

## THE NUTRITIVE VALUE OF RAW AND PASTEURIZED MILK FOR CALVES

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(With 1 Figure in the Text)

THE value of pasteurization in destroying pathogenic bacteria in milk and so safeguarding the health of the human population is beyond question. While admitting this, certain workers have hesitated to give their unreserved support to pasteurization on the ground that it may have some deleterious action on the nutritive value of the milk which will more than counteract the beneficial effect resulting from the destruction of harmful micro-organisms.

A number of papers have been published in recent years describing attempts that have been made—chiefly on rats and children—to determine whether in fact pasteurized milk is in any way inferior in its nutritive qualities to raw milk. The literature on this subject has been reviewed by Stirling & Blackwood (1933) and M' Candlish & Black (1935). Many of the results are ambiguous, and none of them, in our view, definitely answers the main question at issue. The fact that in several experiments no statistically significant difference was found between the two classes of milk is not sufficient to give us the assurance we need, for the numbers of animals or children under observation were sometimes so small as to allow a possible real difference to be obscured by the inevitable accompanying error of sampling. Moreover, the interpretation of the results is rendered difficult by the circumstance that in all these experiments the subjects under test were being fed with milk from a heterologous animal source.

It seemed to us that if a clear answer was to be obtained to our main question it was desirable to make a direct comparison of the two types of milk on the homologous animal species, namely the calf. Comparatively few experiments on this animal are on record, and those that have been described have suffered (1) from being carried out on too small a number of animals to enable a satisfactory result to be obtained, and (2) from being complicated by the occurrence of disease in the experimental animals which may have entirely falsified the outcome of the investigation.

In planning an experiment to be carried out on calves, we determined as far as possible to avoid the sources of these errors. Since for financial and other reasons an experiment on really large numbers of animals presented formidable

difficulties, it seemed of special importance to make our observations on absolutely healthy animals so that the results might not be influenced in any way by the occurrence of latent or overt disease.

#### DESCRIPTION OF EXPERIMENT

With the kind consent of the Committee of the Berks and Bucks Joint Sanatorium, permission was obtained to carry out an experiment on the herd attached to the Sanatorium. The general plan of the experiment, which lasted from July 1934 to September 1936, was to feed alternate calves, as they were born, on raw or pasteurized milk for 8 weeks, and to compare their rate of growth. The relevant details may best be considered under separate headings. It may be pointed out at this stage that the management of the herd and the day-to-day control of the experiment was under the personal control of one of the authors (H. F. C.).

#### *The Peppard herd*

This contains about twenty Shorthorn cows which calve down regularly throughout the year so as to maintain a more or less constant supply of milk for the Sanatorium. Except for two pedigree bulls, which have been bought in, the herd has been self-contained since 1932. The animals are kept out at pasture during both summer and winter, and are never stalled except for the actual purpose of milking, which is done by hand morning and evening. Calving takes place in the open field. Bull calves are sold at about 1 week old; heifer calves are mostly kept for replacements.

Since March 1925 the herd has been tested at 6-monthly intervals with tuberculin; all positively reacting animals have been sold off. The last occasion on which positive reactors were found was in June 1932, when two animals had to be removed from the herd. During the whole course of the feeding experiment the herd remained completely free from tuberculosis. Moreover, at a herd test carried out a month after the conclusion of the experiment, all animals passed satisfactorily.

With regard to contagious abortion, the history of the herd has been peculiarly satisfactory. Two cows aborted in January 1928 and were found to give a positive blood agglutination reaction to *Brucella abortus*. The herd was vaccinated the same month with a living vaccine, since when there has not been a single case of abortion. At a herd test carried out some time before the commencement of this experiment, no animals showed the presence of specific agglutinins in the blood.

Johne's disease has seldom occurred; the last animal to be affected with it was in September 1929.

The herd has always been relatively free from udder troubles. In October 1936, at the conclusion of the feeding experiment, the milk of each cow was

examined culturally by plating in ox-blood agar, with the result that of the eighteen animals present three were found to be affected with streptococcal mastitis in a subclinical form.

