

AN EXPERIMENT WITH RAW AND HEATED COW'S MILK
AND ITS LESSON. WITH COMMENTS ON
BACILLUS ABORTUS *

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In January, 1910, my assistant Dr. George W. Brett and I undertook an investigation on the relative value of raw, pasteurized and boiled cow's milk as a food for unweaned animals. Experimental studies on this subject commonly have one or both of two weaknesses — the use of an insufficient number of animals and an inadequate period of time during which observations are made; hence Dr. Brett and I determined to use the largest number of animals we could properly handle and keep them under observation in all cases from birth until they died or reached adult life, and in some cases after they had reached adult life, to test their vital efficiency as far as this would be measurable by the number and vigor of their progeny during one year.

The animals selected for our investigation were guinea-pigs, as they were the only species of which a sufficient number of the proper age and a definitely known history could be obtained. We realized that data derived from guinea-pigs could not be applied, off-hand, to all species of animals that are at times fed on cow's milk under artificial conditions as a substitute for mother's milk under natural conditions, but we assumed that they would have a fairly broad significance, especially as the main argument against the use of heat to destroy those disease germs with which ordinary commercial milk is too often contaminated, and which cannot be excluded unfailingly from milk that is produced with unusual precautions under exceptionally favorable conditions, is that milk contains important thermolabile enzymes and that its proteins and lime salts are modified by heat in a way that reduces their digestibility and food value.

If heat reduces the quality or the value of the milk provided by Nature for the young of cattle, it is not unreasonable to assume that this can be shown as well or better by tests with guinea-pigs, or animals that require food much like that of cattle, as with animals that are designed to digest food of a wholly different kind. The assumption, on the other hand, that cow's milk includes anything in its physical or chemical

* Attention is called to the paper of Larson and Sedgewick in this issue on the *Bacillus abortus*.

character, thermolabile or thermostabile, that has more value for infants than for the young of cattle or other truly vegetarian species of animals, on general biological principles, is hardly tenable, as Nature cannot reasonably be supposed to provide through the mothers of one species of animals for the needs of the progeny of another wholly unrelated and distinct species.

From one point of view guinea-pigs are not ideal animals for an investigation of the kind we made, and that is their remarkable development at birth and the short period of time during which they are dependent on their mothers for sustenance. But in this respect calves and young guinea-pigs, if we take the respective sizes and lengths of life of cattle and guinea-pigs into consideration, are much alike. Both species are born with their eyes open and their bodies well coated with hair; both are able to move about with ease on their own feet a few hours after birth, and neither has a long period during which milk is an essential article of food. Guinea-pigs are weaned when they are about 20 days old, and calves when they are from 5 to 8 weeks old. Hence, calves and guinea-pigs should be benefited more nearly alike by anything of a thermolabile character in cow's milk, or should suffer more nearly alike from changes induced in cow's milk through its exposure to heat, than calves and infants, or than calves and young animals that are less developed at birth and longer dependent on a milk diet.

The guinea-pigs used in the investigation, a total of 467 that were artificially fed on cow's milk, were removed from their mothers immediately after they were born and divided into three groups as follows:

- Group 1, 155 guinea pigs, fed raw milk.
- Group 2, 156 guinea pigs, fed pasteurized milk.
- Group 3, 156 guinea pigs, fed boiled milk.

As this large number of new-born animals could not be secured or properly handled at one time, notwithstanding that the guinea-pig breeding stock at the Experiment Station is abundant and prolific, the actual, artificial feeding of young guinea-pigs extended over a period of ten months, from January to October, inclusive. Each time new-born animals were selected from the breeding pens they were divided into three equal lots, and one lot added to each of the three previously designated groups.

The milk for the tests was obtained from Experiment Station tuberculin-tested cows; in quality it was equal to or better than the best milk obtainable at any price in our cities, and none of it was more than eight hours old at the time it was fed to the guinea-pigs. The pasteurized milk was exposed to a temperature of 60 C. (140 F.) for twenty minutes and then rapidly cooled, and the boiled milk was slowly heated, in about

ten minutes, to the boiling point, and kept at that temperature one minute and then rapidly cooled.

During the first twenty days of their lives the guinea-pigs were fed five times daily with a special nursing apparatus, consisting of a graduated glass tube fastened to a wooden stand by means of screw clamps and communicating through a fine rubber tube with a nipple. The little animals quickly learned the use of this apparatus and showed as much affection for it as an artificially fed infant shows for its bottle.

