided to carefully check the changes in the curd character of the milk during the entire evaporation process.

There are three evaporated milk plants in Cache Valley, Utah. One of
these is located in Logan; the other two are located at Richmond to the north and Wellsville to the south of Logan. These evaporating milk plants (Borden, Sego, and Morning Milk, respectively) have cooperated in every way possible in conducting this special phase of investigation. Two thousand and six individual tests were run on samples of milk from these factories. The milk was first sampled in its raw state, when it arrived at the plant. If it had received a preliminary heating, it was next tested. It was then sampled after boiling in hot wells immediately before it entered the vacuum pans for evaporation. Samplings were made of the evaporated milk from the vacuum pans and of the evaporated milk as it came from the sterilizers. Samples were taken at regular intervals at each of these three stations in Cache Valley, Utah. They were numbered Evaporated Milk Plants Nos. 1, 2, and 3, with no regard to the listing as given above. The results obtained are graphically shown in Figures 9-12, inclusive.

The effect of the heat treatment of milk on its curd character is clearly shown in these graphs. In Plant No. 3 the average temperature for the first heating was about 114° Fahrenheit. It is evident that heating the milk to this temperature only slightly affects the curd character of the milk. The temperature of the first heating in Plant No. 2 averaged about 180° Fahrenheit. This temperature change produced almost as much difference in the character of the curd as was produced by the final heating—about 204° Fahrenheit. The uniformity in change of the curd character of the milk on heat treatment is truly remarkable. On the average, that milk which had received its final heating in the hot wells had a curd tension of less than one-third of the original curd tension of the milk. The majority of the dairy cows in Cache Valley are of the Holstein breed, which accounts in part for the comparatively soft curd of the raw milk entering the plant. On the average, Holstein milk is softer curded than that of other major dairy breeds. The milk entering Plant No. 1 averaged between 60 and 70 grams of curd tension, while that received at Plants Nos. 2 and 3 averaged between 50 and 60 grams.

By referring again to Table 1 it can be seen that more Holsteins test between 50 and 60 grams than does any other breed. This is graphically shown in Figure 4. If milk, with a higher curd tension, had been received it is probable that all tests made up to the evaporation process itself, would have been higher.

When the milk leaves the evaporators its water content has been reduced about 50 per cent. This evaporated milk has about the same curd tension as has the raw milk when it is received at the plant. If diluted to the consistency of normal milk, it will have about the same curd test as the boiled milk where it leaves the hot wells. This would seem to indicate that the evaporation process itself does not alter the curd character of the milk but that it is changed by the heat treatments used in the process. After evaporation, the milk is canned and then placed in sterilizers for about 30 minutes at a temperature of about 234° Fahrenheit. The sterilization time and temperature is not constant but depends on the condition and the acidity of the milk. This final sterilization has a most pronounced effect on the curd character of the milk. The undiluted sterilized evaporated milk has a curd tension of about 20 to 25 grams. When this milk is diluted to the consistency of normal milk, its curd test is decreased still further, which on the average represents more than a 50 per cent reduction.
Figs. 9, 10, and 11—Effect of heat treatments and evaporation on the curd character of milk, as indicated in Plants 1, 2, and 3, respectively. In the curve for Plant 3 it is noted that evaporated milk when undiluted, is harder curded than is the raw milk.
Fig. 12—Curve showing comparative effect of heat treatments and evaporation on the curd character of milk on Plants 1, 2, and 3, respectively. A=Raw milk; B=Evaporated milk; C=Sterilized, evaporated milk; D=First heating of milk (180°F.); E=Evaporated milk, diluted 50%; F=Sterilized and evaporated milk, diluted 50%.
Table 4—Effect of evaporation and heat treatment of milks on curd character, Evaporated Milk Plants Nos. 1, 2, and 3. Average curd test in grams of curd tension.