#### *Pasteurizer*

To ensure a supply of adequately pasteurized milk, it was decided to pasteurize the milk on the premises. A small batch pasteurizer, of 2-gallons working capacity, fitted for low-pressure steam heating, was specially manufactured for us by Messrs Brown and Son, Ltd., London, N. 19. It was made of copper, coated with pure tin, and consisted of an outer steam-heated jacket and an inner vessel, to hold the milk, which could be lifted out for cleaning and sterilizing purposes. It was provided with an overhead motor-driven agitator and an auto-thermostatic control. In practice the milk was heated up till the indicator thermometer, which dipped into the milk itself, registered 145° F. (62·8° C.). The temperature was maintained at this level for 30 min., after which the steam was turned off. The milk was then cooled, either to 90° F. (32·2° C.) if it was to be fed immediately to the calves, or to the temperature of the tap water if it was to be kept for some hours.

#### *The milk*

The mixed milk of the herd from the morning's milking alone was used. The required quantity was divided into two parts. One part was pasteurized at once at 145° F. (62·8° C.) for 30 min.; the other half was left raw. Part of the raw and part of the pasteurized milk were fed at a temperature of about 90° F. (32·2° C.) to the calves in the morning. The remainder of the raw and pasteurized milk was water-cooled and kept in covered pails in a cool dairy till the evening, when it was warmed to about 90° F. and fed to the calves.

Though this was the routine practice throughout the greater part of the experiment, a misunderstanding occurred at the commencement which was responsible for some trouble during the first 6 months. Instead of the milk, immediately after pasteurization, being divided into two parts, one part being cooled to 90° F. and fed to the calves in the morning, the other part being cooled to tap-water temperature and kept for the evening feed, the whole of the pasteurized milk was cooled only to 90° F., and the part for the evening feed was left to cool down slowly in the dairy. As a result considerable bacterial multiplication occurred in the pasteurized milk destined for the evening feed, and this appears to have been responsible for a certain amount of scouring in the calves. As soon as the trouble was traced to its source, the practice of leaving the pasteurized milk to cool slowly in the dairy was stopped and the routine described above was enforced. No further difficulty was experienced from scouring, except in a mild form in occasional calves. It may be noted that the milk was always produced under cleanly conditions and was of approximately the same standard as Certified milk.

*Selection of the calves*

In order to avoid any unconscious bias in the selection of the calves for the different groups, it was decided to allot alternate calves, as they were born, to the raw and pasteurized groups respectively;<sup>1</sup> no selection whatsoever was made. Though this would have been an ideal method for a large experiment, it proved a little unsatisfactory in the present instance. In the first place it resulted in a very uneven distribution of the sexes, there being far fewer bull calves allocated to the pasteurized than to the raw group. In the second place it so happened that two calves, both of which at birth were quite unfit to be included in the experiment, had to be allocated to the pasteurized group. One calf, P<sub>1</sub>, was born of a mother which had to be slaughtered a week after parturition on account of "actinomycosis" of the larynx. Not only was this calf an undersized weakling at birth, but it further received a mauling by a horse when it was 1 day old from which it never recovered. The other, P<sub>20</sub>, had a very difficult delivery; it was unable to stand and had to be held up for feeding. The first of these animals died in 3 weeks, the second in a fortnight. In neither instance could death be in any way attributed to the type of diet that was being given.

These deaths, it may be noted, were the only deaths among calves that occurred throughout the course of the experiment. During the previous 15 years there had been altogether ten deaths among a total of 250 calves born. A loss of two calves during the experimental period of 27 months might therefore have been expected on the basis of the mortality rate previously experienced in the herd.

In each group there were four animals which were first calves.

*Housing of the calves*

As soon as they were removed from their mothers, the calves were housed in a wooden shed, opening on one side into a yard about 52 × 36 ft. in area. The shed was divided into three compartments, so that the calves could be grouped more or less according to their ages. The animals in the raw and pasteurized groups were run together. Straw was used for bedding.

*The diet*

Every calf had its mother's colostrum for the first 3½ days and was then hand-fed for 8 weeks. At the beginning of the experiment the calves were given 1 lb. of milk daily per 10 lb. of body weight. This amount, though more or less adequate for the first few weeks of life, was found to be insufficient for the calves as they grew older. The amount was therefore increased, though not to

<sup>1</sup> For the sake of convenience we ask pardon for the adjectival use, without inverted commas, of the terms raw and pasteurized in relation to the animals fed.

a sufficient extent, as it subsequently proved, to allow of optimal development. The following summarizes the diet received by the different animals:

(A) Raw calves 1-5, and pasteurized calves 2-6 were given daily 16 oz. of milk per 10 lb. of body weight for 8 weeks.