The amount of milk given at each feeding was 1 cubic centimeter. After the twentieth day a pan of milk was accessible to the guinea-pigs for ten days longer, and then all milk was withdrawn from their diet. From the beginning the animals had access to other food than milk, and most of them began to eat small quantities when they were only a few days old.

An attempt was made to do the same work with rabbits, but the death-rate among them during the first ten days was so high that it was abandoned. Even when the young rabbits, which are born with their eyes closed and their bodies naked, were kept in a soft nest in an incubator after removal from their mothers, most of them died before they were a week old.

The difference in the value of the three kinds of milk, raw, pasteurized and boiled, was measured in two ways—by the mortality among the experimental animals and by the average weight at different periods of the animals that remained alive. The accompanying table gives the mortality record.

TABLE 1.—PERCENTAGE MORTALITY AMONG THE GUINEA-PIGS

Mortality	Young with Mothers, Per Cent.	Young Fed Artificially on Cow's Milk		
		Raw Per Cent.	Pasteurized, Per Cent.	Boiled Per Cent.
First ten days.....	4.0	27.74	30.13	27.56
First twenty days..	5.0	40.00	46.16	39.74
First thirty days...	6.0	44.52	51.28	42.95
First year	14.0	52.90	53.85	46.79

The first column of percentages is based on guinea-pigs that were raised by their mothers in the Experiment Station breeding pens, from which all the animals for the investigation were derived.

The enormous difference in this table between the death-rates of the guinea-pigs that remained with their mothers and those that were fed artificially on cow's milk, or the milk of a foreign species, is very impressive. The percentage death-rate for the guinea-pigs left with their

mothers is based on all the young born alive, weaklings as well as others, and no weaklings were selected for the artificial feeding tests. If we bear this in mind, the difference between the use of mother's milk under natural, and of the foreign milk under artificial, conditions will be recognized as really greater than the figures in the table show it to be.

The difference between the results with the raw, pasteurized and boiled milk are in favor of the boiled milk. During the first thirty days of life there is no well-marked difference between the raw and boiled milk, and both, unexpectedly, have a better record than the pasteurized, which latter, however, seems to have left the animals alive at the end of thirty days in such condition that a sufficient proportion of them

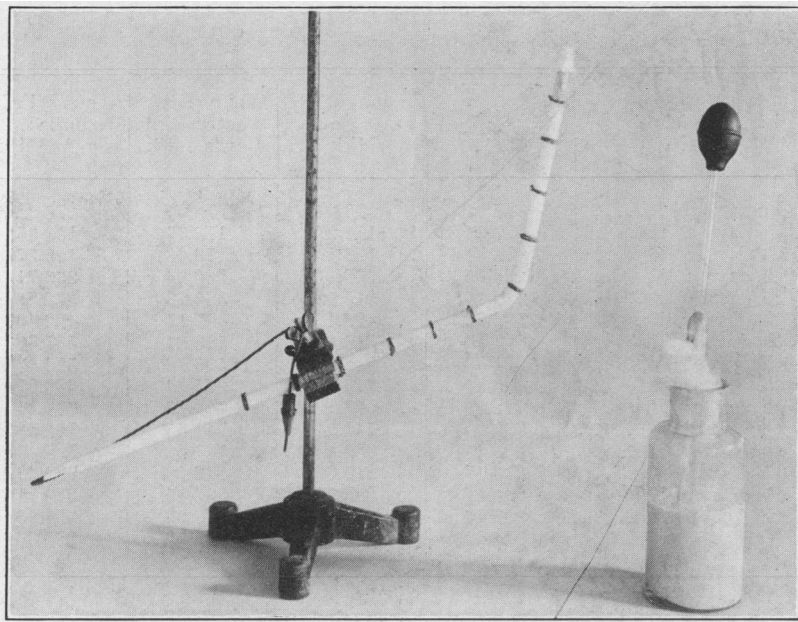


Fig. 1.—Apparatus with which young guinea-pigs were artificially fed on cow's milk.

remained alive during the following eleven months to make the records for the raw and pasteurized milk at the end of the year practically alike.

The percentage mortality table, reduced to its simplest terms, means that, in four groups of new-born guinea-pigs, each of which was composed of 156 animals, 134 of the natural group were alive at the end of the year, while of the other three groups, only 74 raw, 72 pasteurized and 83 boiled cow's milk animals survived. The natural group is 51 animals, equal to nearly one-third of the total number in each group, ahead of the boiled cow's milk group, which latter is 9 animals ahead of the raw and 11 ahead of the pasteurized cow's milk groups.

