

THE PRODUCTION OF MILK OF LOW BACTERIAL CONTENT BY MEANS OF MILKING MACHINES.

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(With 1 Text-figure.)

IN recent years the difficulty of obtaining skilled milkers which has long been experienced by dairy farmers, has much increased with the result that many are turning their attention to mechanical milkers.

For years a few milking machines had been in use in England, and during the War, because of the labour shortage, they were installed in numbers. For various reasons many of them were abandoned after a few years and it appeared unlikely that milking machines would become really popular in England.

In many cases, experiences in the past had not been satisfactory, and a widespread prejudice against the use of machines was evident.

However, in some areas, the labour difficulty has now become so acute as to force farmers to consider the use of mechanical milkers. There is considerable evidence to support the common belief that machines in ordinary use adversely affect the keeping quality of milk as it has been abundantly proved by workers in several countries that machine-milked milk is often heavily contaminated with micro-organisms which cause early souring. This may or may not be the fault of the machines, but it seemed desirable in view of the importance of the question to undertake experiments designed to show whether or not it was possible to produce milk by machine which would have uniformly good bacterial counts and good keeping quality. That milk should have a uniformly low bacterial count is always desirable, but it is essential for those farmers who hold licences under the Milk (Special Designations) Order and for the increasing number of those who are being paid on the basis of the bacterial count of the milk they supply.

In the autumn of 1925 an Alfa-Laval milking machine was presented to this Institute by the Ministry of Agriculture when their demonstration farm at Methwold was closed. An experiment was, therefore, planned with the primary object of discovering whether or not it was possible by practical methods to produce milk of consistently low bacterial count and good keeping quality.

Although published work shows clearly that a good machine has no adverse effects on the cows or their milk yields, the opportunity of investigating these facts as far as possible, was taken.

The machine used is, in the main, typical of most successful milking machines in use at the present day. Milking is performed by suction used in conjunction with alternating suction and atmospheric pressure applied to the outside of the teat. Power is supplied by a small electric motor, or internal combustion engine, which drives the pulso-pump, from which one pipe line carries constant vacuum¹ and the other an alternating vacuum; to ensure that no serious weakening of the alternating vacuum occurs relay valves are placed between the vacuum pump and the milking units. The necessary pulsations are distributed to the teats in pairs by means of a small non-lubricated piston situated in a small pulse distributing chamber below the teat cups of each unit; thus while one pair of teats is under the influence of suction, the other pair is under atmospheric pressure, so causing the thin rubber teat liners to collapse and prevent milk being drawn for the duration of a pulse. The teat cups are connected to the pulse distributing chamber and milk claw by short thick rubber tubes, and from the claw the milk passes to the receiving pail by a large bore heavy rubber tube. The constant vacuum passes from the pump to the teat cups through the milk receiving pail, in the lid of which is a check valve whose chief function is to prevent a sudden loss of vacuum from the pail should the engine stop, thus preventing the teat cups falling off without warning. A rubber ring fits between the pail and the lid to prevent air being drawn into the milking units and so causing a reduction of efficiency. The interior of the teat cups is lined with thin rubber tubes which are maintained in a state of tension.

Plan of Experiment.

Two milking units were used during the experiment. One was washed and the other sterilized by the methods described below. Various American and continental publications advocate the use of disinfectants for the cleansing of the machines. Since, however, recently published work² shows that these disinfectants as used in practice are not to be compared in efficiency with the less expensive sterilisation by steam, they were not considered in this work.

The Washed Unit.

This unit was "washed" according to the instructions issued by the makers, of which the following is a summary.

"Immediately after each milking cold water is sucked through the unit by attaching the receiving pail to the vacuum line. The lid is removed and washed, first in cold and then in hot water. The milk tubes and claw are brushed through with the brushes provided, allowed to drain and dry, and re-assembled. Water at 185° F. is then drawn through and the assembled teat cups hung up to dry in a clean place.

Twice weekly (on Monday and Thursday mornings), the teat cups and

¹ "Vacuum" is not absolute but the word is used to denote reduced pressure.

² Hoy, W. A. and Rennie, Janet R. L. (1927), The Use of Hypochlorites as a Sterilizing Agent for Dairy Utensils, *J. Hygiene*, 26, 127-131.

liners are dismantled with the rest of the unit and the parts immersed in a soap bath ($\frac{1}{2}$ lb. soft soap to 5 gallons of water) for 45 minutes. They are then taken out, rinsed in a large volume of hot water, re-assembled, and hot water at 185° F. drawn through. The unit is then allowed to dry."

