TIME FACTORS IN THE PASTEURIZATION OF MILK

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Now that pasteurization is established as a technical and commercial process capable of providing the community with a safe and economic food, it may be expedient to inquire how far its efficiency depends upon a comprehensive observance of time and other factors associated with its constituent procedures. This seems the more necessary at the moment, since there is a somewhat general impression that pasteurized milk has poor keeping qualities and that the name covers the usage of less clean, or old, market milks. Of course the latter is not true: the majority of the distributors aim at the production of the best possible commodity. Nevertheless, the medical attendant who recommends pasteurized milk for the patient or the household has frequently to listen to such views. They can only be met satisfactorily by a detailed knowledge of the process and its possibilities. For the housewife is, as a rule, more concerned with the economic than with the hygienic side of the supply. The breakfast milk that has soured during the night, or leaves grains of dirt at the bottom of the jug, forms a distressing contemplation.

It has to be admitted that there are valid grounds for this attitude from the standpoint of utility. So much time seems to be required for transport and delivery. While local dairies may collect, cool, and deliver to a small round twice a day, the milk collected from a radius of fifteen to twenty miles only under exceptional circumstances reaches the consumer before the following morning. As the distance is increased, so also is the delay between collection and delivery. For pasteurization there intervene, in addition, the processes of handling and heating. The time required for these has been perhaps insensibly extended by the sense of safety that the name engenders. Conditions vary in each district, and road and train mileage play their part.

But as an average it may be taken that during winter time the collecting lorries reach the farms in the early morning and pick up, not only the morning's milk, but that of the evening before, which has stood in churns in the farmer's dairy. Both lots are then pasteurized during the morning at an average of three to sixteen hours after milking. In the summer a second collection is made about 5 to 6 p.m., the milk being placed in cold storage until pasteurization the following morning. When the milk is carried long distances by train the process is reversed. But, in all the arrangements, the pasteurized product is

not available until the late morning, so that when the milk reaches the consumer it may be anything from twenty-four to thirty-six hours old.

Present Investigation

It has been an object of the experiments now described to ascertain if these times constitute the optimum periods or whether any others could with advantage be substituted. To this end winter milks have been collected directly from the milk pail in the cowshed and also after passing over the cooler. Pasteurization has been carried out at two, four, and sixteen hours later, the milk being kept meanwhile at 40° to 45° F. As there has been no handling in churns, and no contact with filter residues, bottles, or cups, there has been little chance of external contaminations.

In Table I the effects of delayed pasteurization and delivery upon the keeping properties and bacterial contents of milk are demonstrated. It may be noted that in the quoted experiment the milk that was pasteurized, whereas if it had been delivered to the consumer the next morning had an economic life of only thirty-five hours, whereas if it had been delivered within four hours it would have remained sweet for fifty-two hours. Neglecting the intervening but significant figures, it appears that if the delay before pasteurization of the milk had been only two hours the delivery after four and sixteen hours would have extended its utility to sixty-five and fifty-three hours. From the bacterial standpoint the early pasteurization seems to exert a remarkable restraint upon the proteolytic and pin-point colonies (streptococci and various unclassified Gram-negative bacilli) as well as conducing to a sparsity

Diagram of bacterial contents of milk after delayed handling. P. and D. numbers = hours delay. T = hours of tainting. Dots = bacteria.

Delays expressed in terms of keeping qualities, indicating comparative values of milks to consumer.

TABLE I.—Bacterial Counts, showing Effect of Delays in Pasteurization and Delivery

Delays in Pasteurization. (Kept at 40° F.)							Delays in Delivery. (Kept at 45° F.)							
	Total c.cm.	+	±	Alk.	P ₁	P ₂		Total c.cm.	+	±	Alk.	P ₁	P ₂	T
Two hours ...	3,000	—	1,000	—	2,000	—	Four hours	1,580 m.	—	1.08 m.	500,000	—	—	65 hours
	Tainted 74 hours.		A.G. in 0.5 c.cm.=0		→		Sixteen hours	16.40 m.	2,000	16 m.	200,000	—	—	53 ..
	Curdled 116 ..													
Four hours ...	300,000	—	70,000	—	30,000	200,000	Four hours	5.85 m.	950,000	900,000	300,000	—	3.7 m.	65 ..
	Tainted 72 hours.		A.G. in 0.5 c.cm.=0		→		Sixteen hours	121 m.	70 m.	9.1 m.	11.6 m.	0.1 m.	40.2 m.	51 ..
	Curdled 114 ..													
Sixteen hours	1,720 m.	330,000	60,000	300,000	—	1.03 m.	Four hours	17 m.	6.5 m.	6 m.	—	—	4.5 m.	52 ..
	Tainted 53 hours.		A.G. + in 0.5 c.cm.		→		Sixteen hours	27 m.	5 m.	5 m.	—	—	17 m.	35 ..
	Curdled 94 ..													

