Bulletin No. 207 - The Physical Cure Character of Milk and its Relationship to the Digestability and Food Value of Milk for Infants

R. L. Hill

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R. L. Hill

Fig. 4. Difference in texture of curd from hard- and soft-curded milk
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THE PHYSICAL CURD CHARACTER OF MILK AND ITS
RELATIONSHIP TO THE DIGESTIBILITY AND
FOOD VALUE OF MILK FOR INFANTS

R. L. HILL

HISTORICAL

In the feeding of infants, cows' milk is the best and most common substitute for human milk. In the feeding of delicate infants, however, considerable difficulty is often experienced from its use. The ideal substitute for mothers' milk has not been found, and most of the clinical effort has been directed towards the modification of cows' milk for infants.

Comparatively little research has been done on the difference in the digestibility and food value of milks from different cows for the infant. It is a well-known fact that the curd of cows' milk forms in a tough mass which varies considerably from the soft flaky curd obtained from human milk. That there is a wide variation in the toughness of the curd obtained from the milk of different cows is not generally known. Variation in the toughness of the curd of milk from different cows has been given very little attention in the field of research.

In 1914 Buckley (7) published the result of his work at the Maryland Agricultural Experiment Station. He compared the milk of different breeds of dairy cattle in regard to the strength of HC1 solution that was required to precipitate the proteins in one drop of milk. He also compared the texture of the curd obtained by the rennet coagulation of these milks and classified the milks by this means. The results of his work indicated a superiority of Holstein and Ayrshire milk over Jersey and Guernsey milk.

In 1916 the present research was begun by the writer at the Maryland Agricultural Experiment Station. One of the main objects of the research was to develop, if possible, a test that could be utilized to determine the true value of different milks when used as a food for infants.

The work of Buckley was repeated and the great difference in the curd from the different breeds noted. The curds were first classified into five classes, grading from a fine creamy-like curd to a tough rubbery type. An effort was next made to devise some means of mechanically measuring the degree of toughness of these curds. For this purpose a star-shaped curd knife was developed similar to the one now employed in the test.

Approved for publication by Director, June 1, 1928
About this time Allemann and Schmid (1), working in Europe, developed an apparatus consisting of three concentric rings attached to a vertical axis for determining the elasticity of the curd. This device was carefully compared with the curd knife used by the writer and was found to give results that were not as uniform or dependable; it was, therefore, discarded. While the curd knife usually cut through the curd, the device of these workers had a tendency to lift the curd bodily when it was withdrawn from the coagulated milk.

Allemann and Schmid studied milk from the standpoint of the cheese manufacturer. Their research was devoted to the determination of the factors affecting the coagulation of milk as related to the manufacture of cheese. No reference is made to the food value of the milk itself for infants. However, they observed a great difference in the texture of the curd of milk from different cows as well as the effect of temperature, concentration of rennet, and additions of salts and acids, on the coagulation of milk.

Considerable work was done by the writer at the Maryland Station with the test in its original form. While it was not perfected to the present test, yet a vast variation in the milks of different breeds and of individual cows within the breed was demonstrated and the practical value of the test indicated.

The World War caused this project to be discontinued in 1918, but it was resumed again in 1919 at the Utah Agricultural Experiment Station. Considerable time was spent in perfecting the test so that more uniform results could be obtained. Pepsin was substituted for rennin in the test, and the milk was coagulated at 35° C. instead of at the optimum temperature of 41° C. The milk was not diluted with water before coagulation. Uniform and instant coagulation was insured by the addition of one part of a 45 per cent solution of calcium chloride to three parts of a 0.6 per cent solution of 1-to-3000-scale pepsin, the resultant solution being used as a coagulant.

The test and results obtained by its use on the milk from the cows in the U. A. C. dairy herd were published in 1923 (12). It is not the purpose of this publication to unnecessarily repeat material published in 1923 but rather to give the test, summarize previous results, and then give more recent findings and their practical application to the nutrition problem.

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 is used as a handle and 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 of an inch in diameter.

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 200 grams and a sensitivity of one-half gram is used. This balance is manufactured to order by John Chatillon and Sons of New York. They also manufacture a balance with a capacity of 250 grams and a sensitivity of 5 grams which is satisfactory for the test and is much...
cheaper than the former balance. Both of these balances have a start of 18 grams; so the curd knife is tared.

The Coagulation Cylinder.—The 8-ounce mayonnaise jars (No. 63 C.T. finish), manufactured by the Pacific Glass Company, are used as containers for the milk during coagulation. These jars are jobbed by the Intermountain Dairy Supply Company of Salt Lake City. The jars should be examined for uniformity before use and should be about 2 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-scale pepsin to one part of a solution of calcium chloride containing 378 grams of dry granular calcium chloride per liter of solution.