(B) Raw calf 6 and pasteurized calf 7 were given daily 20 oz. of milk per 10 lb. of body weight for 8 weeks.

(C) Raw calves 7-25 and pasteurized calves 8-25 (with the exception of P<sub>20</sub>) were given daily 16 oz. of milk per 10 lb. of body weight for the first 4 weeks, and 20 oz. of milk for the second 4 weeks.

The milk was fed at a temperature of about 90° F. morning and evening. During the first year of the experiment each calf was given a special feeder, from which it sucked its allotted quantity of milk through a teat. These feeders, however, proved rather troublesome, and later they were replaced by hand-feeding from a bucket.

Besides milk, the calves were provided with hay *ad lib.* Observation showed that during the first month of life they merely "played" with it, but after that each animal consumed about 1 lb. a day, rising to 3 lb. by the eighth week.

After they had completed their experimental period of observation of 8 weeks, the calves that it was decided to keep in the herd were removed from the experimental shed and were given flaked maize, bran, and roots or molassed sugar-beet pulp, together with a little milk for the next few weeks.

#### *Recording progress*

Each animal was weighed when it entered the experiment on the fourth day of life, and thereafter at weekly intervals. Careful observations were made on general condition, and a special watch kept for the development of rickets. From time to time outside observers, such as the milk recorder of the county and local farmers, were brought in to inspect the animals and make an attempt to distinguish those in the raw from those in the pasteurized group.

#### RESULTS

The detailed results are set out in Tables I and II.

It will be noted that the average weight of animals in the raw group was 2.23 lb. greater than that of the pasteurized group at the commencement of the experiment; this was mainly the result of the smaller proportion of bull calves in the pasteurized group. At the end of the experiment the average difference in weight between the two groups was 2.09 lb. The average increase in the animals of the raw group was 53.72 lb., and in those of the pasteurized group 53.86 lb. In other words, so far as the average weight gained throughout the whole course of the experiment was concerned, the two groups behaved for all practical purposes identically (Fig. 1).

This was all the more remarkable considering the difference in the sex distribution of the animals in the two groups. Male animals usually grow more

rapidly than female. This is well shown in the raw group, in which the bull calves put on an average of  $6\frac{1}{2}$  lb. more weight than the heifer calves. In the pasteurized group there were approximately twice as many female as male animals and the average increase in weight of both sexes taken together might well have been expected, independent of the nature of the diet, to have been less than that in the raw group in which the sexes were more evenly distributed.

TABLE I. *Raw milk group*

No.	Sex	Weight in lb. at commencement	Weight in lb. after 8 weeks	Increase in weight in lb.	Age in months when sold	Price obtained £ s.	Remarks
4	Bull	92	145	53	2	2 15	
5	"	89	144	55	2	2 10	
8	"	98	161	63	2	2 15	
10	"	89	141	52	2	2 10	
11	"	80	140	60	2	2 10	
13	"	93	164	71	2	3 0	
14	"	90	149	59	2	2 10	
16	"	70	120	50	2	2 0	
18	"	80	126	46	2	2 10	
19	"	92	150	58	2	2 10	
21	"	106	161	55	2	2 10	Suckled mother for 7 days
22	"	80	141	61	2	2 10	Slight scouring, 5th week
24	"	115	171	56	2	3 0	
1	Heifer	90	145	55	—	—	
2	"	76	122	46	2	2 4	
3	"	79	127	48	19	9 10	
6	"	75	110	35	15	9 10	
7	"	98	152	54	—	—	
9	"	90	140	50	12	9 10	
12	"	80	131	51	9	6 10	
15	"	90	140	50	—	—	Suckled mother for 10 days
17	"	79	125	46	—	—	Slight scouring 2nd and 3rd weeks
20	"	90	140	50	2	2 10	
23	"	86	145	59	—	—	
25	"	88	148	60	—	—	
Total 25: 13 bull, 12 heifer							
A.M.	Bull	90.31	147.15	56.85			
S.D.	"	11.29	9.59	10.64			
A.M.	Heifer	85.08	135.42	50.33			
S.D.	"	6.85	11.88	6.37			
A.M.	Both sexes	87.80	141.52	53.72			
S.D.	"	9.78	14.03	7.01			

A.M. = arithmetic mean; S.D. = standard deviation.

