EXPERIMENTS ON THE PASTEURISATION OF MILK, WITH REFERENCE TO THE EFFICIENCY OF COMMERCIAL PASTEURISATION.

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Introduction.

At the present time, pasteurisation of milk is being extensively applied on a commercial scale and the "Holder" process of heating at 62·8° C. (145° F.) for 30 minutes has become an officially accepted method. Doubts have been cast, however, on the uniform efficiency of commercial pasteurisation in fulfilling its essential purpose, *i.e.* the elimination of pathogenic organisms and the material reduction of the total bacterial content. Even if the temperature employed in the Holder process is theoretically sufficient to destroy pathogenic organisms such as the tubercle bacillus, the "margin of safety" between the thermal death point of these organisms and the temperature of pasteurisation might appear to be a narrow one, especially when possible variability in the heating process is taken into consideration and also the personal factor of those operating the large scale pasteurising apparatus. Such questions that have been raised in regard to milk pasteurisation are of great hygienic importance and merit the most careful consideration.

Traum and Hart (1916) found that by keeping naturally infected tuberculous milk at 60° C. for 20 minutes, the tubercle bacilli present were rendered avirulent. Barthel and Stenstrom (1917) stated that when milk obtained from tuberculous cows was heated to 60° C. and kept at this temperature for 10 minutes, it was rendered non-infective: this observation referred to pasteurisation by a commercial plant, 1 litre of the infective milk being added to 100–200 litres of milk in the holder. According to Ragsdaile (1923), heating at 60° C. for 30 minutes destroyed tubercle bacilli in colostrum. Campbell Brown (1923) found that the thermal death point of the tubercle bacillus in milk was 60° C. after 20 minutes' exposure and 70° C. after 5 minutes' exposure. Beattie and Lewis (1920), using the electrical process of pasteurisation, claimed that temperatures from 62 to 64° C. for 30 minutes killed tubercle bacilli in milk. In the most recent publication on pasteurisation by American authors (1925, *Amer. Publ. Health Bull.* No. 147), tubercle bacilli were found to be destroyed at 137° F. (59·7° C.) when the temperature was maintained for 30 minutes: this result was obtained by the use of commercial plants of three types, each of which had been constructed, tested and improved by engineers, so that the conditions were extremely favourable for obtaining the most satisfactory results.

Ayers and Johnson (1914), in a paper on "The Survival of Streptococci in Pasteurized Milk," observed that streptococci from the mouth and faeces of the cow were more resistant than those from the udder, but the majority of strains were able to withstand a temperature of 63° C. for thirty minutes. The same workers, along with Davis (1918), isolated 27 strains of pathogenic streptococci and determined their thermal death point in milk; this was never higher than 60° C. in the case of an exposure of 30 minutes. Salter (1921) stated that haemolytic streptococci, when present in milk in large numbers, might survive a temperature of 60° C. for 30 minutes but were destroyed by Holder pasteurisation. Davis (1920) again investigated the effect of pasteurisation on streptococci from cases of septic sore throat and found that they were unable to survive the temperature employed in this process: this is in accordance with the results of Pease and Heulings (1920), who considered that pathogenic streptococci had a low thermal death point and were killed by pasteurisation; they also stated that the majority of non-pathogenic streptococci were destroyed at 63° C. after 30 minutes but that a few might survive.

Ayers and Johnson (1915) found that colon bacilli were less resistant than streptococci, and in only a few cases were they able to isolate strains which survived 63° C. for 30 minutes. Pasteurisation at 63° C. for 20 minutes was reported by Vanderleck (1917) as insufficient for the destruction of *B. coli*, but no reference was made to the effect of maintaining the temperature for longer periods. Finkelstein (1919), however, found that efficient pasteurisation killed coliform bacilli. Twiss (1920) stated that pasteurisation at 63° C. for 30 minutes was not sufficient to kill *B. typhosus*, *B. paratyphosus* and *B. enteritidis*, but Krumwiede and Nobel (1921) repeated this work and arrived at the conclusion that pasteurisation was perfectly adequate for the destruction of these pathogenic bacteria. In the *American Public Health Bulletin* (1925), pasteurising milk on the commercial scale was recognised as being efficient in the destruction of organisms of the "*typhosus*" group.