METHOD OF PROCEDURE

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° C. 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 very rapidly flowing pipette. It is necessary to enlarge the opening in the
pipette to allow a more rapid flow, and the last of the coagulant is blown in from the pipette. The jar 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 agitation given the jars during the addition of the coagulant is very 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 the same for a period of ten minutes when the spring balance is hooked through the loop in the curd knife, and 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 very 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. If 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 under his manipulation 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-curbed milks is so great as to overcome slight variations in samples.

Normal Variation in the Physical Curd Character of Cows' Milk.—Buckley (7) and Allemann and Schmid (1) observed considerable variation in the milk from different breeds of cows. Washburn and Bigelow (18) obtained considerable variation in the coagulation time with rennin of milk from different cows. Koestler (13) has divided milk into three types: (1) Type A—which coagulates very quickly. This comes from diseased
udders and is abnormal in composition. (2) Type B—normal milk but slow to coagulate unless calcium chloride is added. (3) Type C—normal milk, but after coagulation the drying of the curd is much delayed. This milk also coagulates normally when calcium chloride is added. Analysis of the milk from different cows for the protein content will show a wide range of variation (10). Comparatively little work, however, has been published on the variation of the physical curd character of milk from different cows.

The amount of variation that can be obtained in the toughness of the curd of the milk from cows in the same dairy herd and also of the same breed is astonishing. Taking the U. A. C. dairy herd as an example, it is found that when measured by this test the milk from some cows has a curd tension or toughness ten times that of others. By examining Table 1 this variation is obvious. The milks of Cow No. 156 and some of the other softer-curbed cows have a curd so soft that it resembles ordinary buttermilk more than curd. When coagulated, the milk from some of the hard-curbed cows, such as Cows. Nos. 38 and 48, gives a tough rubber-like curd which quickly forms into a hard ball. The average pull, "curd tension," required to pull the curd knife through the curd is 60 grams which is about four

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>Breed</th>
<th>Average Curd Tension (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Jersey</td>
<td>110</td>
</tr>
<tr>
<td>49</td>
<td>Jersey</td>
<td>52</td>
</tr>
<tr>
<td>51</td>
<td>Jersey</td>
<td>62</td>
</tr>
<tr>
<td>157</td>
<td>Holstein</td>
<td>22</td>
</tr>
<tr>
<td>48</td>
<td>Jersey</td>
<td>160</td>
</tr>
<tr>
<td>44</td>
<td>Jersey</td>
<td>52</td>
</tr>
<tr>
<td>38</td>
<td>Jersey</td>
<td>124</td>
</tr>
<tr>
<td>39</td>
<td>Jersey</td>
<td>70</td>
</tr>
<tr>
<td>148</td>
<td>Holstein</td>
<td>72</td>
</tr>
<tr>
<td>121</td>
<td>Holstein</td>
<td>20</td>
</tr>
<tr>
<td>142</td>
<td>Holstein</td>
<td>34</td>
</tr>
<tr>
<td>162</td>
<td>Holstein</td>
<td>45</td>
</tr>
<tr>
<td>50</td>
<td>Jersey</td>
<td>85</td>
</tr>
<tr>
<td>55</td>
<td>Jersey</td>
<td>68</td>
</tr>
<tr>
<td>156</td>
<td>Holstein</td>
<td>16</td>
</tr>
<tr>
<td>150</td>
<td>Holstein</td>
<td>25</td>
</tr>
<tr>
<td>144</td>
<td>Holstein</td>
<td>40</td>
</tr>
<tr>
<td>155</td>
<td>Holstein</td>
<td>63</td>
</tr>
<tr>
<td>136</td>
<td>Holstein</td>
<td>27</td>
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<tr>
<td>129</td>
<td>Holstein</td>
<td>42</td>
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<tr>
<td>158</td>
<td>Holstein</td>
<td>47</td>
</tr>
<tr>
<td>52</td>
<td>Jersey</td>
<td>78</td>
</tr>
<tr>
<td>Average</td>
<td>Jerseys</td>
<td>86</td>
</tr>
<tr>
<td>Average</td>
<td>Holsteins</td>
<td>38</td>
</tr>
<tr>
<td>Average</td>
<td>Herd</td>
<td>60</td>
</tr>
</tbody>
</table>
times that of the softest-curded milk and a little more than one-third as great as the harder-curded milk. The average for all the Jerseys in the herd is 86, while the Holsteins average 38. This is an extremely low average for Holstein cows and is lower than the average for any other Holstein herd tested by the writer. Table 1 shows the results of a typical test of part of the cows in the U. A. C. dairy herd. It will be noted that the variation in curd tension is from 16 to 160 grams.