m = millions. + = acidifiers. ± = weak acidifiers. Alk. = alkalines. P₁ = peptolytics. P₂ = pin-point colonies. T = tainted.

of acid-producing organisms. On the other hand, the outstanding increases of all these types and the appearance of coliform bacilli after sixteen hours tend to emphasize the differences resulting from lack of more speedy handling. The findings also suggest that some of the heat resistants and the coliform organisms reported in pasteurized milk may be attributed to the effects of delay rather than invariably to technical faults in the plant.

Thus from the laboratory standpoint there seems no reason why the consumer should not be supplied with milk that contains a minimal rather than a maximal number of bacteria, that, apart from purely pathogenic action, may possess latent capacities for souring, tainting, and digestive disturbances.

FLASH HEATING REPLACING COOLER

In view of the lessened bacterial content and enhanced keeping properties demonstrable in the samples of milk pasteurized after only two or four hours' delay, it lies near

TABLE II.—Flash Heating at Dairy Cowshed compared with Thirty Minutes' Pasteurization after Varying Delays (Milk held meanwhile at 50° F.)

	Tainted	Curdled	Bacteria in 0.5 c.cm.	Cream Lines
	days hrs.	days hrs.		
Flash temperature:				
160° F.	11 0	18 0	Coliform absent	Slightly retarded
155° F.	7 0	13 0	"	Normal
150° F.	3 12	8 4	"	"
145° F.	3 6	6 20	"	"
Pasteurization (after cooling):				
Delay, 2 hours	3 2	4 20	"	"
" 4 "	3 0	4 18	"	"
" 16 "	2 5	3 22	A.G. +	"
Raw (after cooling)	3 2	4 22	A.G. +	"

at hand to wonder whether the protective heating could not be interposed at a still earlier period. The compulsory cooling of milk introduces many opportunities for external contaminations: its efficacy is variable, especially during

summer water shortage, when its action is most called for. It seemed worth while, therefore, to ascertain the effect of replacing the cooler by "flash" heating. Accordingly, milk has been taken directly from the milking pail, its natural temperature raised to superpasteurization temperatures, and its bacterial counts and keeping properties compared with portions from the same pail that were passed over the cooler and pasteurized in the usual manner. Four minutes were required, as a rule, to raise the temperature of the milk to 145° F. After heating, the milk was transferred from the heater to a sterile bottle, cooled quickly, and examined in the laboratory within twenty minutes.

The cream line was slightly decreased by the flash heating at 160° F., but was unaltered by the other temperatures (Table II). All the "flash" heatings yielded better keeping properties than those of delayed pasteurization. None of them showed presence of coliform organisms, although these were demonstrable in the raw cooled specimen and in the sample that had been kept sixteen hours before pasteurizing.

Differential bacterial counts (Table III) show confirmatory findings. The raw milk prior to cooling had a total count of 3.5 millions, 1.274 millions slightly acid, and 1.180 millions pin-point colonies. In the flashed portions the total was cut down to 228,000, with an absence of pin-points. This compares well with the sample pasteurized for twenty minutes that yielded a total of 412,000 and 11,000 pin-points. The figures stated trace the total and interacting changes up to the hour of curdling. The "flashed" soured two days later than the pasteurized, and although coliform organisms were demonstrable in 0.5 c.cm. of the raw and pasteurized portions, they were absent in the flashed. The pasteurized sample curdled when added to hot tea on the eleventh day, but the "flashed" did not curdle similarly until the thirteenth day.

It has been claimed that "flash" heating alters the flavour and cream line to a less extent than thirty minutes at 145° F.¹ Evidence has been obtained that "flash" heating for fifteen seconds destroys tubercle and other pathogenic bacilli, although the margin with commercial

TABLE III.—Differential Bacterial Counts at Varying Intervals after Flashing at Dairy and Early Pasteurization* (Milk held meanwhile at 50° F.). Cultures incubated at 22° C.

