THE NUTRITIVE VALUE OF BOILED MILK*

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The experimental work involved in this report is the result of an attempt to determine the comparative nutritive efficiency of milk heated to different temperatures. There is considerable evidence in the literature to the effect that scurvy among infants may be caused by feeding cooked milk exclusively; in fact, this notion is so prevalent that many pediatricians still insist on giving raw cow's milk, notwithstanding that the hygienic conditions of this may be far from desirable. It is only in our larger cities that certified milk may be obtained, and even here the price makes it prohibitive for the great majority of homes.

In order to meet present conditions and to make milk more nearly safe for infant feeding, the practice of pasteurizing or boiling has been resorted to. Pediatricians differ as to the relative value of these two processes. The European pediatricians¹ report excellent results with boiled milk—the time of boiling varying within comparatively wide limits. The American pediatricians, on the other hand, have favored the pasteurization process. However, the fact that casein curds sometimes found in the stools of infants fed either raw or pasteurized cow's milk are almost unknown in the European clinics, leads us to believe that boiled cow's milk may be better digested by infants than raw or pasteurized. This assumption is further borne out by the work of Brenneman,² who has shown that the clot formed from boiled cow's milk during gastric digestion more nearly resembles the clot formed during the digestion of woman's milk. It is much finer than that formed from raw milk, thus making for more complete digestion and absorption further on in the digestive tract. But conclusive experimental evidence as to the relative nutritive value of raw and cooked milk is lacking, owing to the fact that the experiments with animals have been continued for too short a time, and in the case of

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1. The literature has been reviewed by Lane-Claypon. Report to the Local Government Board, London. New Series, 1912, No. 63.
babies, other substances, such as cereal waters, or various fruit juices have been superimposed on the basal diet. Furthermore, in many cases, the records leave one in doubt as to just what is meant by boiling. It is conceivable that milk brought just to the temperature of 100 C. is less changed chemically than that sustained at this temperature for a considerable period. The importance of knowing more definitely regarding the nutritive efficiency of pasteurized milk and milk boiled for different lengths of time, is obvious.

**PLAN OF INVESTIGATION**

In our investigation, rats just past the suckling period were fed milk boiled one minute, five minutes, and forty-five minutes, respectively. Other rats were fed pasteurized milk and one group was given milk heated in an autoclave to a temperature of 114 C. for forty-five minutes. Rats on raw milk were used as controls. In each case, the milk was supplied *ad libitum*; as soon as the containers were emptied, these were refilled. During our preliminary trials, the experimental animals were given daily in addition to the milk, 10 gm. of a cooked cornstarch-agar-agar mixture, consisting of 15 per cent. cornstarch, 2 per cent. agar-agar, and 83 per cent. water. But since later work showed that defecation took place normally in the absence of this, it was discontinued.

**RESULTS OF EXPERIMENTS**

The growth curves of all animals fed milk boiled one minute and ten minutes, respectively, are surprisingly uniform (Charts 1 and 2). In no case, however, do these conform to the normal growth curves as given by Osborne and Mendel and McCollum and Davis. During the first six weeks of the diet, growth was apparently normal. From this time on, the weight curves show little or no gain. The curve of growth of those animals fed milk boiled forty-five minutes (Charts 2 and 3) show considerable variation; none of these, however, is in accord with the normal growth curve. This variation, we believe, is explained by the fact that during the early part of the investigation we had some difficulty in keeping the rats from killing one another. On several occasions, small portions of the dead animals were eaten. Those animals (Chart 5) fed milk heated during forty-five minutes at 114 C. grew for a short time at about the same rate as those animals given milk heated to the lower temperature. Nutritive disaster, however, was much more sudden. All animals fed this diet exclusively, died within eleven weeks of the beginning of the experiment, whereas

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3. The process involved consisted in heating the milk to 83 C. by passing it over heated drums and then cooling it immediately.
the animals which received milk heated only to the boiling point lived many months. But what is even more significant than the slow growth, is the fact that we never had reproduction with any of our experimental animals fed boiled milk, although many were long past the period of sexual maturity, and in many cases, their weight was greater than our normal animals which were reproducing.