Effect of the Period of Lactation on the Physical Curd Character of the Milk.—According to Eckles and Shaw (10), the total protein begins high, immediately after the colostrum period, and gradually diminishes for four to six weeks. The lowest point is then maintained up to about the eighth month of the lactation period, when the percentage again rises. The rise is rapid toward the end of lactation.

The curd tension of the milk is much higher immediately after the colostrum period. The increase in hardness of the curd at this time is greater than the increase in the composition of proteins. This would indicate that some other factor is partially responsible. From four to six weeks after freshening the curd becomes normal in texture and varies only slightly, until toward the end of the lactation period. It then may become harder than normal. If the milk is abnormal it is often softer and sometimes will not coagulate at all. Palmer and Eckles (17) state “that cows’ milk becomes abnormal in composition as soon as the lactation stimulus becomes an artificial one on the part of the dairyman, and that this result bears no relation to the stage of the gestation period.” This may account for some of these results.

There is some variation from day to day in the curd character of cows’ milk, but this variation is slight when compared with the difference between the milks of various cows. Tests

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>1923</th>
<th>1924</th>
<th>1925</th>
<th>1926</th>
<th>1927</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 (Jersey)</td>
<td>122</td>
<td>127</td>
<td>111</td>
<td>136</td>
<td>.....</td>
</tr>
<tr>
<td>135 (Holstein)</td>
<td>23</td>
<td>20</td>
<td>14</td>
<td>16</td>
<td>25</td>
</tr>
<tr>
<td>28 (Jersey)</td>
<td>140</td>
<td>97</td>
<td>119</td>
<td>122</td>
<td>117</td>
</tr>
<tr>
<td>136 (Holstein)</td>
<td>32</td>
<td>41</td>
<td>29</td>
<td>22</td>
<td>.....</td>
</tr>
<tr>
<td>45 (Jersey)</td>
<td>.....</td>
<td>109</td>
<td>112</td>
<td>119</td>
<td>132</td>
</tr>
</tbody>
</table>

*Average curd tension for the periods in which the test was run during each year. The 1927 tests include only those tests made prior to April 3, during which period Cow No. 135 was dry; Cow No. 45 was not tested for this period.
at the Utah Station have shown that a cow, tested when a heifer and at that time shown to give a characteristically soft-curded milk, will continue to give the same character of milk for a period of several years. In all probability, this character is a permanent one. Table 2 shows the curd character of certain cows in the U. A. C. dairy herd from 1923 to 1927, inclusive. This table shows clearly the uniformity of the curd character from year to year.

The difference in the curd character of the milk from different cows is apparent to the eyes without the use of a spring balance or curd knife. Figure 3 shows the difference in texture of the curd from the milk of Cows Nos. 48 and 135. Both of these milks were coagulated in the same manner as used in the curd test. The jars containing the curds were given a rotary motion, and the curd from the milk of Cow No. 48, coalesced together in one mass, while that from Cow No. 135 remained flaky and evenly distributed throughout the whey. Each was then transferred to a petrie dish and photographed.

A larger sample of the milk from each of these cows was then taken and coagulated as before and the whey carefully separated from the curd. One curd was tough and rubbery and was easily molded into a large pyramidal-shaped chunk, while the other curd was so soft that it could not be molded into a solid piece. The difference in texture is shown in Figure 4 (cover cut).

To further show the difference in texture, the curd from the milks of these two cows, suspended in a fine grade of closely
woven cheesecloth, is compressed by twisting the cheesecloth. The curd from the soft-curded milk is readily expressed through the meshes of the cheesecloth and leaves no chunks behind. Only the clear whey passes through the meshes of the cheesecloth, when the curd from the hard-curded milk is compressed. The curd remains a hard, rubbery mass. These results are shown in Figure 5. The beaker on the right contains all of the curd from the soft-curded milk. This curd very closely resembles buttermilk. It is of very fine texture with no large pieces. The beaker in the center contains the whey from the hard-curded milk, while on the watchglass on the left is seen the curd from the hard-curded milk that did not pass through the cheesecloth. The imprint of the cheesecloth is distinctly visible on this curd.