<table>
<thead>
<tr>
<th>Plant No.</th>
<th>No. of Tests Made</th>
<th>Raw Milk</th>
<th>First Heating</th>
<th>Second Heating</th>
<th>Evaporated</th>
<th>Evaporated Diluted</th>
<th>Sterilized Evaporated</th>
<th>Sterilized Evaporated, Diluted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>520</td>
<td>65.8 gr.</td>
<td></td>
<td>19.4 gr.</td>
<td>63. gr.</td>
<td>12.9 gr.</td>
<td>25.5</td>
<td>5.7 gr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>197° F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>945</td>
<td>56.5 gr.</td>
<td>26.3 gr.</td>
<td>22.5 gr.</td>
<td>54.4 gr.</td>
<td>15.1 gr.</td>
<td>20.7</td>
<td>5.1 gr.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>182° F.</td>
<td>203° F.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>541</td>
<td>55.9 gr.</td>
<td>53.9 gr.</td>
<td>18.4 gr.</td>
<td>65.75</td>
<td>17 gr.</td>
<td>24.6 gr.</td>
<td>6.3 gr.</td>
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<td>114° F.</td>
<td>200° F.</td>
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</tbody>
</table>
From the standpoint of curd character, evaporated milk is undoubtedly superior to market milk and compares favorably with raw soft-curd milk. When soft-curd milk is boiled its curd character is softened; often it does not coagulate at all when the curd test is applied to it.

The literature on the use of evaporated milk in infant feeding is quite voluminous; it is neither the purpose of this article to review this literature nor to act as a brief as to food value of evaporated milk. The results of these researches, however, would substantiate the claim of the Evaporated Milk Association, namely, that the curd obtained in the digestive process from evaporation is softer and more digestible than that obtained from ordinary market milk.

In the manufacture of sweetened condensed milk the high concentration of sugar acts as a preservative; the milk, therefore, is not run through the final sterilization. Since this final sterilization has the greatest effect on the curd character of the milk it might be reasoned that the sweetened condensed milk would be harder curded than evaporated milk. Actual tests have shown this to be the case, since its curd character approaches that obtained from the unsterilized evaporated milk. It would probably be more difficult for the delicate infant to digest this milk.

CURD CHARACTER OF GOATS' MILK

It has been impossible to test a large number of milk goats; therefore, no prediction can be made as to the expectancy of the soft-curd character in goats' milk. In those goats tested a variation of from 20 to 200 grams of curd tension has been observed. This would indicate that variation in milk goats in this regard is similar to that in dairy cattle. However, there is a decided difference between the curd obtained from goats' milk and that obtained from cows' milk. Hard-curd cows' milk is tough and rubbery, while hard-curd goats' milk is tough but granular in nature and can easily be broken up into small tough particles. In all probability, hard-curd goats' milk would be easier to digest than would hard-curd cows' milk; however, it doubtless would be more difficult to digest than the soft-curd cows' milk.

PRACTICAL VALUE OF SOFT-CURD MILK IN THE NUTRITION OF INFANTS AND INVALIDS

No longer can there be any doubt as to the variation in the curd character of milk of different cows. The key to the comparative value of these various milks will be in the correlation of the curd tests to the digestibility of the milk.

Results to date indicate that the curd test is an index to the digestibility of the milk.

The following case studies on the use of soft-curd milk in feeding infants are from the files of the Utah County Health Unit and were under the personal supervision of Dr. Lloyd L. Cullimore and Mrs. Evaline Reed, R. N. The first four cases are given verbatim from Utah Agricultural Experiment Station Bulletin 207 (1928).