The influence of pasteurisation on the normal milk flora has been investigated by Weigmann, Wolff, Trensch, and Steffen (1914), who found that milk bacteria, though not much diminished in numbers, became much less active, multiplying less rapidly and producing smaller quantities of acid.

All other workers are agreed that pasteurisation brings about a marked decrease in bacterial numbers, and Ayers and Johnson have claimed that the reduction in numbers resulting from commercial pasteurisation is ninety-nine per cent.

Allen (1916) found that bacteria multiply more rapidly in pasteurised than in raw milk: in 1917 he published results showing that pasteurised milk was more favourable to the growth of *B. coli* and *B. aërogenes* than raw milk. With regard to the multiplication of bacteria in pasteurised milk, Jacobsen (1918) found that in one case this was due to heat resistant organisms present in the raw milk and that these multiplied after pasteurisation. The presence of heat resistant non-sporing organisms in pasteurised milk was reported by

Robertson (1924). Ayers and Johnson (1924) isolated from a pasteurising plant a non-sporing organism, *Lactobacillus thermophilus*, with an optimum temperature of 62·3° C., and thermal death point of 80° C. (after five minutes' exposure) which produced pin-point colonies on agar. Jensen (1921) has given a good deal of attention to the flora of pasteurised milk, and in addition to the thermophilic organisms mentioned by other workers, has frequently isolated a non-sporing bacillus capable of withstanding relatively high temperatures and designated by him *Microbacterium*.

The acid-producing bacteria, according to Ayers and Rupp (1923), are more resistant to pasteurisation than the protein-splitting bacteria; so that souring of pasteurised milk may occur as in untreated milk. This is in harmony with the finding of Pease and Heulings (1920) that certain non-pathogenic streptococci in milk may survive pasteurisation.

Beattie and Lewis (1913, 1914, 1920) have investigated pasteurisation by electrical methods and obtained very satisfactory results so far as reduction in bacterial numbers, destruction of the pathogenic powers of the tubercle bacillus and the preservation of the valuable food constituents of the milk are concerned. Lodge and Leith (1914), who repeated and extended this work, suggested that the effect was mainly thermal; Anderson and Finkelstein (1919) attributed their satisfactory results from electrical milk pasteurisation to the thermal effect of the current.

Though the experimental evidence points generally to the effectiveness of pasteurisation when carried out under exact conditions, the uniform efficiency of the method as applied to milk in bulk on a commercial scale may be questioned, and routine bacteriological examinations of vended specimens of pasteurised milk have often tended to confirm the suspicion that the process may fail to achieve its essential object. Any further information obtained by careful and controlled experiments relative to the effectiveness, or otherwise, of pasteurisation in reducing the bacterial content and in eliminating pathogenic organisms, especially when applied for commercial purposes, is therefore of the greatest importance. Further enquiry is also necessary as to the factors likely to interfere with the efficiency of commercial pasteurisation and how the defects in the procedure can be remedied.

The investigation and experiments recorded in this paper may be outlined as follows:

(1) The general bacteriological condition of vended samples of commercially pasteurised milk was ascertained and compared with that of ordinary market milk, certified milk, and Grade A (T.T.)[1] milk.

(2) The general results of laboratory pasteurisation of small quantities of milk were carefully observed for comparison with those of commercial pasteurisation applied on a larger scale and for the purpose of determining to what extent commercial pasteurisation falls short of an ideal method. Laboratory pasteurisation was carried out at different temperatures—59°,

[1] (T.T.) = Milk derived from tuberculin tested cows.—ED.

60°, 61°, 62°, 63° C. for 30 minutes, with a view to ascertaining whether temperatures slightly lower than the usual temperature of pasteurisation materially altered the results.