Figure 6 shows the above test applied to the milk of Cow No. 148, a Holstein giving a hard-curded milk. On the right is shown the whey and on the left the curd that did not pass
through the cheesecloth. While this curd is not as tough and rubbery as was the hard curd in Figure 5, yet it is much tougher than the soft curd. The method of wringing the curd through the cheesecloth and also the difference in appearance between the two curds while wringing them is shown in Figures 7 and 8.
THE PHYSICAL CURD CHARACTER OF MILK FOR INFANTS

THE EFFECT OF THE FEED UPON THE CURD CHARACTER OF THE MILK

An opportunity was afforded to test the effect of the feed upon the curd character of the milk during a feeding test at the U. A. C. Experimental Dairy Farm. All of the cows in this test were Holsteins. Nine cows were placed upon a hay-grain-and-silage ration, while another group of nine was given a ration of hay, grain, and beet-pulp. Both groups were on the same ration during a preliminary period before the test rations were started (February 11, 1927). They received the new rations until May 5, at which time they received pasture only.

Curd tests were run at various intervals during the preliminary period, the test period, and while the cows were all on pasture. The averages of these results are shown in Table 3. The curd character of each cow is shown by this table to be remarkably uniform and apparently independent of the feed used. The experiment is not conclusive, as insufficient work has been done to warrant any positive conclusions regarding feeds other than the ones used in this experiment. Some of the cows came into lactation too late to be included in the preliminary test, and this accounts for the blanks in the first column of Table 3.

Table 3. The effect of feed on the curd character of the milk

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>Average Curd Tension</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before Receiving Ration</td>
</tr>
<tr>
<td><strong>Pulp, Hay, Grain</strong></td>
<td></td>
</tr>
<tr>
<td>A 17</td>
<td>30</td>
</tr>
<tr>
<td>E 3</td>
<td>51</td>
</tr>
<tr>
<td>E 6</td>
<td>...</td>
</tr>
<tr>
<td>E 8</td>
<td>...</td>
</tr>
<tr>
<td>E 9</td>
<td>...</td>
</tr>
<tr>
<td>E 10</td>
<td>40</td>
</tr>
<tr>
<td>E 11</td>
<td>...</td>
</tr>
<tr>
<td>E 12</td>
<td>67</td>
</tr>
<tr>
<td>W 10</td>
<td>36</td>
</tr>
<tr>
<td>Average</td>
<td>45</td>
</tr>
<tr>
<td><strong>Silage, Hay, Grain</strong></td>
<td></td>
</tr>
<tr>
<td>A 24</td>
<td>...</td>
</tr>
<tr>
<td>A 42</td>
<td>...</td>
</tr>
<tr>
<td>E 1</td>
<td>...</td>
</tr>
<tr>
<td>E 4</td>
<td>39</td>
</tr>
<tr>
<td>E 7</td>
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<tr>
<td>W 7</td>
<td>56</td>
</tr>
<tr>
<td>W 12</td>
<td>...</td>
</tr>
<tr>
<td>Average</td>
<td>35</td>
</tr>
</tbody>
</table>
CURD CHARACTER OF MILK FROM DIFFERENT BREEDS OF DAIRY CATTLE

It has not been possible to experiment on all the breeds of dairy cattle at the Utah Station, and the work conducted to date has been on a limited number of cows in three breeds. However, the work has been done largely on the Holstein and Jersey breeds. Table 1 and Figures 9 and 10 show a general comparison of the curd character of the two breeds of dairy cattle. These results show, on the average, that the Holsteins tested were much softer in the curd character of the milk than were the Jerseys. The figures are curves of curd character for a 6-month period in which the Holstein average is always below that of the Jersey. Figure 10 shows that some Jerseys (Cow No. 36, for example) are uniformly softer-curded than are some of the hard-curded Holsteins (Cow No. 137, for example). One might assume from these results that the curd character is controlled by the fat content of the milk. To test this point, large samples of milk were taken from twelve cows, six Jerseys and six Holsteins. A small sample of each cow's milk was set aside and run for curd tension according to the usual method. The
THE PHYSICAL CURD CHARACTER OF MILK FOR INFANTS

The rest of the milk from each cow was separated in a very small Viking separator. The separator was washed after each sample discarded. The curd test was then made on the skim milk of each cow. The results of these tests are shown in Table 4 and in Figures 11, 12, and 13.

It is apparent that curd tension was increased by the removal of the fat from the milk and also that there was no direct correlation between the fat content of the milk and the curd tension. By comparing Figures 12 and 13 the remarkable uniformity in the results of April 10 and 21 can be seen. In general, the higher the fat content of the milk the greater will be the increase in the curd tension as a result of its removal, its presence serving to soften the curd of the milk. This may account for the fact that sometimes infants that cannot digest whole milk do well on "top" milk.

Since the objection might be raised that the removal of the "slime" from the milk in separation might remove constituents other than fat which would affect curd tension, a later experiment was outlined to further test this point.