Note. All animals that were not sold were added to the Sanatorium herd.

The fact that no such difference occurred suggests that pasteurized milk is at least equal in value to raw milk in promoting the growth of young calves.

It is interesting to note that the highest individual gain—80 lb.—in a bull calf and the highest individual gain—63 lb.—in a heifer calf both occurred in animals fed on pasteurized milk ( $P_7$  and  $P_{21}$ ).

It will be observed that in the pasteurized group the average increase in weight of the male animals, instead of being greater than that of the female, was

slightly less. This circumstance was due mainly to the occurrence of scouring in the bull calves P<sub>2</sub> and P<sub>5</sub> which retarded their growth during the first 3 weeks and consequently led to a depression in the average weight of the male animals. In this connexion attention has already been drawn, when describing the milk, to the trouble that was experienced from scouring during the early stages of the experiment. This appeared to be due, in some measure at least, to inadequate

TABLE II. *Pasteurized milk group*

No.	Sex	Weight in lb. at commencement	Weight in lb. after 8 weeks	Increase in weight in lb.	Age in months when sold	Price obtained £ s.	Remarks
2	Bull	77	106	29	2	1 2	Scouring for first 3 weeks
3	"	90	140	50	2	1 15	
5	"	90	138	48	2	2 10	Scouring for first 2 weeks
7	"	98	178	80	2	2 15	
11	"	95	160	65	2	2 10	
17	"	84	127	43	—	—	Registered for breeding purposes
19	"	73	128	55	2	2 0	
22	"	98	154	56	2	2 10	
4	Heifer	94	148	54	—	—	
6	"	86	132	46	—	—	
8	"	74	126	52	13	9 10	
9	"	84	135	51	—	—	
10	"	80	132	52	—	—	
12	"	97	150	53	—	—	Slight scouring during 3rd week
13	"	90	138	48	—	—	
14	"	70	118	48	7	3 10	
15	"	82	141	59	—	—	
16	"	79	135	56	6	4 10	
18	"	83	141	58	—	—	Slight scouring during 2nd week
21	"	88	151	63	—	—	
23	"	97	158	61	—	—	Slight scouring during 2nd week
24	"	87	150	63	—	—	
25	"	72	121	49	—	—	
Total 23: 8 bull, 15 heifer							
A.M.	Bull	88·13	141·39	53·26			
S.D.	"	8·79	20·09	14·12			
A.M.	Heifer	84·20	138·40	54·20			
S.D.	"	8·12	11·24	5·38			
A.M.	Both sexes	85·57	139·43	53·86			
S.D.	"	8·57	15·42	9·43			

A.M. = arithmetic mean; S.D. = standard deviation.

Note 1. Calves P<sub>1</sub> and P<sub>20</sub> which, for causes already stated in the text, died during the first 3 weeks of life, have been omitted from this table.

Note 2. All animals that were not sold were added to the Sanatorium herd.

cooling of the milk after pasteurization leading to gross multiplication of the organisms in the milk destined for the evening feed. It seems probable that this alone was sufficient to give rise to gastro-intestinal disturbance in animals receiving the pasteurized milk. It is true that in both the raw and the pasteurized groups slight scouring occurred in occasional animals at a later date, but never with the serious results observed in calves P<sub>2</sub> and P<sub>5</sub>.

Table III shows the average weekly increase in weight of the two groups.