The greatest care was taken to make this treatment as effective as possible.

The Sterilised Unit.

Immediately after milking, cold water was sucked through in the way described for the "washed unit." All rubber parts including teat liners were then detached, thoroughly washed and brushed with hot water, suspended separately in the steriliser in a string bag and, together with all the metal parts, sterilised by steam with the ordinary milk utensils for ten minutes at 210° F.

During part of the experiment the teat cups and liners were dismantled as described after each milking so that no rubber was in contact with metal during sterilisation. This method was found to be too time consuming and was abandoned. Latterly the teat cup liners were removed only twice weekly, on Tuesdays and Thursdays, after the morning milking. On other occasions they were put into the sterilizer after washing without dismantling. When the experiment was almost finished a tool for inserting the teat liners was received. This shortened the time required for assembling the teat cups and liners to such an extent as to make it possible if desired to dismantle the teat cups and liners after each milking.

Cleaning the Pipe Line.

Once a week a hot concentrated solution of washing soda was drawn through the entire vacuum pipe line system in order to prevent it from becoming foul. A certain amount of this water remained in the pipe lines and supplemented the water of condensation which collects during milking. The effect of the water is discussed later.

The Experimental Cows.

Ten cows were used for the experiment of which five were always milked by the "washed" unit and five by the "sterile" unit. Amongst them were first, second, third and fourth calvers. No udder disease existed in the cows but the whole herd was searched for cows showing as many physical abnormalities of the udder as possible, with the object of testing the efficiency of the machine in milking those cows with abnormally shaped udders and teats which occur in most herds.

Some of the selected animals had short teats while others had large balloon teats. One cow was for some months suffering from numerous warts which ordinarily impede milking. Other cows had udders lacking in symmetry resulting in splay teats, and one cow had a quarter from which it was very difficult to draw milk.

In order to avoid any irregularity of the bacterial counts, due to varying udder floras, cows which were milked at one milking by the washed unit, were milked at a subsequent milking by the sterile unit. During the winter the cows were bedded in straw in the usual way and were milked in the places where they slept. In summer when the cows were out at grass, no bedding was used.

Preparation of Cows.

The cows received no special cleaning beyond that found on farms producing graded milk, the ordinary methods of clean milk production being followed. The hair on the udder and flanks was, of course, kept clipped, and the udders washed and dried before milking.

The fore milk was in all cases rejected and the strippings were taken into a sterilised covered pail.

Sampling.

In the early part of the experiment for a period of three months, the milk of each individual cow, without strippings, was sampled, after the milk had been weighed.

The whole of the milk taken by the washed unit was then mixed in a sterile churn and a bulk sample taken. The milk from the sterile unit was similarly treated and sampled. The samples were then cooled, by immersing the containers in water, and kept in the dairy. Bacteriological examinations and keeping quality tests were then made by routine methods when the samples were about 28 hours old. The strippings taken from each cow were weighed separately. Sterile apparatus was used throughout for handling the milk.

The percentage of fat in the strippings and in the milk taken by the machine was determined for each individual cow.

The experiment was begun on January 10th, 1926. Careful observations of any occurrences likely to affect the milk yield or bacterial count were made throughout the experiment.

Results of bacteriological examinations.

For convenience the bacteriological results and the milk yields are discussed separately.

At intervals throughout the experiment tests for visible dirt were made but in no case was any dirt found.

Table I shows that at some milkings both the sterile and the washed units were responsible for heavily contaminated samples and that the milk of some cows which showed excellent counts at one milking, gave very large counts at subsequent milkings.

Table I A shows further that at some milkings high counts from one cow were followed by low counts from the next cow to be milked.

In order to discover the cause of the contamination the following experiments were carried out.

Table I. *Fluctuations in Bacterial Counts of Milk.*

Date	Name of cow	Milking unit	Agar count per 1 c.c.
2. II. 26	Carlet	Sterile	220
4. II. 26	"	"	3,680,000
7. II. 26	"	Washed	500
9. III. 26	Fanny	Washed	8,800
11. III. 26	"	"	5,000,000
9. III. 26	Cherry	Washed	1,960
11. III. 26	"	"	10,000,000
9. III. 26	Duchess	Sterile	280
11. III. 26	"	"	850
15. VII. 26	Mixed sample	Washed	10,000,000
	"	Sterile	3,500,000
3. IX. 26	"	"	1,050
	"	Washed	2,264,000

Table I A.