The samples of milk were separated as before, and the
Table 4. 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></td>
<td>Whole Milk</td>
<td>Skim Milk</td>
</tr>
<tr>
<td>108</td>
<td>3.5</td>
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<tr>
<td>135</td>
<td>2.7</td>
<td>19</td>
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</tr>
<tr>
<td>28</td>
<td>6.1</td>
<td>109</td>
<td>132</td>
</tr>
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<td>157</td>
<td>3.8</td>
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<tr>
<td>47</td>
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</tr>
<tr>
<td>136</td>
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</tr>
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<td>3</td>
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<td>88</td>
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<td>140</td>
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<td>143</td>
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</tr>
<tr>
<td>44</td>
<td>4.5</td>
<td>62</td>
<td>67</td>
</tr>
</tbody>
</table>

amount of cream required to bring up the fat content of the skim milk to that of the original whole milk was added. The curd tests were then made on this prepared milk, on the whole milk, and on the skim milk. Table 5 shows the results obtained.

From this table it is evident that the removal of the fat from the milk is responsible for hardening the curd, since the separated milk and cream when thoroughly mixed together gave the same curd test as was obtained from the milk before separation. These results substantiate the results obtained in the laboratories of Bergeim et al. (3) on the coagulation and digestion of milk in the human stomach. According to these authors, skim milk formed larger and harder curds than whole milk when taken as a food into the stomach.

The Physical Character of the Milk from Six Purebred Dairy Herds.—Six purebred dairy herds near the Utah Agricultural Experiment Station were tested for curd toughness. Five of these were Holsteins and one was a Jersey. Table 6 gives the average results obtained in this test. None of the cows in these herds gave a milk that was as soft-curded as was obtained from the U. A. C. dairy herd. The Holstein herds tested from 26 to 117 grams in curd tension, with an average between 50 and 64 grams. The Jersey herd varied from 63 grams to 141 grams, with an average of 97 grams.

The Physical Curd Character of the Milk from 1017 Cows Located in Seven Different Counties in Utah.—During the summer of 1927 a trip was made through seven counties in Utah, and samples of milk in 27 different communities tested for curd character. The majority of the cows tested were not purebred. If the cow was largely of the Jersey breeding it was classed as a Jersey; likewise with the other breeds. Cows of doubtful breeding were classified as "grades". Table 7 gives the results
of these tests. Since the cows tested in each breed were not all purebred these results should only be considered as indicative of the possible trend of curd character in the different breeds. Of the 1017 cows tested, 334 were classified as Jerseys, 263 as Holsteins, 71 as Durham (Short-horns), and 349 as “grades”. There were a few Guernseys tested but not enough to justify classification. In all cases the morning’s milk was taken and tested as soon as possible after milking. All of the samples were tested while they were still fresh and sweet. However, it was impossible in all cases to check on the period of lactation of each cow. In cases where the cows were just beginning or completing their lactation period the results obtained would not be reliable. There were, however, relatively few cases of this type.

Table 7 and Figure 14 show the percentage of the cows in the breeds indicated that gave soft- and hard-curded milks; the degree of hardness of their milk is also included. In all of the breeds examined there are some cows that give a milk that is soft-curded, while others secrete a hard-curded milk. The curd character of the milk appears to be an individual characteristic of the cow rather than a breed characteristic. The table, however, indicates that there is a greater probability of obtaining cows giving soft-curded milk in some of the breeds than in
There are relatively few cows that give a milk that could be classed as soft-curdled. In the following paragraph actual experiments on the feeding of milk to infants will be found.

The Effect of Heat Treatment of Milk on Its Curd Character.—Much work has been done on the effect of the digestibility of boiled milk. A very careful review of the literature up to 1912 is given by Lane-Claypon (14). These results are contradictory to a commonly accepted view that raw milk is more digestible than boiled. In a more recent work (1916) this same author (15) gives the results of her own and also the research of others, which in the main are strongly in favor of boiled milk. Brennemann (5,6) conducted investigations of the digestibility of raw and boiled milk in the human stomach. The subject was a healthy young man who, at will, was able to empty the stomach without discomfort.

The results in all cases show that raw milk forms larger, tougher curd particles, requiring a longer period to digest than those obtained from boiled milk. Similar results were also obtained
According to these authors, "milk which had been boiled five minutes formed small, soft, flaky, yellow curds which left the stomach soon and were more easily digested than the tough curds from raw milk. These results would indicate that, dietetically, boiled milk is to be preferred to the raw product except for the fact that its antiscorbutic value may have been lowered."

Dennet (9) from clinical observations has concluded that boiled milk, if properly administered and if used in connection with orange juice to supply vitamin C, does not necessarily cause nutritional disorders, such as rickets, anemia, scurvy, and malnutrition. It is, however, more likely to cause constipation than raw milk. Space will not permit a further discussion of the literature which is rather extended on this subject.