TABLE III. *Average weekly increase in weight of the animals in the raw and pasteurized groups*

Week	Increase in weight in lb.	
	Raw	Pasteurized
1	3.88	3.73
2	4.16	3.92
3	4.40	4.08
4	5.32	5.18
5	7.32	8.17
6	9.16	8.83
7	9.12	9.82
8	10.36	10.13
Total	53.72	53.86

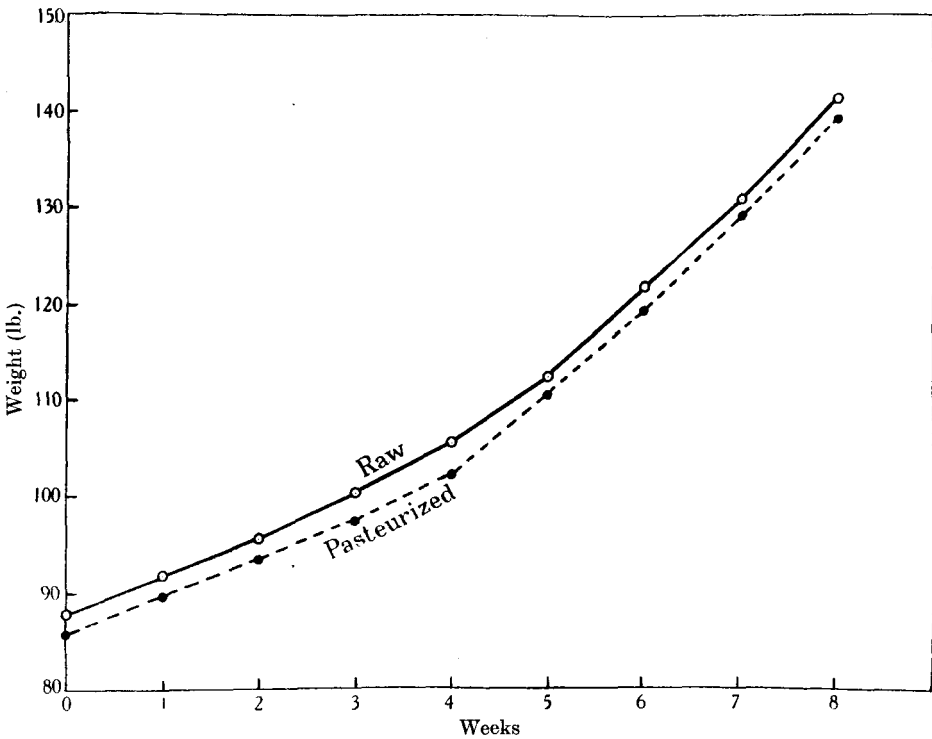


Fig. 1. Graph to show weights of all calves after 1-8 weeks.

As is to be expected with relatively small numbers of animals, the differences are subject to a certain amount of variation. On the whole the mean increase in weight tended to be slightly higher in the raw than in the pasteurized group during the first month. This was probably due in the main to the depression of the average by one or two animals in the pasteurized group which, as already noted, suffered from scouring during the first 2 or 3 weeks of life. In spite of this, the average total increase for the whole experiment was slightly higher for



the pasteurized than for the raw animals, the percentage figures being 62.94 and 61.18 respectively.

Compared with calves fed on a normal diet, the gains in weight were undoubtedly low. The amount of milk given, while permitting good skeletal development, was insufficient to fatten the animals. Their weight and their market value at the end of 8 weeks was therefore inferior to those of calves receiving a more generous diet. As soon as their period of experimental observation was over, and the animals that were not to be sold at once were put on to a liberal mixed diet, their weight increased rapidly and within about 2-3 months equalled that of normally fed animals.

Throughout the experiment the general condition of the calves was good. Though lean, they appeared perfectly healthy, and showed no sign of rickets, or of symptoms referable to anaemia such as have been noted by several workers who have fed calves on an exclusive diet of raw milk (see Cannon, 1931; Knoop *et al.* 1935). The slight scouring that occurred in occasional animals after the faulty cooling of the pasteurized milk had been put right, and which was seen in both raw and pasteurized groups, may well have been due to the system of pail feeding, since it is known that this is liable to give rise to digestive disturbances (Sheehy, 1934). At no time during the course of the experiment was any lay or professional observer able to distinguish between the two groups of animals.

Towards the close of the experiment heifer  $R_1$ , which was 2 years old, was served twice at an interval of 3 weeks, and heifer  $P_4$ , which was 22 months old, was served once. Both animals are now "in calf".