The better showing of the boiled milk must be considered with a clear appreciation of the fact that we are not dealing with ordinary commercial milk, but, on the contrary, with a milk of superlative quality.

The causes of death were mainly inflammation of the stomach and bowels and pneumonia. The post mortem examination of some of the animals that died very young revealed no satisfactory lesions to account for death.

The next table (Table 2) shows the average weight of the guinea-pigs in each group at different ages.

The first column of Table 2 is based on the average weight of 100 guinea-pigs raised under normal conditions in the Experiment Station breeding pens.

TABLE 2.—AVERAGE WEIGHT IN GRAMS OF GUINEA-PIGS AT DIFFERENT AGES

Time of Weighing	Young with Mothers	Young Fed Raw Cow's Milk	Young Fed Pasteurized Cow's Milk	Young Fed Boiled Cow's Milk
At birth	75.94	75.94	76.04	76.22
10th day of life....	127.34	116.27	118.37	119.35
20th day of life....	182.84	175.19	176.68	180.57
30th day of life....	234.65	228.81	230.04	233.71
50th day of life....	349.15	317.25	320.23	318.36
80th day of life....	502.29	422.16	427.17	430.49
110th day of life....	597.76	528.30	523.84	531.88
140th day of life....	671.56	587.81	596.72	592.43
170th day of life....	732.34	645.29	655.69	646.07
200th day of life....	776.63	697.12	700.15	699.14
230th day of life....	822.00	741.14	741.65	750.58
260th day of life....	858.84	789.48	781.61	795.42
290th day of life....	913.27	817.87	813.08	839.46
320th day of life....	944.07	853.81	836.15	879.71
350th day of life....	965.23	885.03	872.99	904.86
End of first year....	974.29	895.51	888.40	920.86

It is remarkable how nearly the average weights of the guinea-pigs in the different groups correspond on the thirtieth day, or ten days after weaning. This is partly due to the fact that the weaker and less thrifty animals in the artificially fed groups had been practically all eliminated by death before they were thirty days old, and that a much larger proportion of the weaker and less thrifty remained alive under natural conditions. After the thirtieth day the average weight in the natural group increased more rapidly than in the artificial groups, and at the end of the year shows a clear advantage of 53.5 gm. over the heaviest artificial group.

As in the mortality records, the boiled milk weight record is distinctly better than that of either the raw or the pasteurized milk, and the pasteurized drops a little behind the raw milk.

It is not fair to base conclusions on such slight differences as we have in this investigation, both as to mortality and weight, between the raw and pasteurized milk animals, else one might be inclined to infer, with the better records for the boiled milk, that the milk of a foreign species, when it is used as food for unweaned animals, contains both desirable and objectionable thermolabile elements, and that the desirable elements, which we can well afford to sacrifice to be rid of the objectionable, are

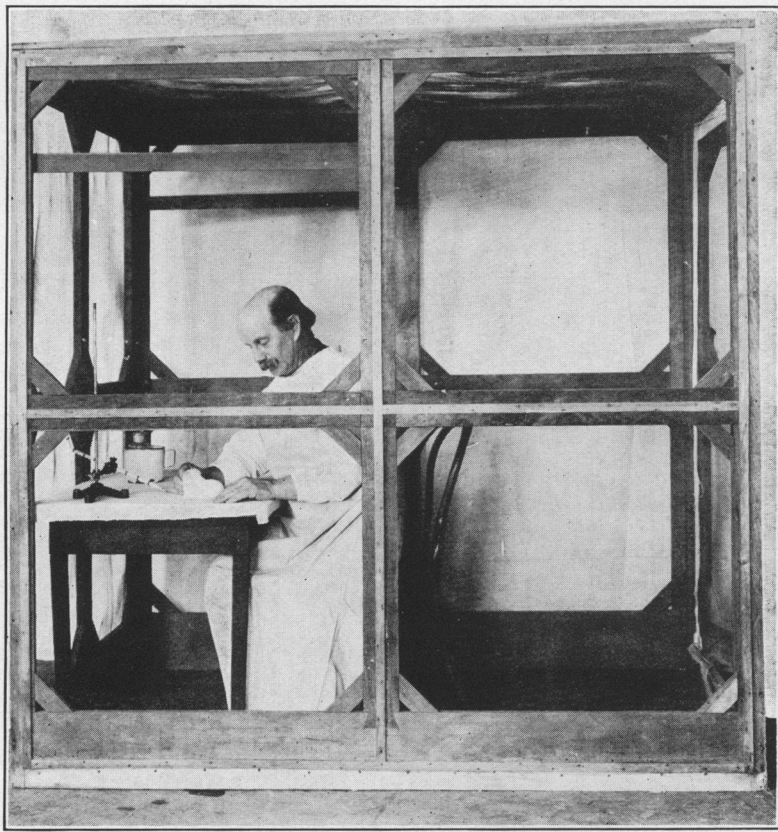


Fig. 2.—Young guinea-pig being fed artificially on cow's milk. The feeding was all done in fly-proof cages.