In an effort to quantitatively measure the difference in curd character between raw and boiled milk the following experiment was outlined:

Duplicate samples of each cow's milk were taken; one was set aside for the curd test, while the other was heated on a waterbath for a period of five minutes after the temperature of the milk reached 92° C. (198° F.). The waterbath was used because of the greater uniformity of results obtained

by Bergen et al. (3).
by this method. Without prolonged heating, 92° C. is about as high as the temperature of the milk will rise in an open water-bath at this altitude.

The results obtained are tabulated in Table 8. The curd obtained from the heated milk was invariably softer than that obtained from the raw milk. Both the raw and heated milk samples were coagulated at the same time and under identical conditions. By heating the milk as indicated, the average curd hardness for the entire herd was reduced 69 per cent. Milk that gave a very soft curd when raw barely coagulated when it had been previously heated. It resembled thin buttermilk rather than curd.

**Table 5. 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>
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<th>Prepared Milk</th>
<th>Skim Milk</th>
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<tr>
<td>44</td>
<td>62</td>
<td>56</td>
<td>73</td>
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**Table 6. Curd tension of milk from six typical dairies**

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>No. 1 Jerseys</th>
<th>No. 2 Holsteins</th>
<th>No. 3 Holsteins</th>
<th>No. 4 Holsteins</th>
<th>No. 5 Holsteins</th>
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<td></td>
<td>70</td>
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</tbody>
</table>

Averages of Herds: 97 51 60 51 64 60
Later experiments were conducted on raw and pasteurized milk. Half-pint bottles of milk were taken from each cow to be tested. One of these was set aside for the curd test, while the other was pasteurized in the bottle, by immersing the bottle in hot water and maintaining the temperature of the milk at 143° to 144° F. for one-half hour.

The average results obtained in these tests are recorded in Table 9. The results obtained were variable. In some cases the pasteurized milk formed a curd that was softer than that obtained from raw milk, while in other cases there was practically no change in the softness of the curd. In no case was the curd from the pasteurized milk nearly as soft as the corresponding curd from boiled milk.

Is the Curd Character of Milk a Transmitted Characteristic?—Insufficient work has been done on this subject to warrant any positive statements. The two cows giving the softest-curbed milk in the U. A. C. dairy herd are No. 135 and her daughter, No. 156. Cow No. 136 and her dam also gave soft-curbed milk. Cow No. 136, however, did not transmit this characteristic to her daughter, Cow No. 155. Some evidence has also been obtained regarding the ability of the sire to transmit this characteristic. Before positive conclusions could be drawn it would be necessary to carry on breeding experiments where both the dam and sire were selected with this characteristic in mind.
The Effect of External Weather Conditions on the Curd Character of Cows' Milk.—It has been reported by the Georgia Experiment Station (11) that long periods of hot weather have a depressing effect on milk production accompanied by a slight increase in butterfat percentage.

During the subzero weather of 1926 curd tests were run at the Utah Station, and the milks from all of the cows were found to be harder-curded than normal. By comparing the tests run
### TABLE 8. Effect of heat treatment of milk on curd character (1923-27)

<table>
<thead>
<tr>
<th>Cow No</th>
<th>Dates</th>
<th>Unheated* Average</th>
<th>Heated Average</th>
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<td>156</td>
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</tr>
<tr>
<td>144</td>
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</tr>
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<td>136</td>
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<tr>
<td>147</td>
<td>23</td>
<td>58</td>
<td>72</td>
</tr>
</tbody>
</table>

*These samples of milk were taken during extremely cold weather, and the subzero weather of some of these days apparently made the curd harder than usual. This may account for some irregularity in the table.

During this extremely cold weather with those run before and after the cold spell it was observed that on the average the tests run during the subzero weather were about 40 per cent harder than the others. The change in the composition of the milk, other than the curd, was not determined. This would indicate that during extremely cold periods, cows' milk may be harder for infants to digest than under normal weather conditions. The water the cows received during this extremely cold weather was not warmed, and it is possible that they drank less water and gave a more concentrated milk. However, no analyses of the milk were run.

### RESULTS OBTAINED FROM THE FEEDING OF SOFT-CURDED MILK TO INFANTS

The main object in view in developing the curd test was to obtain some means of determining in advance the digestibility of milk for infants. The milk was tested for its curd character by the use of the curd test as described in the methodology. The results obtained from the feeding of soft-curded milk to infants are presented in Table 9.