The value of raw milk as a food which meets all the nutritive requirements for growth and reproduction has been shown by various investigators. McCollum fed a pig for a period of 395 days on raw cow's milk. It grew from a 23-pound animal to one weighing 406 pounds. During this time the sow gave birth to two dead and eight living young, each weighing from 2 to 3 pounds. The latter were suc-

Chart 1.—Curves of growth of rats fed milk boiled one minute. Rats 18 and 20 (Period 2) show the influence of the addition of small amounts of egg to the diet. The addition of casein from boiled milk also caused growth to be resumed. (Rat 21, Period 3). The addition of neither 6.5 per cent. sucrose (Rats 16, 19, 21 and 22, Period 4), nor of dextrimaltose (Rats 16, 21 and 22, Period 5), caused an appreciable increase in weight. The curve of normal growth is represented by the broken line.

cessfully suckled. Osborne and Mendel state that in their "numerous experiments milk has proved to be an adequate food both for growth and maintenance. Young rats fed solely on a milk food which we have been accustomed to use, not only have grown from infancy to full maturity, but have also given birth to litters of normal young. . . . One must conclude from these facts that the milk food con-

tains all that is essential for both growth and maintenance." The milk food referred to consists of a mixture of milk powder, starch, and lard. We infer that in these experiments in which the authors state that milk has proved to be an adequate food, milk powder was used. Wheeler\textsuperscript{6} reports normal growth over a period of sixty days in mice fed raw cow's milk to which was added 6.5 per cent. sucrose. There are no records of reproduction with these mice, but we have no reason to doubt that, had the experiment continued longer, this would have taken place.

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the early part of the growth period than with either boiled or pasteurized milk; in fact, we have been unable to keep rats alive on this diet. Three of a group of six on raw milk exclusively, died. Two others, apparently doomed, were given very small amounts of other food material—eggs, toast, fruit, etc.—in addition to the raw milk. Normal growth was at once resumed. Other rats fed raw milk to which was

![Chart 4](http://archpedi.jamanetwork.com/)

Chart 4.—Curves of growth of rats fed milk boiled forty-five minutes. The addition of well-washed egg yolk to the boiled milk diet caused growth to be resumed in Rats 13 and 25. The curve of normal growth is represented by the broken line.

added daily a small amount of beef extract (0.3 gm. per rat) grew at the normal rate (Chart 8, Rats 70, 72, 73, 74). Rat 71, the only female of the group, received raw milk for four weeks. During the third week there was no gain. Beef extract was then added to the diet; growth was at once resumed, and four weeks later this animal gave

![Chart 5](http://archpedi.jamanetwork.com/)

Chart 5.—Curves of growth of rats fed milk heated to 114 C. during forty-five minutes. The addition of egg yolk to the diet of Rat 36, and egg white to the diet of Rat 34, caused growth to be resumed. The curve of normal growth is represented by the broken line.

birth to two living young. These were successfully suckled. For three weeks following the weaning period two rats (Chart 7, Rats 64 and 65) were given raw milk plus small amounts of meat extract.
These were then transferred to the untreated raw milk diet and continued to grow at the normal rate for about four weeks. Following this, there was a decline in weight. Another raw milk animal (Chart 7, Rat 63) which was about to die, was given a mixed diet for three days and then returned to raw milk. Growth was at once resumed.

Those animals on pasteurized milk grew normally for about five weeks and then began to lose weight. Four died. Four others (Chart 6, Rats 42, 43, 44, 46) which were in the same moribund condition as those which died, were given small amounts of meat extract (0.3 gm. per rat) added to the pasteurized milk. Recovery followed and the animals continued to grow at the normal rate during the time of the investigation period.

DISCUSSION OF RESULTS

We appreciate that criticism may be made to the effect that our animals were not kept under strictly aseptic conditions and that our failure to raise rats on either raw or pasteurized milk exclusively may be due to bacterial invasion. The results cited above, however, show that such cannot be the case, for all of our animals were kept under the same conditions. Apparently raw cow's milk is not well borne by young rats. By boiling, the milk has been made more digestible, but at the same time it has been chemically so changed as to render it an inadequate food. These results are comparable with those of other investigators who have shown that boiled milk of another species may be better borne than raw milk of another species. The milk powder used by Osborne and Mendel was apparently in such form as to be easily digested.

The part played by the beef extract in increasing the nutritive efficiency of raw and pasteurized milk is not clear. Obviously, the
increase in weight of our animals is much more than can be accounted for by the increase in the calorie value of the food ingested. Furthermore, the addition of the same amount of the extract to boiled milk caused no increase in weight during the brief experimental period—two weeks (Chart 3, Rat 8). It is well known that this material contains measurable amounts of amino-acids and inorganic salts, as well as very small quantities of soluble proteins, and the so-called extractives of muscle. But we can hardly believe that milk is deficient in those amino-acids essential for growth; nor can we think that the inorganic material is insufficient, since such noteworthy results have been obtained in investigations in which the mineral content of the food has been similar to that of milk. It is probable that the explana-

Chart 7.—Curves of growth of rats fed raw milk. Rats 64 and 65 received raw milk plus small amounts of beef extract during the first five weeks. From this time raw milk only was given. Rats 63 and 66 received a mixed diet for three days following a raw milk diet; the raw milk diet was then resumed.