The criteria used for comparison were:

(*a*) Total bacterial content;

(*b*) *B. coli* content.

The types of bacteria persisting in pasteurised milk were also investigated.

(3) The possible deficiencies of commercial pasteurisation were investigated by examining milk bacteriologically at different stages of the process with a view to ascertaining wherein any defects lay.

(4) Milk was inoculated with virulent tubercle bacilli from cultures and then pasteurised under laboratory conditions at 62·8° C., and naturally infected milk from a cow with udder tuberculosis was pasteurised at temperatures ranging from 55° C. to 63° C. The survival of virulent tubercle bacilli in the heated milk was determined by guinea-pig inoculation tests. A sample of milk from a cow similarly affected was pasteurised in a commercial plant (the temperature being carefully maintained at 62·8° C.) and tested also by inoculation of guinea-pigs.

Methods.

The method which has been employed for counting the number of viable bacteria in milk is the following: dilutions of 1 in 10, 1 in 100, 1 in 1000, 1 in 10,000, and 1 in 100,000 were made in sterile stoppered flasks containing sterile water. By means of a sterile pipette, 10 c.c. of milk were added to 90 c.c. of water, which gave the 1 in 10 dilution. After thorough shaking, 10 c.c. of this dilution were transferred to 90 c.c. of water and so on till the five dilutions were completed. 0·5 c.c. from each of these dilutions was then plated on nutrient agar standardised to *p*H 7·6; the plates were incubated at 37·5° C. for 48 hours; and the number of colonies on a plate which was not overcrowded was counted: this gave the number of viable bacteria per c.c. In the few cases where plates were incubated anaerobically, a Bulloch's apparatus was employed.

For determining the *B. coli* content of the milk, a bile-salt lactose litmus peptone water was used. To 10 c.c. quantities in Durham's tubes the following series of amounts of milk were added:

1·0 c.c. undiluted milk.
0·1 c.c. ,,
0·1 c.c. of 1 in 10 dilution.
0·1 c.c. of 1 in 100 dilution.
0·1 c.c. of 1 in 1000 dilution.
0·1 c.c. of 1 in 10,000 dilution.
0·1 c.c. of 1 in 100,000 dilution.

The milk was obtained each morning, and, when brought to the laboratory, was put into sterile test tubes. The laboratory pasteurisation was carried out in these tubes, which were immersed in a hot water bath kept at constant temperature. As it was found by experiment *that 10 minutes elapsed before the temperature of the milk reached that of the bath*, an exposure of 40 minutes was allowed. On removal from the water bath the tubes were cooled in running water for ten minutes and allowed to stand at room temperature for half an hour. The dilutions were then made.

For the experiments with *B. tuberculosis*, a weighed amount of growth from Dorset's egg medium was ground up in an agate mortar in a known volume of 0·85 per cent. saline

and 0·025 gram added in the saline suspension to 10 c.c. of milk, which was pasteurised, as before, at different temperatures, except in the control experiments where the milk was unheated. The milk was then centrifuged; the sediment was examined microscopically for the presence of tubercle bacilli and 1 c.c. injected subcutaneously into a guinea-pig. Samples of naturally infected tuberculous milk obtained from cows with udder tuberculosis were also pasteurised and treated in the same way, part of the cream as well as the sediment obtained by centrifugalisation being injected into guinea-pigs.

RESULTS.

In Table I, the figures for the total bacterial content and *B. coli* content of various *unselected* samples of commercially pasteurised milk, market milk, certified milk, Grade A (T.T.), are given.

Table I.