It should be clearly understood that in these researches no financial support was rendered by the Evaporated Milk Association. The results, therefore, have no financial bias. If additional information on the use of evaporated milk in infant feeding is desired, it is recommended that requests be addressed to the Evaporated Milk Association, 231 South LaSalle Street, Chicago, Illinois.
“Case No. 1. At birth (June 2, 1927) weighed 9 1/2 pounds. Breast-fed for 2 months. From then until 6 months of age was fed with dire results on malted milk, Eagle Brand milk, and other milk modifications. On December 1, 1927 (age 6 months), its weight was 5 pounds, 15 ounces, which was only 62 per cent of its weight at birth. It had rickets and regurgitated curd after its feedings. It was then fed on a 50 per cent milk formula, using milk with a curd tension of 50 grams, which was the softest available in that location. It immediately became contented, ceased to vomit curds, and began to gain in weight. In February, at 8 months of age, weighed 10 pounds, 6 ounces, and was making splendid progress. At 9 months its weight was 11 pounds, 10.5 ounces. At this time it was using milk with a curd tension of 20 grams. At 11 months of age its weight was 14 pounds, 7 ounces, and it was 7 per cent above normal weight. It digested milk perfectly and was in splendid condition. In five months it had gained 8 pounds, 8 ounces.

“Case No. 2. At birth (February 3, 1927) weighed 8 pounds. Received breast feedings for 3 months. Taken to clinic June 9, 1927 (4 1/2 months old); at this time weighed 10 pounds, 2 ounces; was 25.5 per cent underweight and was rachitic; regurgitated curds. Changed to a mixed-herd milk, varying from 100 to 33 grams in curd tension. Still regurgitated curds. Also received some breast feedings at this time. In July changed to milk from the same herd testing 33 grams curd tension. Immediately it ceased vomiting curds. Entirely weaned by September 8. On October 10 weighed 16 pounds, 10.5 ounces, or was 8.5 per cent underweight. On November 30 (when 10 months old) it weighed 19 pounds, 4 ounces. The rachitic condition had improved; it was above normal in weight and was making splendid progress.

“Case No. 3. At birth (March 25, 1927) weighed 8 pounds. Mother died when it was 2 months old. Was fed on cows’ milk which it did not digest; regurgitated curds. When brought to clinic on June 9, 1927, it was 11 weeks old. At this time it weighed 8 pounds, 9 ounces, and was 19 per cent underweight and in a very run-down condition. In July it was changed to milk testing 25 grams in curd tension. It then weighed 10 pounds, 4 ounces, or was 14 per cent underweight. It digested the milk and ceased to vomit curds. On September 8 it weighed 14 pounds, 6 ounces; on October 10, 15 pounds, 12 ounces, which was above normal in weight. On November 30, at 6 months of age, it weighed 18 pounds, 15 ounces, which was about 6 per cent overweight. At this time no difficulty was experienced in digesting the milk.

“Case No. 4. At birth (July 12, 1926) weighed 6.5 pounds. Was fed on breast for 2 months. When 9 months old (April, 1927) it was taken to clinic; weighed 15 pounds, 8 ounces. Had rickets at this time and was not doing well. Was given first Holstein milk and then mixed-herd milk, averaging 60 grams in curd tension with a range of from 100 to 33 grams. This milk was not properly digested. On July 1, changed to 33-gram-tension milk from same herd. It immediately ceased regurgitating curds, which had previously been the usual occurrence. At 16 months it weighed 21 pounds; it was 10 per cent above weight; and the rachitic condition was entirely cured. Weights as follows: 9 months—15 pounds, 8 ounces; 11 months—17 pounds, 4 ounces; 12 months—18 pounds; and 16 months—21 pounds.”

Case No. 5. This baby weighed 6 pounds at birth. When he was 9 days old his mother developed septicemia; it was necessary to take the baby from the breast entirely. He was fed soft-curd milk with a curd tension of 16 grams. This milk was sterilized by boiling but otherwise was not modified or diluted, except by the addition of 1 ounce of diluted orange juice to 7 ounces of milk. The baby digested the milk perfectly and was never ill. Figure 13 is a photograph taken of this baby when it was 8 months old. It then weighed 18 pounds and 14 ounces, having more than tripled its weight in eight months. This child is now almost 6 years old; it has had perfect health and has never had any digestive troubles.