### TABLE 9. The effect of pasteurization on the curd character of milk

<table>
<thead>
<tr>
<th>No. of Cow</th>
<th>Average Curd Tension (gms.)</th>
</tr>
</thead>
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<td></td>
<td>Raw Milk</td>
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<td>129</td>
<td>47</td>
</tr>
<tr>
<td>147</td>
<td>42</td>
</tr>
</tbody>
</table>
of a certain milk when fed to infants. There is considerable evidence that the physical character of the curd is one of the main factors to be considered in the digestibility of milk by infants. Practically all methods of modifying milk for infants are based on known methods of rendering the curd softer when it is coagulated in the child's stomach. Brennemann, a prominent child specialist (6), concludes that raw and boiled milk are clinically very different foods, and that unless modified so that hard curds will not be formed the casein of raw milk offers serious digestive difficulties not present in boiled milk.

Boiling milk is one method used to soften the curd. Milk will not coagulate in the absence of soluble calcium salts. According to Palmer (16), the calcium phosphate (CaHPO₄) of cows' milk is in a colloidal solution and is precipitated out by heat. This is substantiated by a number of different workers. Daniels and Loughlin (8) have found that due to this precipitation, heat-treated milks are often deficient in calcium. According to these authors, this deficiency can be overcome by including the precipitate on the bottom and sides of the container in the milk feeding. Palmer (16) maintains that the softening of the curd, due to heat treatments, is not due to the precipitation of calcium salts but rather to the change in the protein molecule itself by heat. Addition of soluble calcium salts to boiled milk does not restore its normal curd hardness.

Another method of softening the curd of the milk is by the addition of lime water to the milk. This treatment, according to Bosworth and Bowdith (4), brings about a precipitation of calcium, phosphorus, and citric acid, a mixture of dicalcium phosphate (CaHPO₄) and tricalcium phosphate (Ca₃(PO₄)₂) being the insoluble phosphates formed. In the modification of milk, carbohydrates are often added. According to Aschenheim and Stern (2), pure milk and water mixtures show a more consistent coagulum than do the milk-oatmeal and milk-gruel mixtures. Of the latter, the milk-oatmeal gives the most flocculent coagulum, closely resembling that of human milk.

In spite of all these modifications, a great many delicate infants do not properly digest cows' milk. If it is possible to select cows that give milk which resembles very closely human milk in the curd that it forms with rennin, the feeding of infants will be greatly simplified. Present indications are that the curd test described in this article can be so used. The practical results obtained from the feeding of milk, shown by the test to be soft-curbed, indicate that the test is an index to the digestibility of the milk.

The following are a few of the many results obtained by
the use of this test in the selecting of milk for the feeding of infants. Part of these feeding cases are from the records of the Utah County Health Unit and were under the personal supervision of Lloyd L. Cullimore, M.D., and of Mrs. Evalina Reed, R.N., Utah County Health Nurse. The writer is indebted to the latter for the reports on these cases. However, the original county case numbers are not used in describing these cases.

Case No. 1. At birth (June 2, 1927) weighed 9½ 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 (4½ 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.
Since it is not the prerogative of the Utah Agricultural Experiment Station to conduct investigations on the feeding of infants, cooperation with physicians and clinics in the state has been welcomed. Statements from clinics and physicians using the soft-curded milk are herewith published in order to give to the public the opinions of those who have had most contact with the test as it is applied to the feeding of infants.

The following are abstracts from letters received and are published with the permission of the individual writers.

"I feel there has been no greater service rendered the modern baby, since so many have to be fed artificially, than that which located the soft-curded cows. For about one year now I have been using exclusively the soft-curded milk, when it could be had, with excellent results. I have also employed it with excellent success in feeding adult convalescent patients with gastric ulcers and other stomach disorders. I have observed it in about 100 cases. Some of these cases have been very difficult feeding problems, but all have responded to these feedings. Our only exception has been when the cows had been giving milk too long." (Lloyd L. Cullimore, M.D., Provo, Utah, May 23, 1928).

"I welcome the opportunity of expressing to parents, physicians, and all interested in child welfare, the great service which the Utah Agricultural Experiment Station is rendering to the people, giving them a means whereby the curd tension of cows' milk can be measured, thus rendering a digestible milk for infants who are deprived of mothers' milk.

"We have the curd-testing apparatus installed in the nine high schools of the county and a trained man to do the testing. From a group of over seven thousand infants and small children registered in our conferences, we have a very great number who owe their lives to the fact that a known soft-curded milk, easily digestible, can be secured. Our doctors are very much pleased with this service and feed only soft-curded milk to their delicate feeding cases. I believe it is rapidly solving the difficult problem in infant feeding.

"As infant welfare nurse for Utah County, let me again say I highly appreciate and value this means of securing a known easily digestible food for infants and small children." (Evalina Reed, R.N., Public Health Nurse of Utah County, May 28, 1928.)