Date	Name of cow	Order of milking	Agar count per 1 c.c.
11. III. 27	Fanny	1	5,000,000
	Cowslip	2	1,800
	Queen	3	1,100
	Betty	4	3,000,000
	Cherry	5	10,000,000

It was considered that possibly the cleaning of the units was not satisfactory. Therefore, after cleaning by the methods described, the units were twice thoroughly washed through with sterile water and the washings plated.

In repeated experiments, during the winter period, only an insignificant number of organisms was found in the washings from the washed unit, and none in the sterile unit. Similar results were obtained when the teat cup liners and all the milk tubes were cut open and thoroughly swabbed with sterile water. This, therefore, could not be regarded as a possible source of contamination.

It was then thought that owing to the fact that after removal from a cow's udder and before attachment to another cow, it is necessary to release the vacuum in the receiver, it was possible in an atmosphere to some extent dust laden, that contamination of the milk might originate in this way. In order to test this point, a litre of milk of known bacterial count was poured into the sterile unit and vacuum created and released ten times, the air being contaminated by agitation of the straw bedding. Bacterial counts were then made. It was found that the amount of contamination received in this way was so small that it could not account for the very high counts which were found.

The irregular appearance of comparatively enormous counts interspersed with good counts, led to an investigation of the vacuum pipe line. It was then found that water was collecting in the pipe line which had been extended to the dairy for washing purposes, and it was thought that some of the water, which on examination proved to be very heavily contaminated with bacteria, which enter from the air through the relay and other valves, and through the taps, was finding its way into the milk receivers, although a check valve was provided in the lids. A suspension of carmine, was, therefore, sucked into the

pipe line and then as far as possible drained out. Much of the insoluble carmine was deposited on the inside of the pipes and by watching the filter through which the milk was eventually passed in the dairy, specks of carmine were found from time to time over an extended period. By observing glass traps fitted between the taps in the pipe line and the rubber tubes which connected it to the milk receiving pail it was found that small quantities of moisture carrying particles of carmine were making their way down the connecting tubes to the receiving pail where they accumulated on and around the check valve through which some passed into the milk. This water which was found to collect continually during working was so heavily contaminated with bacteria that a few drops entering the receiver were sufficient to raise the bacterial count of the milk to a serious extent. It seemed, therefore, that unless the possibility of the entry of water from the pipe line into the receiving pail could be removed, there was little chance of producing milk of consistently low bacterial count.

After several trials it was found that the provision of simple traps in the pipe line between each five cows, turning all vacuum supply taps upwards, giving a generous slope of not less than 3 in. in 15 ft. to all parts of the pipe line and providing drain cocks at the end of each sloping section, made it possible to exclude water from the receivers (Fig. 1). In addition, air was drawn through

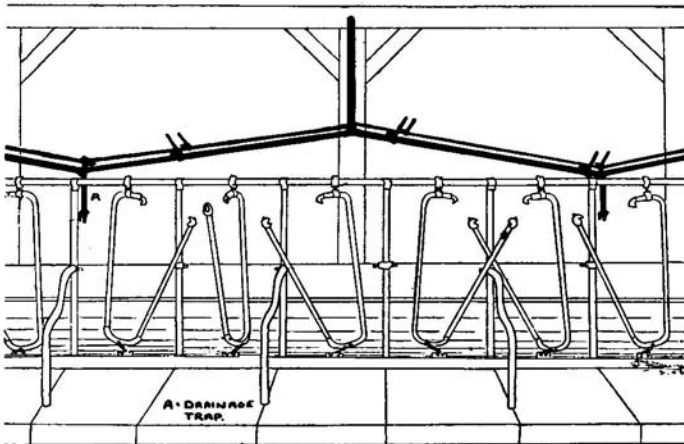


Fig. 1.

the system with all taps open for three minutes, before and after milking, in order to dry out any moisture which might have collected in the pipe line. Taps were always left open between milkings to facilitate drainage. At this time also that section of the pipe line supplying vacuum to the sterile unit was made detachable for sterilisation. This section was removed and sterilised after each milking and for a period of a month uniformly excellent counts were obtained with the sterile unit. However, during the same period the counts of the samples taken from the washed unit receiving vacuum from an un-

sterilised section of the pipe line were equally satisfactory. Sterilisation of the pipe line was therefore abandoned as being unnecessary.