#### DISCUSSION

The results, which have been set out in detail, without any reservations, need little discussion. They speak for themselves. That slight variations should occur in the behaviour of different animals in the two groups was inevitable, but there is nothing whatever to suggest that they are attributable to the difference in the nature of the milk received, or that the differences as a whole are significant. In some respects the results are surprising. Each one of us at the commencement of the experiment was not only prepared to find a difference, but actually expected to find a difference, in favour of the animals in the raw group. Moreover, the farm hands who looked after the animals were strongly prejudiced against the use of pasteurized milk for the feeding of the calves. This prejudice, which affected all of us, in favour of raw milk for calf feeding, was based of course on pure *a priori* reasoning without any experimental justification. The outcome of the present experiment seems to leave little doubt that, judged by all the criteria we have used, milk produced in a clean manner from healthy animals and submitted to low-temperature pasteurization followed by adequate cooling is equal in nutritive value to milk from the same source consumed in the raw condition. It may be noted that Blackwood *et al.* (1936), who made a careful study of the assimilation and retention of nitrogen,

phosphorus, and calcium by calves, were likewise unable to detect any significant difference between raw and low-temperature pasteurized whole milk.

Reference should perhaps be made to the work of M'Candlish & Black (1935), which has frequently been quoted as showing that raw milk is of higher nutritive value for calves than pasteurized. Such an interpretation seems to us to be unjustified. It is true that in certain small groups the animals fed on raw milk increased in weight more rapidly than those on pasteurized, but in other groups the reverse was the case. If an analysis is made of the figures relating to all the animals, it is found that the weighted mean increase was actually greater in the pasteurized than in the raw group, the percentages being 311·3 and 308·4 respectively.

It is not proposed to enter here into the possible application of this knowledge to practical farming conditions. Suffice it to point out that adequate pasteurization of milk should prove of considerable value in the rearing of healthy calves in diseased herds. Some success has already been reported from California in the eradication of tuberculosis from dairy herds by this method (see Roadhouse & Perry, 1930). In deciding whether or not to adopt pasteurization, farmers need no longer be deterred by the fear that calves brought up on pasteurized milk will develop less satisfactorily than those brought up on raw, because of any hypothetical nutritive inferiority of the pasteurized product.

#### SUMMARY AND CONCLUSIONS

1. An experiment on the feeding of calves is described, which lasted over 2 years, and which was carried out on a healthy Shorthorn herd free from tuberculosis and contagious abortion.

2. Alternate animals as they were born were allocated, without any selection whatever, to one or other of two groups. One of these was fed on raw, the other on pasteurized milk. Every animal received its mother's colostrum for 3½ days before being put on the milk diet.

3. The milk used was taken from the mixed morning's milk of the whole herd. It was divided into two parts, one of which was given raw, the other of which was submitted to low-temperature pasteurization at 145° F. (62·8° C.) for 30 min. and subsequently cooled. The animals were fed morning and evening on measured quantities that were in strict relationship to their body weight.

4. In addition to the milk, hay was allowed *ad lib*. Observations showed that practically none was eaten during the first month, after which each animal consumed about 1 lb. a day, rising to 3 lb. by the eighth week.

5. With the exception of two weaklings which died after 15 and 23 days respectively from causes apparently unconnected with the nature of their diet, all the animals—twenty-five in the raw and twenty-three in the pasteurized group—throve well, and showed no obvious signs of rickets or anaemia.

6. The average increase in weight over the 8-week period for the animals in the raw group was 53·72 lb., and in the pasteurized group 53·86 lb., or 61·18 and 62·94 per cent respectively. This practical identity in weight increase is all

the more surprising in view of the fact that the number of bull calves was very much less in the pasteurized than in the raw group.

7. The highest individual gain among the bull calves—one of 80 lb.—and the highest individual gain among the heifer calves—one of 63 lb.—both occurred in animals fed on pasteurized milk.

8. At no time throughout the experiment was any observer, lay or professional, able to distinguish between the two groups of animals.

9. The diet given, though permitting of good skeletal development, was insufficient to fatten the animals. After they had been transferred, however, to a normal diet at the conclusion of their 8 weeks in the experiment, they soon put on weight and within 2 or 3 months were indistinguishable in size or condition from animals that had received a more generous diet from birth.

10. There is nothing in these results to suggest that the nutritive value of pasteurized milk for calves is in any way inferior to that of raw milk.

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