Case No. 6. This baby was reared from birth exclusively on soft-curd milk. Except for the first few feedings, this milk was fed unmodified ex-
Fig. 13—Case No. 5. Eight-months-old baby when nine days old. Fed undiluted unmodified soft-curd milk with splendid results.

except by boiling and the addition of a small amount of carbohydrates. Figure 14 shows this baby when she was 6 months old. At that time she weighed over 16 pounds and was in perfect health and had never had a day’s illness. This child is now two years old and weighs 35 pounds; in the two years of her life she has never been ill.

Dr. Wilkie H. Blood of Salt Lake City, Utah, a specialist in infant nutrition and who has probably had more experience on the use of soft-curd milk in infant feeding than any other physician, makes the following statement:

"Individual case histories are too numerous to cite in this communica-

*Correspondence with Wilkie H. Blood, M. D., October 14, 1930.
tion, but brief mention must be made of a few groups in which I have found the use of soft-curd milk of inestimable value.

"Group I—Newly-born and other healthy young infants who have been deprived of mothers' milk. These thrive on undiluted whole milk of very low curd-tension with no modification aside from the addition of carbohydrate.

"Group II—Persistent vomiters of whey and leathery curds. The great majority of these babies cease vomiting within 48 hours of the change from regular to soft-curd milk, and within ten days they begin to show a gain in weight—quite uncommon to the group.

"Group III—Colic babies—particularly those with indigestion typified by the presence of numerous protein curds in the stools. These cases, almost without exception, respond immediately when placed on the more easily digestible protein of soft-curd milk.

"Group IV—The 'never-do-well' group—those babies which, on whatsoever modification of regular cows' milk, gain but slowly until they reach the age when addition of extras in the diet bring them up. This important group needs no longer be placed on the various proprietary foods. They thrive on low-curd tension milk which may, as usual, be served undiluted but with slight addition of carbohydrate. It has been my experience that once these infants get started on the proper quantity of very low curd-tension milk they grow as rapidly and as normally as do the average breast-fed babies.

"Group V—The coeliac and other chronic intestinal indigestion cases. High-protein diet has appeared to be a necessity in this group. I have favored its use, and here again I have noted the superior value of the protein products of soft-curd milk—whether they be served in the form of protein milk, buttermilk, cottage cheese, or skimmed milk.

"Group VI—Infantile eczema cases. Great numbers of these patients show marked improvement and many are totally cured by a change from regular to soft-curd milk."

AVAILABILITY OF SOFT-CURD MILK IN THE UNITED STATES

The use of soft-curd milk in infant feeding is not confined to the West. For over a year the Sheffield Farms Company has been supplying certified soft-curd milk in New York City. In a brief article Barnes\(^9\) gives the advantages of soft-curd milk and also includes eight case studies showing its practical value. Soft-curd milk is now being delivered on the market in Detroit, Michigan; Milwaukee, Wisconsin; it will soon be delivered in a number of other large cities. The "Hill Test" for soft-curd milk has been run preparatory to selling soft-curd milk in thirty-five different cities located in twenty different states in the Union. Tests have also been run in Canada. A number of the larger institutions in the country are now conducting research on soft-curd milk.

NUTRITIONAL ADVANTAGES OF SOFT-CURD MILK

When ordinary market milk is used in feeding infants it requires modification, dilution, and sugar supplementation. Any single method of modification will not work in all cases. While some babies thrive on a given formula, others are not properly nourished by this formula. The proper care and preparation of the milk for infants requires considerable time and medical supervision. When soft-curd milk is available, this dilution