affected by lower degrees of heat to a greater extent than the latter. If the difference between the raw and the pasteurized milk was as great as the difference between the raw and the boiled, we would have satisfactory grounds for this inference. Incidentally, I would like to say that there are problems along this line regarding which we are very much in the dark, and that, apart from any treatment artificially used milk may require because of its contamination with pathogenic or other micro-

organisms, we have just as much evidence to support a hypothesis to the end that the milk of one species should be neutralized by heat before it is used as food for the unweaned young of another species, as to support the more commonly entertained hypothesis that the milk of one species contains thermolabile properties that are valuable for the young of another species.

From the guinea-pigs that were alive and well when they reached the age of 1 year, a number of males and females, fair representatives of each of the different groups, were selected and placed under conditions identical with those under which the Station's regular breeding stock is kept, and this gave us the data on which Table 3 is based.

The young were kept under observation until they were 30 days old, at which age there was no material difference among those from different groups of parents.

TABLE 3.—BREEDING RECORD

Guinea-Pigs Raised on	No. of Males	No. of Females	No. of Litters	No. of Young	Young Born Dead	Young Living Less Than 30 Days	Young Alive at End of 30 Days
Mother's milk	5	15	62	210	12	11	187
Raw cow's milk	5	15	37	120	15	6	99
Pasteurized cow's milk	5	15	52	170	15	8	147
Boiled cow's milk	5	15	52	177	11	10	156

Table 3 shows clearly that the artificial feeding of young animals on the milk of a foreign species imposes a handicap which may persist long after the milk-drinking period of life has been left behind. The naturally raised guinea-pigs show a greater productivity than the artificially raised, and again the boiled milk is more satisfactory than the raw or the pasteurized.

For the very poor record of the raw milk at this stage of the investigation, however, a fairly satisfactory explanation has been found, and this is based on the fact, discovered by Dr. W. E. Cotton and myself, that the bacillus of infectious abortion of cattle commonly occurs in the milk of infected, apparently healthy cows that produce healthy calves at full term.

While milk was being fed to our guinea-pigs it was not known that one cow in the herd that supplied the milk was infected with the abortion bacillus, and I do not see how we could have known, or discovered, or guarded against, this condition. At the time it was not known that the abortion bacillus of cattle causes peculiar, almost unmistakable lesions in guinea-pigs, which develop slowly, rarely cause death and gradually

disappear. Neither was it known that the bacillus is eliminated from the bodies of infected cows with their milk, as it had never been demonstrated to occur in milk. Cotton and I had previously discovered the lesions of abortion disease in guinea-pigs inoculated with samples of milk from the District of Columbia supply, and in guinea-pigs inoculated with milk from one Experiment Station cow that was not in contact with the healthy herd, but we did not know the cause of the lesions. It was not till sometime afterward before we isolated a bacillus from the lesions in the guinea-pigs, and another interval of time elapsed before the bacillus was positively identified as the etiological factor of infectious abortion in cattle.

The occurrence of the abortion bacillus in the milk of infected cows is now supported, not only by the evidence supplied by Cotton and myself, but also by the work of Theobald Smith and Marshall Fabyean

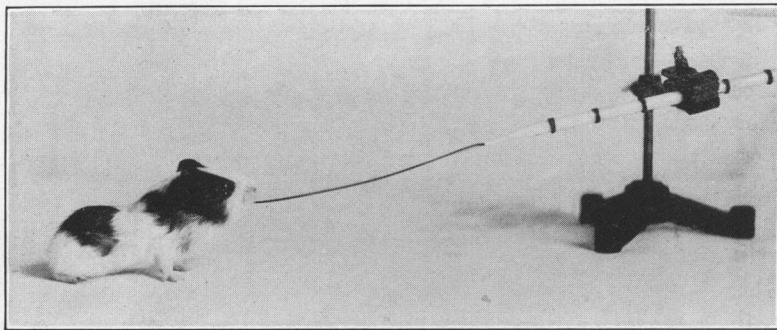


Fig. 3.—A young guinea-pig thoroughly acquainted with its artificial foster mother.

