THE EFFECT OF HEAT TREATMENT OF MILK FEEDINGS ON THE MINERAL METABOLISM OF INFANTS.*

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It has been observed that young rats fed long heat-treated milks—evaporated, condensed, and pasteurized by the "hold" process—fail to grow normally, the degree of stunting being proportional to the length of time of heating rather than to the temperature employed. For example, rats fed milk pasteurized by the "hold" process made only about half their normal growth; whereas, those fed milk pasteurized by the "flash" method, or quickly boiled, grew quite normally. Animals fed evaporated milk made scarcely any growth, while with those on the sweetened condensed milk, growth was comparable to that on milk pasteurized by the "hold" process. The nutritive failures in all cases appear to be due to the fact that during the process of heating, the calcium salts are thrown more or less out of solution and thus made less readily available to the animals, by adhering to the sides and bottom of the containers, or by more complete precipitation, most noticeable in evaporated milks. When care was taken to incorporate the precipitated calcium salts into the various milks by suspension in a starch paste, growth was normal. In the investigation there is nothing to indicate whether the results were due to a readjustment in the calcium, a change from the mono- and diphosphate to the triphosphate, or to a change in the colloid structure of the milk.2

It is conceivable that slight losses in the calcium content of cow’s milk subjected to various methods of heat treatment may

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have considerable influence on the nutritive condition of rats fed exclusively thereon, for their calcium requirement is relatively high; but that such losses should have a practical bearing on the artificial feeding of infants did not at first seem probable since the customary milk mixtures used in infants' feedings are considerably higher in calcium than is human milk. However, a study of the weight charts of a number of well babies in our clinic suggested that the method of "sterilizing" milk feedings may have a direct influence on the physiologic well-being of the baby. The particular babies under observation appeared normal in every way, although they were not gaining on pasteurized milk feeding mixtures which furnished considerably more food than is often considered necessary, and were on formulas which we had every reason to believe furnished enough of the various essential constituents. The feedings, which were carefully prepared by one of us, consisted of Holstein milk equal to 10 per cent or more of the body weight of the baby, cream in some cases, a carbohydrate addition, Dextri-Maltose or lactose, and boiled water. The usual ¹ ounce of orange juice was given daily, thereby ruling out the possible influence of the destruction of the antiscorbutic vitamin in the various mixtures. In a certain number of cases when the method of sterilizing the milk mixtures was changed from pasteurized to quickly boiled, growth which had hitherto been stationary, was at once resumed. The case of J. W. (Chart 1) is particularly noteworthy. On the same feeding mixture this baby's weight during two pasteurized periods remained stationary, while on the two boiled milk periods there was a marked increase in weight.

Although there is a considerable evidence pointing to the conclusion that the antineuritic vitamin as found in foods is thermostable at least up to 120°C., it is possible that some slight destruction may take place even at pasteurization temperatures, and in a mixture containing the vitamin in low concentration this would be evidenced by a stationary weight. Quick boiling

1 Theoretical weight, after Finkelstein = birth weight in grams + (age in months × 600) - 300 for first 6 months; birth weight + (age in months × 500) for the second 6 months.
**Chart 1.** Comparison of growth curves of babies fed milk mixtures pasteurized by the "hold" process during one period, and quickly boiled during a subsequent period.

**Chart 2.** The addition of wheat embryo extract to boiled milk feedings stimulated growth in the case of E. H.; whereas, the addition of this to the pasteurized feedings in the case of A. H. resulted in only a slight gain in weight. When this mixture was subsequently boiled there was a marked increase in weight.
may produce less change in the vitamin that the "hold" method of pasteurization. The weight increases, however, during the boiled milk periods, would seem to be the results of some factor other than the possible larger amount of the antineuritic vitamin of the boiled milk. The addition of 50 cc. of our water-alcoholic extract of wheat embryo (known to contain the antineuritic vitamin) to the pasteurized feedings of Baby A. H. (Chart 2) caused only a very slight increase in weight. When, subsequently, this milk mixture was boiled, there was a marked increase in weight, the result, apparently, of the combined influence of the shorter time of heating and the antineuritic vitamin addition.