	Total	+	±	Alk.	P ₁	P ₂	Bacteria in 0.5 c.cm.
Flashed at 155° F.:							
Counts made 20 minutes later	228,000	5,000	135,000	—	88,000	—	<i>B. coli</i> absent
" " 2 hours "	2.15 m.	20,000	750,000	—	1.38 m.	—	
" " 6 " "	7.15 m.	200,000	6.5 m.	—	45,000	—	
" " 24 " "	84.6 m.	1.5 m.	51 m.	2.1 m.	12 m.	18 m.	
" " 4 days " "	185 m.	50 m.	30 m.	25 m.	10 m.	70 m.	
" " 13 " "	3,430 m.	60 m.	140 m.	530 m.	—	2,700 m.	{ Tainted 7th day. Curdled 13th day.
Pasteurized at 145° F.:							
Counts made after cooling and heating—20 minutes later	412,000	61,000	332,000	—	8,000	11,000	Coliform organisms present
" " " 2 hours " "	540,000	—	220,000	—	200,000	120,000	
" " " 6 " "	12.9 m.	—	5.65 m.	—	—	7.15 m.	
" " " 24 " "	279 m.	—	89 m.	13 m.	107 m.	70 m.	
" " " 4 days " "	155 m.	40 m.	80 m.	10 m.	—	25 m.	
" " " 6 " "	9,020 m.	1,400 m.	1,840 m.	1,010 m.	10 m.	4,760 m.	Tainted 6th day
" " " 11 " "	32,160 m.	10,240 m.	9,760 m.	3,200 m.	—	8,950 m.	Curdled 11th day
Flash Heating at dairy cowshed plus pasteurization 20 minutes later.							
Initial total and differential after standing at 50° F. for 24 hours:							
Flashing plus pasteurization	3,000	—	1,000	—	2,000	—	{ Tainted 14 days. Curdled 21 days
Pasteurization without Flashing	6,000	—	4,000	—	2,000	—	{ Tainted 6 days. Curdled 12 days

m. = millions. + = strong acid producers. Alk. = alkali producers. ± = weak acid producers. P₁ proteolytics. P₂ = pin-points. The raw milk (after cooling) yielded—Total 3.458 m. (+1.274 m., Alk. 210,000, P₁ 79,100, P₂ 1.183 m.). It was tainted in five days, and curdled in eight days with a count of 126,000 millions.

* All counts were made from plates of milk-proto media incubated forty-eight hours at 22° C. as described in *Pasteurized Milk*, issued by the Department of Preventive Medicine, University of Bristol, 1935 (Gordon, Old King Street, Bristol).

milk is a little too slight for safety.² The findings now stated point to the possible value of flash heating in the dairy and a shortened heating at 145° prior to distribution. When the flashing was combined with subsequent pasteurization the counts were halved and the keeping period extended (Table III).

Although the adoption of this practice would involve a period for the development of technical factors, the immediate provision for pasteurization near the sources of supply and the elimination of delays prior to distribution are suggestions that may merit the attention of those interested in the increased consumption of safe milk.

Summary

It is submitted:

That milk must be regarded as a perishable commodity calling for efficient preservation and rapid delivery. Delays between producer and consumer bring hardships to both.

That more effective preliminary measures might be carried out prior to transport; and "flash," or usual pasteurization, might precede, not follow, long-distance transport.

That morning and evening pasteurizations might be advantageous, at least during summer months.

That as cream lines are unaffected by "flash" heating there might be a similar protection for cream marketed in bulk

REFERENCES

¹ *Svenska Mejeritidningen*, 1933, xxxviii, 323.

² Mattick and Hiscock: World's Tenth Dairy Congress, Rome, 1934.