"The discovery of a method for testing the curd of tension of cows' milk has brought to light something of great value in the feeding of babies. Many infants that do poorly on ordinary cows, thrive when a change is made to soft-curded milk. I recommend the soft-curded milk for the majority of artificially fed babies that come under my care. The results have been very satisfactory generally and in many cases remarkable. I certainly appreciate this addition to our knowledge of infant feeding and recommend the method as one that will give fine results in many different feeding cases." (Charles M. Smith, M.D., Provo, Utah.)

"For the past year in our artificial baby feeding we have been using soft-cur'd cows' milk, using formulae for diluting according to indications. We have been very much pleased and gratified with the results and feel that this is a big advance in infant feeding." (Clark Clinic—Stanley Clark, J. C. Clark, and Garn Clark, Provo, Utah.)

The following data represent cases from different parts of the state. At the time of publication of this bulletin, complete clinical data regarding these cases are not available.
Case No. 5. Baby was being fed from the mixed milk of a Jersey herd; the milk was not being digested and the curds were being regurgitated. Changed to Holstein milk but showed no improvement. On testing the herd it was found to vary from 200 to 63 grams in curd tension. Holstein milk tested 122 grams curd tension. Infant changed to 63-gram-tension milk in same herd. This milk was digested; it ceased to regurgitate curds; at the present time child is making splendid progress.

Case No. 6. Family with two cows; milk from one of these cows fed to baby. Did not digest the milk and was not gaining weight. Curd test of one of the cows showed a milk curd tension of 130 grams; the other showed a 25-gram milk curd tension. Baby had received the milk with 130-gram tension. When changed to the 25-gram-tension milk, from the initial feeding the milk was digested; most favorable results noted.

Case No. 7. Man with gastric ulcer. On a milk diet but had considerable hemorrhage. Was given soft-curded milk; hemorrhage ceased. On changing again to mixed-herd milk, hemorrhage recurred.

Case No. 8. Baby was fed the milk from two purebred Jersey cows. At irregular intervals it did not digest the milk and regurgitated it. One cow's milk was shown to be soft-curded, while the other was hard-curded. When the baby was fed from the soft-curded milk only, no further trouble resulted.

Case No. 9. Baby nine days old was fed on Holstein milk with a curd tension of 16 grams. The milk was boiled and one ounce of diluted orange juice added to seven ounces of milk. It was not otherwise modified. The baby digested the milk perfectly; did not regurgitate curds or have curded stools. It made splendid gain.

These and many other feeding cases would seem to warrant the assertion that the curd test properly applied to milk will give an index to its comparative digestibility by delicate infants. While most physicians prefer milk from a mixed herd for the feeding of infants, yet in every case where mixed-herd milk was compared to soft-curded milk from one cow in the feeding of infants it was shown to be inferior. The daily variation in the curd hardness from a mixed-herd milk may account for some of the digestive disturbances of infants using the milk. It is impossible at this writing to state just how hard-curded a milk can be and still be digested by infants. Some infants can digest a milk with a curd tension of 60 grams; others require a milk with about 20 to 30 grams tension for proper digestion. If the milk has a curd tension less than 20 grams very little modification is needed for infant feeding, and splendid results have been obtained when it was used unmodified.

SUMMARY

A curd test has been developed which may be used to determine the physical curd character of milk. By the use of this test the following facts have been demonstrated:

1. There is a range of from 15 grams to over 200 grams in the curd tension (hardness) of the milk from different cows.
2. Curd character of milk is an individual characteristic of the cow and is fairly uniform and apparently permanent.

3. The period of lactation has little effect on the curd character of the milk except at the beginning and at the end of the lactation period, when the curd is harder than normal. If the milk becomes abnormal at the end of the lactation period, the curd is usually softer than normal.

4. Since all breeds examined have both extremes in curd tension, it is assumed that curd character of the milk is not a breed characteristic. However, a larger percentage of the cows give soft-curded milk in some breeds than in others.

5. So far as the rations tried were concerned, curd character of the milk is independent of the feed of the cow.

6. When coagulated, boiled milk forms a curd which is only about 31 per cent as hard on the average as that obtained from raw milk. Pasteurizing milk at 143°F for one-half hour has little effect upon the hardness of the curd formed by its coagulation by pepsin. In some cases the curd is softened, while in others it is not.

7. The presence of butterfat in milk tends to soften the curd. Separated milk forms harder curds than whole milk. The fat content of milk is not an index to its curd character.

8. In some cases the physical curd character of the milk has been transmitted from dam to daughter. In one other case this character was not transmitted.

9. Feeding tests with infants so far observed indicate that the physical curd character of the milk, as determined by use of the curd test, is an index to the comparative digestibility of the milk by delicate infants. Before positive statements can be made it will be necessary to further continue the investigation.

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