Changes in the method of heat-treating the milk feedings have not resulted in growth stimulation in all our babies. It is possible that those children who failed to gain were receiving enough of the essential inorganic constituents, and the additional amount made available by the shorter heating was without influence; or there may have been other factors as yet unappreciated, concerned in the growth stimulation.

So far as we have been able to find the literature contains no data concerning the availability of the mineral constituents of milk "sterilized" by different methods. Söldner early pointed out that the lime salts in heated milk are not only useless for rennet coagulation but are also not suitable for absorption. Arndt and Cronheim and Müller studied the metabolism of calcium in infants on fresh and boiled milk. The results are not conclusive. Many comparative clinical studies of children fed milk, raw and boiled, and raw and pasteurized, have also been reported, but these were not sufficiently controlled to be of more than general interest.

The prevalence of rickets and the generally accepted hypothesis that rickets is the result of a faulty calcium and phosphorus metabolism led us to investigate the availability of the inorganic salts, more particularly the calcium and phosphorus in milk

8 Cronheim, W., and Müller, E., Jahrh. Kinderh., 1903, Ivii, 45.
feedings "sterilized" by the two more usual methods of heating, and to determine whether the growth stimulation in our babies following the change from pasteurized to quickly boiled feedings might not be in part, at least, the result of better calcium utilization.

In the investigation, mineral balance studies were made on normal boy babies varying in age from 3 to 7 months. And because previous experience had taught us that collections made by the busy undergraduate nurse could not be relied upon, during the period of study the babies were cared for day and night in the metabolism ward by graduate nurses trained in metabolism ward technique. These were on 8 hour shifts.

Especially care was taken in feeding the babies so that there were no refusals or food losses. By special adaptation of the Hoobler metabolism frame, stools and urine were collected quantitatively during 3 day periods. The fecal periods were marked off with charcoal prepared from cane-sugar. During some preliminary work, when the stools were not marked off, it was observed that the daily variations in the fecal calcium, phosphorus, and nitrogen were so great as to make us question the constancy of daily elimination; therefore, the procedure of marking off the stools for the 3 day period was adopted. With this method the differences in daily excretion were found to be relatively slight. As soon as the stools

<table>
<thead>
<tr>
<th>Baby W.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk.</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>Pasteurized.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Boiled.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Such results may not be averaged, and in the work reported have not been included because they seemed unreliable.
were passed they were thoroughly mixed with acid alcohol, dried on the water bath, pulverized, dried to constant weight, and an aliquot was taken for analysis. The urines were collected under toluene. Occasionally a "leak" occurred. In such instances, the collection for the day was discarded and a new period started. Creatinine determinations were made on each 24 hour specimen in order to check the completeness of the collections. These creatinine figures were found to be constant, varying only from 1 to 5 mg. from day to day. In the tables the average for the 3 day period is given.

Several days before the babies were put on the frame they were given the particular milk mixture to be tested. In all cases during the first period of a series, the milk feedings were pasteurized. In the second period, begun immediately after the close of the first period, the feedings were quickly boiled, no other change being made. Although the babies seemed perfectly contented and happy on the frame at all times, they were allowed a bed rest of 3 or 4 days before being returned to the frame for a second period. With a few of the older babies double periods were run. It is unfortunate that this was not possible in every case, but with many babies, especially the younger ones, it is not comfortable to hold them on a given milk mixture longer than 2 weeks.

The milk feedings were prepared with laboratory accuracy. Distilled water, free from all traces of calcium and magnesium, was used in making up the feedings and in diluting the daily dose of orange juice (1/6 ounce). Those mixtures to be pasteurized were distributed evenly in the requisite number of bottles (one for each feeding) and subsequently pasteurized at 145°F. for 30 minutes. With the boiled feedings, the ingredients were mixed in an open aluminum pan, brought quickly to the boiling temperature over a gas flame, and allowed to "roll up" three times, the entire process taking approximately 8 minutes. The feeding mixtures were then poured into the required number of sterile bottles. In both cases the filled bottles were cooled as quickly as possible in running water and kept on ice until needed. The samples of feeding mixtures taken for analysis were prepared similarly, an aliquot of the 24 hour mixture being used.