Grade of milk	Specimen	Total no. of bacteria per c.c.	No. of *B. coli* per c.c.
Pasteurised (commercial)	1	40,000	10
	2	5,000	10
	3	54,000	1
	4	10,000	10
	5	4,800	1
	6	1,000	0
	7	5,000	10
	8	2,000	0
	9	1,000	10
	10	400	1
	11	220	10
Market milk	1	48,000	100
	2	260,000	100,000
	3	66,000	100
	4	76,000	100
	5	1,400	10
	6	2,440,000	100
	7	26,000	10
	8	89,000	1,000
	9	90,000	1,000
	10	8,000	10
	11	18,000	10
	12	18,000	100
	13	12,000	10
	14	80,000	10,000
Certified	1	1,200	1
	2	160	0
	3	120	0
Grade A (T.T.) ...	1	1,000	1

These results elicited considerable variation in the total bacterial content of the commercially pasteurised specimens, the numbers ranging from 220 to 54,000 per c.c. The *B. coli* content also varied, from 0 to 10 per c.c. The specimens of ordinary market milk varied in their total bacterial content from 1400 to 2,440,000 per c.c. and in *B. coli* content from 10 to 100,000 per c.c. Thus, in some instances the total bacterial content of pasteurised milk may be actually greater than that of many specimens of ordinary market milk, but the contrast in favour of pasteurised milk is more marked in the average content of *B. coli*. Though the results of only a small number of specimens are given here, they are sufficient to illustrate the average difference between

the various grades of vended milk. The frequently high *B. coli* content of ordinary market milk is noteworthy and specially significant of the nature of the contamination to which milk is subject when collected and distributed in a large community. This is in accordance with the results of Cunningham (1920).

In Table II, the total bacterial and *B. coli* contents of milk samples before and after pasteurisation at different temperatures are shown, and in Table III are given the numbers of bacteria developing, under anaerobic conditions, before and after pasteurisation.

Table II.

Specimen	Temperature of pasteurisation ° C.	Before pasteurisation. Total no. of bacteria per c.c.	After pasteurisation. Total no. of bacteria per c.c.	% reduction	No. of *B. coli* per. cc. Before pasteurisation	No. of *B. coli* per. cc. After pasteurisation
1	59	60,000	8,000	86·6	100	0
2	59	40,000	5,200	87	10	0
3	60	50,000	4,000	92	10	0
4	60	640,000	16,000	97·4	1,000	0
5	60	12,400	6,000	51·6	10	0
6	60	18,000	6,000	66·6	1	0
7	61	180,000	50,000	72·2	10	0
8	61	6,000	540	91	10	0
9	61	180,000	9,400	94·7	100,000	0
10	62·5	20,000	900	95·5	1,000	0
11	62·8	32,000	800	97·5	10	0
12	62·8	4,000	200	95	10	0
13	62·8	40,000	2,000	95	10	0
14	62·8	56,000	1,820	96·7	1	0
15	62·8	10,000	600	94	10	0
16	62·8	20,600	1,200	94·5	100	0
17	62·8	74,000	3,000	94·5	10	0
18	62·8	22,000	1,000	95·4	10,000	0

Table III.

Incubated anaerobically.

Specimen	Temperature of pasteurisation ° C.	Before pasteurisation. Total no. of bacteria per c.c.	After pasteurisation. Total no. of bacteria per c.c.	% decrease
12*	60	500	60	98·8
17*	63	29,200	100	99·3
14*	62·8	20,400	800	96·1
10*	62·8	5,000	10	99·8

* See Table II.

The results of laboratory pasteurisation at 62·8° C. have also shown variation as regards the *total bacterial content*, the numbers ranging from 200 to 3000 per c.c. This is dependent mainly on the varying initial bacterial content. The percentage reduction varied from 97·5 to 94. At lower temperatures, 59–61° C., the percentage reduction in the bacterial content ranged from 97·4 (at 60° C.) to 51·6 (at 60° C.). At all temperatures from 59 to 62·8° C., however, the contrast between the pasteurised and untreated milk specimens was most striking as regards the *B. coli* content. Thus, in the pasteurised milk *B. coli* was uniformly absent from 1 c.c. though in some cases the untreated