The failure of our rats to grow normally and reproduce when fed milk heated to a temperature of 100 C. or over, is undoubtedly due to the destruction, at least in part, of one or more of the essential constituents of milk. There is considerable evidence that high temperatures bring about definite chemical changes in the proteins of the milk.

Rettger found that on heating milk above 85 C. a partial decomposition of milk protein occurs, resulting in the liberation of volatile sulphid. Earlier work by Schulz showing that one of the sulphur cleavage products of albumin, namely, cystin, gave off only part of its sulphur by boiling with alkali, suggests that in the process of heating milk some of the cystin is destroyed. It is possible that the chief protein of milk is somewhat deficient in this essential amino-acid; when some of this is destroyed by heating, there is too little left to furnish the adequate amount for growth and reproduction. This theorem is further enhanced by the work of Osborne and Mendel. These investigators have shown that rats can be maintained on a very much smaller amount of casein as the sole protein in an otherwise adequate diet if cystin is added. Our experience seems to bear this out. Two rats (Chart 1, Rats 19 and 20) which had ceased to grow on milk boiled one minute, were given daily in addition to the regular diet 13

Chart 8.—Curves of growth of rats fed raw milk. Rat 71 received raw milk for four weeks following the weaning period; from this time a small amount of beef extract was added daily to the raw milk. Rats 70, 72 and 73 received raw milk and beef extract during the entire experimental period.

gm. of hard cooked egg. Within a very few days there was a marked improvement in appearance. Rapid growth then followed and the female, two months later, gave birth to a litter of eleven young. Hard cooked egg yolk, from which all soluble material had been removed by repeated washing, was as efficient as the whole egg in correcting the deficiency of heated milk (Chart 4, Rats 14 and 25). The addition of casein, precipitated from boiled milk and having a protein content equivalent to nearly twice that supplied by the egg, also caused growth to be resumed (Chart 3, Rats 6 and 10; Chart 1, Rat 21). Up to

the present time—eight weeks after the beginning of the casein diet—we have had no reproduction in these rats. It appears, therefore, that the protein of egg is more efficient as a corrective of the defects of heated milk than is an increased amount of casein. Nevertheless, we must not fail to appreciate that there may be other contributing factors, such as the inorganic materials, growth determinants, etc., present in the egg yolk or present in larger proportions than in the casein. The practice among some pediatricians of feeding babies with boiled or pasteurized milk mixtures having a higher protein content than is usual for raw milk feeding, is noteworthy in this connection. Also the practice of introducing egg yolk into the diet of infants fed on cooked cow's milk at an earlier age than those fed on mother's milk, is apparently justified.

The increase in weight in our animals to which small amounts of egg, in some cases, and casein in others, were added, might seem to be explained by the increase in the caloric value of the food ingested. Experiments aimed to determine this point were tried. To the diet of rats fed boiled milk was added 6.5 per cent. sucrose, 6.5 per cent. lactose, and 6.5 per cent. dextrimaltose, respectively. The very slight and not well sustained increase in some cases (Charts 1 and 3, Rats 16, 18, 8, 10 and 11) and the lack of increase in others (Charts 1 and 3, Rats 19, 21 and 22) show that this cannot be the explanation. Moreover, the fact that rats can grow normally and reproduce on raw milk to which small amounts of meat extract are added, indicates that the animals are able to ingest enough milk to fulfil physiologic requirements.

**SUMMARY**

Our results point to the conclusion that milk heated to the boiling temperature or thereabouts is an inadequate food. Rats fed on boiled milk grew to about half their normal size. Although we have been able to keep these experimental animals for many months on boiled milk, in no case have we got reproduction, nor have any of our animals reached the normal weight for adult rats.

Milk which is kept at the boiling temperature for forty-five minutes is no less efficient as a food than milk boiled for much shorter periods—ten minutes or one minute. The chemical changes which make heated milk an inadequate food are brought about at the boiling temperature or thereabouts. The value of pasteurized milk as a food, therefore, will depend on the temperature to which it is heated during the pasteurization process. Heating milk to a higher temperature than boiling (114 C.) makes it even less valuable as a food.
Although boiled cow’s milk is an inadequate food for rats, it is apparently better borne than raw or pasteurized cow’s milk, for we have been unable to raise young rats on either exclusively. However, rats fed both raw and pasteurized milk to which small amounts of meat extract were added grew at the normal rate. The explanation of this lies, possibly, in the fact that the meat extract caused an increase in the digestive secretions, thus making the milk more available.

The advantage of using raw milk for infant feeding is obvious. When babies are unable to digest raw cow’s milk, however, or there is danger that the milk may be contaminated, we believe that the pediatrician is justified in using boiled milk. When this is given, the mixture should have a higher protein content than when raw milk is used.