Since our chief interest in the investigation was concerned with the difference in the availability of the calcium and phosphorus
TABLE I.
Calcium (CaO) Retention in Infants Fed Pasteurized and Boiled Milk Mixtures.

<table>
<thead>
<tr>
<th>Case.</th>
<th>Age</th>
<th>Weight</th>
<th>Milk period.</th>
<th>CaO excretion (3 days).</th>
<th>CaO intake.</th>
<th>CaO retention.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Urine.</td>
<td>Fece.</td>
<td>Total.</td>
</tr>
<tr>
<td></td>
<td>mo.</td>
<td>gm.</td>
<td></td>
<td>gm.</td>
<td>gm.</td>
<td>gm.</td>
</tr>
<tr>
<td>M. I.</td>
<td>5</td>
<td>5,550</td>
<td>Pasteurized.</td>
<td>0.085</td>
<td>2.951</td>
<td>3.026</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,200</td>
<td>Boiled.</td>
<td>0.068</td>
<td>2.711</td>
<td>2.800</td>
</tr>
<tr>
<td>W. A.</td>
<td>6</td>
<td>6,400</td>
<td>Pasteurized.</td>
<td>0.148</td>
<td>3.290</td>
<td>3.357</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,500</td>
<td>Boiled.</td>
<td>0.121</td>
<td>2.915</td>
<td>3.036</td>
</tr>
<tr>
<td>G. V.</td>
<td>3</td>
<td>4,450</td>
<td>Pasteurized.</td>
<td>0.102</td>
<td>2.685</td>
<td>2.787</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4,620</td>
<td>Boiled.</td>
<td>0.069</td>
<td>2.307</td>
<td>2.376</td>
</tr>
<tr>
<td>M. P.</td>
<td>7</td>
<td>6,925</td>
<td>Pasteurized.</td>
<td>0.112</td>
<td>3.870</td>
<td>3.982</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,000</td>
<td>Boiled.</td>
<td>0.087</td>
<td>3.811</td>
<td>3.898</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,175</td>
<td>Pasteurized.</td>
<td>0.105</td>
<td>3.769</td>
<td>3.874</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7,350</td>
<td>Boiled.</td>
<td>0.090</td>
<td>3.761</td>
<td>3.860</td>
</tr>
<tr>
<td>G. G.</td>
<td>7</td>
<td>6,050</td>
<td>Pasteurized.</td>
<td>0.184</td>
<td>3.135</td>
<td>3.319</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,400</td>
<td>Boiled.</td>
<td>0.062</td>
<td>2.611</td>
<td>2.673</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,550</td>
<td>Pasteurized.</td>
<td>0.081</td>
<td>3.221</td>
<td>3.302</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,700</td>
<td>Boiled.</td>
<td>0.094</td>
<td>2.503</td>
<td>2.686</td>
</tr>
<tr>
<td>D. W.</td>
<td>6</td>
<td>5,765</td>
<td>Pasteurized.</td>
<td>0.107</td>
<td>4.389</td>
<td>4.496</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5,950</td>
<td>Boiled.</td>
<td>0.108</td>
<td>3.795</td>
<td>3.903</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,225</td>
<td>Pasteurized.</td>
<td>0.108</td>
<td>4.422</td>
<td>4.530</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6,475</td>
<td>Boiled.</td>
<td>0.106</td>
<td>3.848</td>
<td>3.954</td>
</tr>
</tbody>
</table>
on the different types of heat-treated milks, only those data are reported which point to this end; namely, the calcium and phosphorus content of the milk feedings, urines, and feces, the nitrogen balances, and the urinary creatinines.

The calcium determinations were made according to the method of McCrudden, excepting in the case of the urines. The calcium content of infants' urine is so low that it was found that more uniform results were obtained when the urines were evaporated to dryness with nitric and hydrochloric acids to remove the organic matter, and analyses were made on the residues. 25 cc. of the sodium acetate solution were used in all cases instead of the 10 to 15 cc. recommended. Phosphates (as $P_2O_5$) were determined as the phosphomolybdate and the final precipitate was weighed as magnesium pyrophosphate. Creatinine determinations were made according to the micro method of Folin and total nitrogen by the Kjeldahl-Gunning method.