milk contained large numbers of these organisms. In four specimens in which the bacterial content was estimated by incubation under anaerobic conditions, the percentage reduction was remarkably high—from 96·1 (at 62·8° C.) to 99·8 (at 62·8° C.). For each sample of milk the types of organisms which survived pasteurisation at temperatures from 59° C. to 62·8° C. for 30 minutes were determined; these included *Streptococci*, *Staphylococci* (both chromogenic and "*albus*" types), sporing organisms of the *B. subtilis* group, and a very short Gram-negative bacillus found in a few samples, which corresponds to Jensen's "*microbacterium.*" In very few cases were colonies of *Streptococci* absent from the plates after pasteurisation. Those *Streptococci* which survived heating at 62·8° C. for 30 minutes were of the faecalis type, as shown by their fermentation of various sugars. *B. coli* was always destroyed at these temperatures.

The method of pasteurisation of milk employed in the above experiments is to be regarded as an ideal one, since the pasteurisation was performed in the vessel in which the milk was sampled. In commercial pasteurisation, the bottles in which the milk is delivered to the consumer are filled after the milk is pasteurised, and the milk, during this process, is exposed to contamination. Opportunities may also be afforded for multiplication of bacteria which have survived pasteurisation during the subsequent keeping of the milk. Further, in commercial pasteurisation accurate control of temperature and time of heating is not always easy. As an illustration of the effect of the difference between commercial and laboratory pasteurisation, it is interesting to note that the majority of the figures representing total bacterial content of laboratory pasteurised milk (Table II) were considerably lower than those for commercially pasteurised milk (Table I). Further, the majority of commercially pasteurised samples contained *B. coli* in 1 c.c. or less, whereas in all the laboratory pasteurised samples *B. coli* was absent from 1 c.c. Adequately pasteurised milk should therefore be free from lactose-fermenting organisms, although Ayers and Johnson (1915) state that a few bacilli may escape destruction in a large scale process.

In order to obtain data for the further comparison of commercial and laboratory pasteurisation of milk, the operation of a commercial plant was studied and samples of milk were examined on several occasions at the different stages of the process. The raw milk was obtained from various farms and mixed in a large tank, from which it was conveyed through a tube to the "pre-heater," where it was heated to 145° F.[1], and then passed through another tube to a small container and to the clarifier. From the clarifier it passed to the holding tank, in which it was kept at a temperature of 145° F.[1], the heating being done by steam. The tank was in four compartments, which were mechanically filled so that as the last compartment filled the first began to empty itself, the whole process taking 30 minutes approximately. There was one stirrer in each tank, which moved with a lateral motion. After it was

[1] 62·8° C.

held for 30 minutes, the milk passed through another tube to the cooler, which was uncovered and situated exactly opposite, being about three feet distant from the holding tank. From the cooler the milk was passed into a large tank and retained there till it was filled into bottles. The plant was not a very satisfactory one; there were too many connection tubes which were not adequately sterilised, the mechanism of the holding tank did not always work satisfactorily, and in some cases the milk was not completely held for 30 minutes at 145° F. The following samples of milk were taken for bacteriological examination: (1) raw milk after it had been well stirred in the mixing tank; (2) after pre-heating and clarification; (3) as it left the holding tank, this sample being cooled immediately; (4) as it came off the cooler; (5) after bottling. Bacterial counts were made from the various samples taken, the technique employed being that already described. A quantity of the raw milk was also pasteurised under laboratory conditions. The results are given in Table IV.

Table IV. *Effect of commercial and laboratory pasteurisation on the bacterial content of milk.*