ERYTHEMA NODOSUM AND FOCAL INFECTION

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The need for the recognition of more than one factor in the aetiology of erythema nodosum is being increasingly admitted. Four main theories have been suggested. First, that it is a specific infective disease *sui generis*. This theory was brought forward by Trousseau¹ and later by Lendon² of Adelaide, who suggested the name of nodal fever; Symes and Robert Hutchison have also favoured this view. Experimental evidence in support has been adduced by Moon and Strauss,³ who have satisfied Koch's postulates with an organism of the genus *Corynebacterium*, which they cultivated both from the subcutaneous tissues and from the blood of patients presenting this syndrome. Secondly, that it is a manifestation of acute or subacute rheumatism, a theory introduced by Mackenzie⁴ and handed down by generations of textbooks. G. Josephsen⁵ records that out of forty cases of erythema nodosum complicated by some other ailment, in as many as twenty-six the disease synchronized with an attack of rheumatic fever, while in only four could tuberculosis be definitely demonstrated. He comes to the conclusion, however, that the true interpretation of erythema nodosum is that of anaphylactic reaction to various protein poisons, including tuberculin.

A third theory is that it is an early symptom of infection by tuberculosis. This view has been consistently maintained by the Scandinavian school, notably by Mogensen,⁶ Wallgren,⁷ and Giertsen,⁸ who claim that the evidence of x-ray films, gastric lavage, and tuberculin tests proves that the majority of their cases, up to 95 per cent., are tuberculous. This theory has received strong support from Dickey⁹ in America, and from Collis¹⁰ as the result of his investigations in London and Dublin.

Collis has also very clearly demonstrated that a small proportion of his cases are due to an infection by a haemolytic streptococcus, and that the eruption in these cases is usually preceded by an acute pharyngitis and often followed by a polyarthrititis. He asserts, however, that even in London, where streptococcal infection is common, not more than 15 per cent. of cases could be ascribed to this cause, that the balance are mainly if not all tuberculous, and that our attitude should be to regard every case as tuberculous until proved otherwise. Dickey, from his experience in children, is equally emphatic on this point. Forman and Whitwell,¹¹ from a recent series at Guy's Hospital, consider that the rheumatic theory prevalent in England is undoubtedly a menace to the proper treatment of erythema nodosum, which, they assert, should be regarded as tuberculous in every case, and the sore throat that sometimes precedes the appearance of the nodes is merely an activator of tuberculous foci. Such a line of reasoning could hardly apply in Collis's cases, because all his patients who reacted strongly to streptococcal endotoxin had sore throats, and yet in most of them the Mantoux test was negative.

The fourth theory is that the condition is a reaction to various bacterial allergens, of which only those of the *Mycobacterium tuberculosis* and a haemolytic streptococcus have been recognized. This is the view held by Collis. Josephsen, as noted above, comes to much the same conclusion. Collis does, however, record a case definitely associated with a meningococcal infection, and at the same time mentions a similar one, quoted to him by Robert Hutchison, but he considers that such cases are only of academic importance. In this connexion also it is interesting to note that Lendon,¹² who in 1905 was the apostle of the nodal fever theory, in 1927 admitted that there was an increasing tendency to regard these cases as tuberculous, and at the same time he quoted a new theory suggested by Colonel J. C. Kennedy in the *R.A.M.C. Journal* for July based on the observation of four cases of meningococcal septicaemia, and that was, "Given a case of erythema nodosum, suspect meningococcal infection."

Gerald Slot,¹³ in a recent publication, states that he considers the majority of cases in London are due to streptococcal infection and are not tuberculous, but the only evidence he brings forward in support of his statement is the improvement shown in four cases following the administration of antistreptococcal serum. Although the histories of all these cases certainly do symptomatically suggest a streptococcal infection no further evidence such as that of skin tests or cultures is adduced in support of the diagnosis. In this regard, the value of the intracutaneous test as a means of differentiation between the streptococcal and the tuberculous cases has been fully demonstrated by Collis, who utilized a haemolytic streptococcal endotoxin for the purpose. Apart from streptococcal and tuberculous foci, however, the relation of erythema nodosum to other focal infection does not seem to have been demonstrated. The history of the following case, therefore, should be of particular interest.

Case Report

The patient, a nurse aged 29, was first seen by me in September, 1932. She had a temperature of 101° and displayed an eruption of eight or more typical nodes of erythema nodosum over both tibiae and a small one over the left elbow. An apparently glandular mass the size of a pigeon's egg was found in the right axilla, but was not tender. The patient stated that she had first noticed this mass a fortnight previously, when it had been larger and painful. There was no history of abrasion or sepsis in the area drained by these glands. Examination was otherwise negative; her chest, nose, and throat appeared normal, but she had six crowned and pivoted teeth with bridgework, all dating back some years.