Either duplicate or triplicate determinations were made in all cases, depending upon the amount of material. When there was any question concerning a given result, second duplicate determinations were made. The figures reported are the checks, not the averages, of the various analyses.

The results of the investigation are summarized in Tables I to IV.

The most significant findings in the investigation are the conspicuously greater calcium retention in many of the babies during the boiled milk periods. In one case, Baby D. W., who was in negative calcium balance during both pasteurized milk periods, retained over eight times as much calcium during the first boiled milk period, and in the second series over six times as much calcium, as in the corresponding pasteurized milk periods. Had this baby been continued on pasteurized feedings, he would undoubtedly have developed rickets, although at the time the baby was being studied there were no apparent rachitic symptoms. The results with Baby G. G. were only slightly less striking, from two to three times as much calcium oxide being retained

12 Folin, O., *J. Biol. Chem.*, 1914, xvii, 469.
on the boiled feedings. It would seem from these results that
the calcium in milk pasteurized by the "hold" method is less
readily available than it is in quickly boiled milk.

### TABLE II.
**Phosphorus (P\textsubscript{2}O\textsubscript{5}) Retention in Infants Fed Pasteurized and Boiled Milk Mixtures.**

<table>
<thead>
<tr>
<th>Case</th>
<th>Milk period</th>
<th>(P_{2}O_{5}) excretion (3 days)</th>
<th>(P_{2}O_{5}) intake</th>
<th>(P_{2}O_{5}) retention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Urine, Feces, Total</td>
<td>3 days</td>
<td>Daily per kg.</td>
</tr>
<tr>
<td>M. I.</td>
<td>Pasteurized</td>
<td>2.450, 1.570, 4.020</td>
<td>4.498, 0.270</td>
<td>0.478, 0.028</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.391, 1.440, 3.831</td>
<td>4.498, 0.241</td>
<td>0.666, 0.035</td>
</tr>
<tr>
<td>W. A.</td>
<td>Pasteurized</td>
<td>2.368, 1.740, 4.108</td>
<td>4.498, 0.234</td>
<td>0.390, 0.020</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.038, 1.973, 4.011</td>
<td>4.498, 0.231</td>
<td>0.487, 0.025</td>
</tr>
<tr>
<td>G. V.</td>
<td>Pasteurized</td>
<td>1.429, 1.773, 3.202</td>
<td>3.435, 0.257</td>
<td>0.233, 0.017</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>1.551, 1.473, 3.024</td>
<td>3.435, 0.248</td>
<td>0.411, 0.029</td>
</tr>
<tr>
<td>M. P.</td>
<td>Pasteurized</td>
<td>2.578, 2.608, 5.476</td>
<td>5.298, 0.255</td>
<td>-0.178, -0.008</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.761, 2.569, 5.330</td>
<td>5.298, 0.252</td>
<td>-0.032, -0.001</td>
</tr>
<tr>
<td>G. G.</td>
<td>Pasteurized</td>
<td>2.529, 2.073, 4.602</td>
<td>4.884, 0.269</td>
<td>0.282, 0.015</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.338, 2.054, 4.392</td>
<td>4.884, 0.254</td>
<td>0.492, 0.025</td>
</tr>
<tr>
<td>D. W.</td>
<td>Pasteurized</td>
<td>2.076, 3.088, 5.164</td>
<td>5.559, 0.326</td>
<td>0.395, 0.023</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.422, 2.543, 4.965</td>
<td>5.559, 0.311</td>
<td>0.594, 0.033</td>
</tr>
<tr>
<td></td>
<td>Pasteurized</td>
<td>2.639, 2.519, 5.158</td>
<td>5.559, 0.298</td>
<td>0.401, 0.021</td>
</tr>
<tr>
<td></td>
<td>Boiled</td>
<td>2.457, 2.525, 4.982</td>
<td>5.559, 0.286</td>
<td>0.577, 0.029</td>
</tr>
</tbody>
</table>