	Total bacterial content								*B. coli* content					
No. of specimen	Raw mixed milk	After pre-heating and clarifying	After holding	% reduction	After cooling	After bottling	Lab. past.	% reduction	Mixed milk	After pre-heating and clarifying	After holding	After cooling	After bottling	Lab. past
1	36,000	30,000	1,800	95	2,000	3,000	800	97·7	1,000	1,000	0	1	1	0
2	60,000	3,200	200	99·9	200	260	100	99·8	10,000	100	1	1	1	0
3	9,000	1,200	180	96	200	220	80	99·1	100	10	1	1	1	0
4	170,000	24,600	900	99·4	1,000	1,000	600	99·6	100,000	100	0	0	0	0
5	4,000	3,000	980	75·5	1,000	2,000	200	95	100	10	0	0	0	0
6	6,000	3,400	2,000	66·6	2,000	2,800	180	97	100	10	0	0	0	0
7	40,000	36,000	760	98·1	800	800	100	99·7	1,000	1,000	1	1	1	0
8	32,000	28,000	200	99·3	200	200	200	99·3	100	100	1	1	1	0
		Average % reduction		91·2	Average % reduction			98·4						

It is evident from these results that pasteurisation of milk on a commercial scale may not be so efficient as that carried out in the laboratory on a small scale. It has already been shown (Table II) that *B. coli* does not survive heating for 30 minutes at 62·8° C. In the case of commercially pasteurised milk, *B. coli* was found in the cooled milk in four out of eight cases. The pre-heating and clarifying of the milk reduced the bacterial content considerably, the average reduction being about 46 per cent. This is probably due to removal of hair and particles of dirt, to which bacteria are attached, as well as to the effect of temperature. After the holding process, the average reduction was about 91·2 per cent. After cooling, the bacterial content increased slightly, the uncovered cooler exposing the milk to contamination by bacteria from the air and probably also adding bacteria from its inadequately sterilised surface. After bottling, a further increase took place. The laboratory pasteurisation of the same milk samples gave an average reduction in numbers of 98·4 per cent. and eliminated coliform organisms from 1 c.c., while the commercial process only reduced the bacterial content by 91·2 per cent. and

eliminated coliform organisms in 4 only out of 8 cases. These differences are doubtless due to the combined effect of the following factors: insufficient mixing of the milk in the holding tank so that all the milk was not heated uniformly to the required temperature; failure of the mechanical filling arrangement to function properly, resulting in the milk being heated for too short a period. The unsterilised connection tubes and the uncovered cooler with a contaminated surface were also responsible, probably, for the number of bacteria in the commercial product.

In Tables V and VI, the results of laboratory experiments on the effects of pasteurisation on *B. tuberculosis* are given. In the experiments shown in Table V, milk was inoculated with tubercle bacilli from cultures of human and bovine strains grown on Dorset's egg medium, a weighed quantity of each culture being ground up with saline in an agate mortar and added to the milk so that 10 c.c. of milk contained 0·025 gm. of the saline emulsion of the culture used.

Naturally infected milk was obtained from a cow suffering from tuberculosis of the udder, and subjected to pasteurisation under laboratory conditions (Table VI).

Table V. *Guinea-pigs injected subcutaneously with milk to which tubercle bacilli from cultures had been added.*

Guinea-pig		Temperature of pasteurisation ° C.	Result
1	1 c.c. milk + human tubercle bacilli	62	Remained healthy and thrived. Killed after seven weeks but showed no signs of tuberculosis
2	,, + bovine ,,	62	,, ,,
3	,, + human ,,	63	,, ,,
4	,, + bovine ,,	63	,, ,,
5	,, + human ,,	63·8	,, ,,
6	,, + bovine ,,	63·8	,, ,,
7	,, + human ,,	Unpasteurised	Died as a result of generalised tuberculosis with tubercular lesion at site of inoculation
8	,, + bovine ,,	,,	,, ,,

Table VI. *Guinea-pigs injected with naturally infected tuberculous milk from cow with udder infection.*

Guinea-pig		Temperature of pasteurisation ° C.	Result
1	1 c.c. sediment and cream	53	Died in six weeks as a result of generalised tuberculosis
2	,, ,,	55	,, ,,
3	,, ,,	57·5	,, ,,
4	,, ,,	60	Killed after six weeks but showed no evidence of tuberculosis
5	,, ,,	62·8	,, ,,

From the results recorded in Table V, it is apparent that pasteurising milk infected with pure cultures of human and bovine tubercle bacilli at 62° C. for 30 minutes rendered the milk non-pathogenic to guinea-pigs, since none

of the animals inoculated showed any tubercular lesions while the control animals receiving unheated infected milk died within seven weeks showing typical generalised tuberculosis.