fication and subsequent supplementation is not required. If the milk is not
diluted it is a sufficiently concentrated food as to not require much supple-
mentation. Some may prefer to add carbohydrates to soft-curd milk in
infant feeding but satisfactory results have been obtained by feeding the
milk unmodified and undiluted. Some argue that since it is possible to
modify market milk and make it a satisfactory food for infants, why
bother with soft-curd milk. In spite of all efforts to adapt milk to the needs
of infants, thousands die every year due to malnutrition. Some of these
cases are under the supervision of the best specialists, but the majority are
in homes that cannot afford the services of a specialist. Soft-curd milk
would undoubtedly prove beneficial in most of these cases and it would be
of inestimable value in the homes where the services of the medical pro-
fession cannot be obtained. The same methods that are applied to market
milk to make it more digestible will also render soft-curd milk still more
digestible. Therefore, it appears to be an improvement over ordinary
market milk, regardless of the angle from which it is viewed.

Researches to date would indicate that it is impossible to modify market
milk in any manner to duplicate soft-curd milk without rendering it ab-
normal and in many respects undesirable for infant feeding. If it is pos-
sible by supplying soft-curd milk to obviate the necessity of using a formula
and to allow the use of the milk as it comes from the bottle, a great
service will have been rendered to mankind.

Soft-curd milk is not confined to infant nutrition alone. In cases of
adult indigestion and in gastric ulcers it has been used with remarkable
results. It can thus become a boon to invalids and mature persons in gen-
eral as well as to infants.

RESEARCHES NOW BEING CONDUCTED ON SOFT-CURD MILK

While soft-curd milk is a superior food for infants, results obtained
on the manufacture of cheese from hard and soft-curd milk would indicate
that hard-curd milk is much more valuable for the manufacture of cheese.
This phase of experimentation is being carried on at the Utah State Agri-
cultural College under the direct supervision of Ariel C. Merrill of the De-
partment of Dairy Manufacturing and will be ready for publication in the
near future. Research is also being continued on the variation in the curd
character of milk in various dairy breeds as well as in goats' and human
milk. Analytical work is also being planned to determine the chemical
differences between hard and soft-curd milk.

Observations to date would indicate that the soft-curd character of
milk is a hereditary characteristic that may be transmitted. A breeding
project is contemplated to determine the degree to which this character-
istic may be transmitted or accentuated by breeding.

Researches are being continued on the digestibility and food value of
soft-curd milk when fed to infants. This research may also be extended
to laboratory animals.
SUMMARY

1. The Hill Test for determination of the curd character is described in detail and furnishes a means of segregating those cows which give soft-curd milk.

2. On the average, less than 1 per cent of the cows tested test under 20 grams of curd tension, which is the most desirable standard for soft-curd milk.

3. Soft-curd cows have been located in all breeds; however, there is a greater preponderance of soft-curd cows in some breeds than in others.

4. In general, milk with a high fat content is more likely to be hard-curd. Soft-curd milk is sometimes found with a high fat content.

5. The presence of fat in milk has a softening effect on the curd; its removal by separation increases the hardness of the curd of milk.

6. Prolonged heat treatments soften the curd of the milk. Because of heat treatments and final prolonged sterilization, evaporated milk is soft-curded.

7. Case studies with infants indicate that the curd test is an index to the digestibility and food value of milk for infants.

8. Present results would indicate that soft-curd milk is digested by delicate infants without dilution or modification and that it compares favorably with mothers' milk. These results were obtained with milk testing under 20 grams of curd tension and might not be obtained if the curd tension were above 20 grams.

9. Soft-curd milk is now on the market in a number of the larger cities in the United States; the wide use of the Hill Test would indicate that soft-curd milk will soon be available throughout the nation.

10. For the manufacture of cheese, present researches show a superiority of hard-curd milk over soft-curd milk. Results on effect of hard and soft-curd milk on cheese will be published in the near future.

11. The soft-curd characteristic of milk, which appears to be permanent, in some instances has been shown to be an hereditary characteristic.

12. Except at the beginning and at the end of the lactation period, the curd character of the milk appears to be fairly uniform and apparently is independent of the feed given the cow, except for sudden changes in the feed.