It is well known that the greater part of the calcium eliminated
from the body is by way of the tract; nevertheless, if the different
methods of heat-treating the milk mixtures results in a change
in the form of the calcium contained therein, thereby making it
less available, we should expect that this would be made mani-
fest by a somewhat greater output in the stools of the babies.
when they were receiving the longer heat-treated milk. Such was found to be the case. With two of the babies on the double periods (G. G. and D. W.) it will be observed that the fecal calcium was practically the same on the two pasteurized milk periods,

**TABLE III.**

**Nitrogen Retention in Infants Fed Pasteurized and Boiled Milk Mixtures.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Creatinine 3 days.</td>
<td>Urine</td>
<td>Feces</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(mg)</td>
<td>(gm)</td>
<td>(gm)</td>
</tr>
<tr>
<td>M. I.</td>
<td>Pasteurized.</td>
<td>251 7.74</td>
<td>10.82</td>
<td>2.95 0.158</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>258 6.26</td>
<td>8.67</td>
<td>2.64 0.135</td>
</tr>
<tr>
<td>W. A.</td>
<td>Pasteurized.</td>
<td>245 7.14</td>
<td>8.16</td>
<td>2.46 0.128</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>241 6.64</td>
<td>8.08</td>
<td>2.64 0.135</td>
</tr>
<tr>
<td>G. V.</td>
<td>Pasteurized.</td>
<td>174 4.64</td>
<td>5.48</td>
<td>2.17 0.162</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>171 4.21</td>
<td>4.90</td>
<td>2.75 0.199</td>
</tr>
<tr>
<td>M. P.</td>
<td>Pasteurized.</td>
<td>233 10.06</td>
<td>11.30</td>
<td>1.18 0.056</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>228 8.49</td>
<td>9.76</td>
<td>2.72 0.130</td>
</tr>
<tr>
<td></td>
<td>Pasteurized.</td>
<td>236 9.20</td>
<td>10.34</td>
<td>2.65 0.123</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>229 8.18</td>
<td>9.36</td>
<td>3.63 0.165</td>
</tr>
<tr>
<td>G. G.</td>
<td>Pasteurized.</td>
<td>233 7.19</td>
<td>8.21</td>
<td>2.71 0.149</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>232 7.21</td>
<td>8.25</td>
<td>2.67 0.139</td>
</tr>
<tr>
<td></td>
<td>Pasteurized.</td>
<td>229 8.27</td>
<td>9.47</td>
<td>2.21 0.113</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>234 7.97</td>
<td>9.27</td>
<td>2.41 0.119</td>
</tr>
<tr>
<td>D. W.</td>
<td>Pasteurized.</td>
<td>236 8.50</td>
<td>10.41</td>
<td>3.30 0.194</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>232 9.85</td>
<td>11.40</td>
<td>2.31 0.129</td>
</tr>
<tr>
<td></td>
<td>Pasteurized.</td>
<td>233 10.37</td>
<td>13.71</td>
<td>1.87 0.099</td>
</tr>
<tr>
<td></td>
<td>Boiled.</td>
<td>235 10.09</td>
<td>13.71</td>
<td>2.39 0.124</td>
</tr>
</tbody>
</table>

and within the limits of experimental error on the two boiled milk periods. It seems reasonable to suppose that the differences in the amount of calcium lost through the bowel on the two types of heat-treated milk feedings are the result of changes incidental to the heating processes.
Very little is known positively concerning the conditions which determine the excretion of calcium through the kidneys. The urinary calcium in our series did not run parallel with the fecal calcium. In some cases it was considerably higher on the pasteurized milk feedings; in other cases, it was the same or slightly lower. Were it not for our creatinine values we would be led to believe that these variations were due to incomplete urine collections. As it is, we are unable to offer any explanations for the seemingly discordant results.

The total phosphorus retention on the two types of heat-treated milks was fairly consistent with the calcium retentions, and in all cases was considerably greater during the boiled milk feedings. The relationship, however, between the fecal phosphorus during the two types of milk feedings is not so marked as in the case of the fecal calcium. In some instances there was slightly more phosphorus in the stool during the pasteurized milk feedings, in others the fecal phosphorus was the same, or slightly greater on the boiled milk periods. The urinary phosphorus, on the other hand, was in general higher during the pasteurized milk periods. The increased phosphorus retention in our babies appears to be due to a metabolic adjustment rather than to a greater absorption.