and others. In our work at the Experiment Station we have found ample reasons for believing that many, if not most, cows that become infected with the abortion bacillus remain chronic carriers for long periods of time, probably permanent carriers, and that the bacillus is of common occurrence in the milk of cows that have ceased to abort and have produced several normal, healthy calves in succession. We have records of two cows, one the mother of eight and the other of three calves, the milk of which was infected, though neither had ever aborted. Among aborting cows the bacillus appears in the milk before an abortion occurs, and in one instance was discovered in the milk of a cow that did not abort until 255 days later.

It must be clear from this that the bacillus of infectious abortion of cattle is a factor we cannot afford to omit from consideration when our choice lies between the use of raw and heated milk. We don't know as yet what effect the bacillus has on human health, but we do know, if the

general literature on the subject is reliable, that it is pathogenic for widely different species of animals, and that it is a remarkable organism because of the long time it may linger in the bodies of its hosts with undiminished virulence, and that long periods of time may elapse between its entrance into the bodies of its victims and a manifestation of the disease it causes.

Infectious abortion has become so common among cattle, and seems to be spreading so rapidly, that I have come to the conclusion that its influence on animal industry, from the strictly economic stand, is even more to be feared than that of bovine tuberculosis. In a series of milk tests made at the Experiment Station, in which 516 samples of milk from 90 dairies were injected into 1,068 guinea-pigs, 103 guinea-pigs became affected with abortion disease, and the milk distributed by 29 dairies was proved to be infected, from time to time, with abortion bacilli.

But to return to the breeding record of our guinea-pigs in the milk feeding investigation: When the guinea-pigs were killed at the end of the investigation and examined post mortem, it was found that several of those in the raw milk group showed lesions of abortion disease. Now, as abortion disease in cattle interferes somewhat with conception, it is possible that the smaller number of litters born by the raw milk guinea-pigs may have been due to the same cause, although we are not sure of this. Only one among the fifteen raw milk females used in the breeding tests showed lesions of abortion disease, and the infrequency of the disease among the guinea-pigs of the group generally indicates that the abortion bacillus did not become a factor until the milk feeding part of the tests was near its end. Young born dead were no commoner, but formed a greater proportion of the total number of young produced, among the raw than among the pasteurized milk guinea-pigs. The slightly greater productivity of the boiled than of the pasteurized milk guinea-pigs is important mainly because it gives us still another record in which boiled cow's milk is proved superior to raw and pasteurized milk as a food for young, unweaned guinea-pigs.

The first lesson the investigation teaches is, that the artificial use of the milk of a foreign species, as a food for unweaned animals, is a more lasting handicap than it is generally believed to be. The human organism is infinitely more complex than that of the guinea-pig, and may, therefore, suffer in many ways that cannot be demonstrated by tests with guinea-pigs.

The second lesson is that it is constantly becoming more and more apparent that we lack the means to produce cow's milk that is constantly free from pathogenic agents, just as the number of instances are increasing which prove that seemingly healthy individuals often are dangerous disseminators of disease germs.

The third lesson is that the time has come to ask, when a foreign milk is substituted for the milk natural to the species, whether the modifying effect of heat, irrespective of the treatment living pathogenic contaminations require, may not be beneficial rather than objectionable?

Finally, it is my sincere hope that no one will conclude from my paper that I undervalue the magnificent work of the American Association of Medical Milk Commissions. Milk is a cause of much disease, and there are several kinds of milk that are responsible for this charge. Dirty, stale, adulterated or otherwise objectionable milk, raw, pasteurized or boiled, is and remains a menace to health. Heat, applied to milk, is not a renovating, rejuvenating or a cleansing agent; all we can expect of it is to neutralize those specific germs of disease that find their way into milk, which is the best culture medium for bacteria among all articles of food, in spite of our utmost care to exclude them.

Infected milk? Unless I am greatly in error, I believe those who have studied the question impartially cannot be far from the conclusion that the infants who must, unfortunately, be fed artificially on cow's milk or the milk of a foreign species, and invalids whose diet is restricted as a whole or in part to milk, should receive properly certified milk efficiently pasteurized, or preferably, boiled, and that the general milk-supply should be made as good as the economic conditions affecting the production and handling of milk permit, and should be properly pasteurized, or preferably, boiled, under official supervision.