Table VI shows that pasteurisation of naturally infected tuberculous milk at 60° C. and 62·8° C. for 30 minutes rendered it non-pathogenic to guinea-pigs, though the organisms survived and retained their virulence at 57·5° C. Thus, pasteurisation at 145° F. (62·8° C.), if efficiently performed, appears to be sufficient to annul the infectivity of milk from non-tuberculin tested cows and also allows a small margin of safety, though it is obvious that any variation in the temperature of pasteurisation below 60° C. may allow of the survival of this organism.

In order to test the effect of commercial pasteurisation on *B. tuberculosis* in milk, about one litre of milk was obtained from a cow suffering from tuberculosis of the udder and containing large numbers of bacilli. This was added to 50 gallons of milk in the holding tank of the commercial plant, the whole was well mixed, and 100 c.c. removed. The pasteurisation was then carried out as usual, and before the tap leading to the cooler was opened, another 100 c.c. of the milk was withdrawn and cooled. All samples were centrifuged and 1 c.c. of the sediment and cream mixed and inoculated subcutaneously into guinea-pigs, two animals being used for each sample. After six weeks, all the animals were killed and an autopsy made on each. The two animals inoculated with the milk before pasteurisation showed a generalised tuberculosis infection, whereas the two inoculated with the pasteurised milk showed no evidence of the disease. It is highly significant that even in such a high dilution (approximately 1 in 400) the milk was infective to laboratory animals. This apparatus, whose defects have been referred to, would still appear to be effective in disinfecting tuberculous milk.

Discussion.

Commercial pasteurisation is apparently effective in eliminating any tubercle bacilli that may be present in milk, but, while decreasing the total bacterial and *B. coli* content to a considerable extent, does not supply as satisfactory a grade of milk, from the bacteriological standpoint, as certified and grade A (T.T.) milks, which usually show a much lower bacterial content than the commercially pasteurised milk.

The deficiencies of commercial pasteurisation may, in fact, be due to inadequate heating resulting from the failure of the automatic filling arrangement to function properly. If the mixing of the large quantity of milk in the holding tank is not carefully attended to, there may probably be regions where the milk fails to reach the required temperature and other zones where the milk becomes overheated. In addition to these factors, there is always the risk of re-contamination to be considered, and where connecting tubes in the apparatus and the cooler are not thoroughly sterilised, the milk may be readily contaminated after the heating process is completed. For the pro-

duction of a satisfactorily pasteurised milk on a commercial scale, it is necessary that rigorous attention be paid to these details.

SUMMARY AND CONCLUSIONS.

Pasteurisation at 62·8° C. (145° F.) for 30 minutes leads to a marked reduction in *the total bacterial content* of milk, varying for different specimens from 94 to 99·8 per cent., when the process is carried out under the most exact conditions. At lower temperatures, *e.g.* 60° C., the percentage reduction may vary widely—from 51·6 to 97·4 per cent. The percentage reduction has been found to be slightly less when the same specimens of milk are pasteurised in a large scale apparatus than when treated in small quantities under laboratory conditions, the average reduction being 91·2 per cent. in the former case and 98·4 per cent. in the latter. The reasons for this are discussed.

An effectively pasteurised milk should not contain lactose-fermenting bacilli in 1 c.c., and the *B. coli* content is a valuable index of the efficiency of a pasteurising process.

Milk containing *B. tuberculosis*, when pasteurised at 62·8° C. for 30 minutes (1) in tubes in a water bath in the laboratory, and (2) on a large scale by a commercial plant, is rendered non-infective to guinea-pigs. By laboratory pasteurisation, even at 60° C. for 30 minutes, milk containing tubercle bacilli is rendered non-infective.

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