The data relative to the nitrogen excretion have been included in the report to show, first, that our babies were getting a liberal allowance of protein, and second, that there appears to be some relationship between the calcium, phosphorus, and nitrogen retentions. It will be noted that in all but two cases there was an increased nitrogen retention during the boiled milk period. The conspicuously greater retention in Baby D. W. during the first pasteurized milk period may possibly be explained by the fact that the baby was slightly underfed during the preliminary experimental period although we did not appreciate it at the time. During the 1st night on the frame it was observed that the baby at about 2.00 a.m. seemed very restless and hungry. The nurse in charge, knowing that the baby must be held on the given formula for 2 or 3 weeks, gave him a 2 o’clock bottle, which practice was continued throughout the observation periods. This sudden increase of food, although disturbing the nitrogen retention sequence in the first period, did not appear to alter the calcium and phosphorus relationships.
The fecal nitrogen was not consistently greater during the pasteurized milk periods. In many cases it was the same in both periods. The urinary nitrogen, on the other hand, was in
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general higher during the pasteurized milk period. It would seem, therefore, that the pasteurization process did not affect the availability of the protein of the milk, but that the greater retention of nitrogen during the boiled milk periods was related to the calcium and phosphorus retentions. Furthermore, it is probable that the increase in weight in those babies who were holding on pasteurized milk feedings and gained when the mixtures were subsequently boiled, was due to the greater nitrogen retention. More data, however, on this point are needed before conclusions can be drawn.

A comparison of the data relative to the calcium and phosphorus retention in our babies with those of certain other investigators suggests that our babies even under the most favorable conditions, during the boiled milk periods, were retaining considerably less than what is generally considered the optimum amount of calcium. Holt, Courtney, and Fales13 observed that the average absorption of calcium by breast-fed babies was 0.06 gm. per kilo, and of those fed cow's milk, 0.09 gm. of calcium oxide per kilo of body weight; whereas, our infants were retaining only from 0.008 to 0.055 gm. per kilo with an average of 0.030 on the boiled milk periods, and considerably less on the pasteurized milk periods, in spite of the fact that an adequate amount of fat (4 gm. per kilo13) was being ingested. It should be noted, however, that the majority of the so called normal babies reported by Holt, Courtney, and Fales were considerably underweight. Whereas, ours had gained regularly from birth and were up to the generally accepted standard of weight for their ages. They had no apparent sign of rickets or other physical stigma. It is possible that the lower retention in our babies was due to the fact that they were more nearly "full" of the various essential constituents and thus the retention was less than that found by other workers. On the other hand, it is probable that the calcium requirements of a baby are, in part, determined by its skeletal development. An underweight baby may have the same calcium needs as a normal baby of the same age. A study of the data given by the above mentioned authors from the standpoint of the theoretical weights of the babies, suggests that the calcium requirement of

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Infants on cow's milk is more nearly in accord with the requirements as given for the breast-fed baby, namely 0.06 gm. per kilo; but even this figure is considerably higher than that found by certain other investigators. The breast-fed babies reported by Czerny and Keller\textsuperscript{14} on the basis of their theoretical weights were retaining an average of 0.027 gm. of calcium oxide per kilo; whereas, the artificially fed babies reported by these authors were retaining an average of 0.031 gm. per kilo. Lindberg\textsuperscript{15} reports a daily calcium oxide retention of 0.056 and 0.063 gm., respectively, in a 2\(\frac{1}{2}\) months' breast-fed infant, during two successive 3 day periods. On the basis of its theoretical weight this baby was retaining 0.012 and 0.038 gm. per kilo per day in the two periods. Tobler and Noll\textsuperscript{16} also found what seemed to be a low calcium oxide retention. A 2\(\frac{1}{2}\) months' old breast-fed baby was retaining 0.053 gm. of calcium oxide or 0.0115 gm. per kilo, estimated on its theoretical weight. These findings are more nearly in accord with those we obtained in our 3 months' old artificially fed baby (G. V.), who during the boiled milk period was retaining 0.014 gm. of calcium oxide.

Schloss,\textsuperscript{17} on the other hand, working with older rachitic infants, found in one case a daily calcium oxide retention of 0.024 gm. per kilo (theoretical weight) under most favorable conditions, when cod liver oil was given; and in a second case, a daily calcium retention of 0.013, 0.027, and 0.057 gm., respectively, on three successive cod liver oil periods in which the second contained phosphorized cod liver oil. This child was in negative calcium balance and presumably was depleted when the cod liver oil was added to the food. He probably was retaining somewhat more than the average amount of calcium during the cod liver oil periods, for Schabad\textsuperscript{18} has shown that when convalescence or cure in rickets begins there is a greatly increased retention of calcium, which shows itself earlier than does clinical improvement. Besides

\textsuperscript{15} Lindberg, G., Z. Kinderh., Orig., 1917, xvi, 90.
\textsuperscript{17} Frank, L., and Schloss, E., Jahrb. Kinderh., 1914, lxxix, 539.
the factor of underweight in the babies reported by Holt, Courtney, and Fales, there may have been this added factor, depletion, and therefore the larger calcium oxide retention.

A comparison of the phosphorus retention in our babies on boiled milk mixtures with that of breast-fed infants suggests that in most instances our babies were retaining fairly liberal amounts of phosphorus. Tobler and Noll\(^\text{18}\) report a case of a 2½ months’ old breast-fed baby who was retaining 0.119 gm. or 0.023 gm. per kilo on its theoretical weight, and Lindberg\(^\text{15}\) found in two successive periods a 2½ months’ old breast-fed baby retained 0.04 and 0.03 gm. per kilo, respectively. These figures are in accord with the findings in our 3 months’ old baby who was retaining 0.162 or 0.029 gm. of phosphorus per kilo. Hoobler\(^\text{19}\) on the other hand, obtained a phosphorus retention of 0.093 or 0.015 gm. per kilo in a 5 months’ old breast-fed baby; whereas, our 5 months’ old baby (M.I.) was retaining, on quickly boiled milk, 0.035 gm. per kilo.

What the optimum amount of calcium and phosphorus, infants of different ages should retain, is apparently unknown. Such information can only be obtained through studies of many babies under various conditions. The seemingly lower retentions in some of our cases may have been due to the fact that these babies were more nearly “full” of the various essentials; and thus the total retentions were less than those reported by certain other workers. Or it may be that the types of artificial feedings used were not such as to best meet the nutritive requirements of infants. Some more recent investigations which will be reported in the near future suggest that this may be the case. It is also possible that the difference in the method of collecting the stools explains some of the apparent discrepancies in the literature. The point we wish to make, however, is that the method of heat-treating the milk materially influences the availability of the calcium and phosphorus of the feeding mixture. Pasteurization may be the best method of making milk more nearly safe for infant feeding, although this has recently been questioned, but such heat-treated milk does not seem to be the most satisfactory from the standpoint of fulfilling the physiologic needs of the baby.

SUMMARY.

1. In certain instances babies, who were holding in weight on given milk mixtures when pasteurized by the "hold" method, gained when the mixtures were quickly boiled, no other change being made.

2. Attention is called to the fact that in making calcium balance in infants, it is essential that stools be carefully marked off. When this was done it was found that the fecal elimination on the same diet was very constant.

3. The calcium and phosphorus retention in infants fed quickly boiled milk mixtures was considerably greater than it was when the milk mixtures were pasteurized.

4. The fecal calcium and phosphorus were greater during the period when pasteurized milk feedings were given, indicating that the longer heat treatment of milk results in a decrease in the availability of the phosphorus and calcium in the milk mixtures.

5. There appears to be some relationship between the calcium, phosphorus, and nitrogen retentions.

6. It seems probable that the calcium needs of children are very largely determined by their skeletal development. In determining the calcium needs of normal children it would seem more nearly fitting to include only those who are up to standard in weight, or to determine the calcium needs on the basis of the theoretical weights of the infants.

7. It is probable that a baby fed pasteurized milk over a long period of time is receiving too little calcium for his growth needs.
THE EFFECT OF HEAT TREATMENT
OF MILK FEEDINGS ON THE MINERAL
METABOLISM OF INFANTS
Amy L. Daniels and Genevieve Stearns


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