Contamination of the milk by leakage from the pipe lines is by no means peculiar to the make of machine under test. It has been found to occur in other machines and various devices have been suggested for its prevention. The simplicity of the methods adopted here seem, however, to have much to recommend them.

When these alterations had been made immediate improvement in the bacterial counts of the milk taken by both units was evident. Having reduced the bacterial counts to a low figure it remained to be seen whether or not the improvement was permanent. Consequently an experiment covering all seasons of the year was carried out.

Between September 16th, 1926 and September 16th, 1927, 191 examinations of the milk taken by the washed and by the sterile unit were made, the results being shown in Table II.

Table II. *Bacterial counts of 191 bulk samples of milk taken by the Washed and Sterile Unit.*

September 16th, 1926—September 16th, 1927. Age at examination, 28 hours.

	Number of colonies per 1 c.c. on nutrient agar.							
	0- 1000	1001- 5000	5001- 10,000	10,001- 30,000	30,001- 100,000	100,001- 200,000	200,001- 500,000	Over 500,000
Washed unit	107	30	14	7	5	4	4	20
Sterile unit	126	38	9	11	4	2	1	0

Sterile Unit.

It is seen that the results obtained with the sterile unit are quite remarkable, when the age of the milk (28 hours) at the time of examination is considered.

Of 191 samples examined at all periods of the year no less than 126 showed counts below 1000 per 1 c.c., 173 were below 10,000 per c.c. and 184 below 30,000 per c.c. One hundred and ninety conformed to the Grade A standard of 200,000 per 1 c.c. and one sample only gave a count (360,000) which was greater than 200,000 per 1 c.c. *Bacillus coli* was found on eight occasions only; five times in 1 c.c., twice in $\frac{1}{10}$ c.c. and once in $\frac{1}{100}$ c.c.

Washed Unit.

The results obtained with the washed unit are not so satisfactory although 107 samples gave counts of less than 1000 per 1 c.c. and 151 of less than 10,000 per 1 c.c. However 24 samples showed more than 200,000 colonies per 1 c.c. and 20 samples more than 500,000 per 1 c.c. Further, in the case of the washed unit, *B. coli* was found in 33 of the 191 samples examined; 10 times in 1 c.c., 7 times in $\frac{1}{10}$ c.c. 4 times in $\frac{1}{100}$ c.c. and 12 times in $\frac{1}{1000}$ c.c.

In Table III the bacterial counts of winter samples have been compared with those of summer samples, and it is seen that during the winter there is little to choose between the washed and the sterile unit.

During the summer period, however, it is evident that washing however carefully done is not really effective since the great majority of the high counts obtained with the washed unit occur in the warm months. It is, moreover, unlikely that conditions on the majority of farms would allow of the use of

Table III. *Comparison of bacterial counts of samples from the washed and sterile units during the summer and winter periods.*

	Number of colonies per 1 c c. on nutrient agar.								Total
	0-1000	1001-5000	5001-10,000	10,001-30,000	30,001-100,000	100,001-200,000	200,001-500,000	Over 500,000	
September 16-30th, 1926 and May 1st-September 16th, 1927									
Washed	18	16	11	6	5	3	5	19	83
Sterile	29	29	8	9	4	2	2	0	83
October, 1926-April, 1927									
Washed	89	15	3	0	0	1	0	0	108
Sterile	96	9	1	2	0	0	0	0	108

water for washing the units at 185° F. (85° C.) on all occasions, so that under ordinary working conditions it would be safer to use steam which is less liable to fluctuations.

Keeping Qualities.

Table IV shows the keeping qualities of the samples of milk taken by the washed and sterile units.

It is evident that in this important respect the record of the sterile unit is very satisfactory.

Table IV. *Keeping qualities, in hours from the time of milking, of samples of milk kept at 15.5° C.*

	Number of samples keeping more than 50 hours	Number of samples keeping less than 50 hours	Average keeping quality of all samples in hours	Total number of samples
Washed unit	183	3	86	186
Sterile unit	185	1	96	186

The keeping qualities which were estimated by the routine method¹ are stated in hours from the time of milking, the samples being kept at a constant temperature of 15.5° C. Assuming that a keeping quality of 50 hours from the time of milking is sufficient for trade purposes, it is seen that on only one occasion does the period of sweetness of the milk fall below this figure. It is of interest to note that the average keeping quality of all the samples is no less than 96 hours and in many cases they were sweet for 120 hours.

In the majority of the samples from the washed unit, keeping qualities were also very good, but in three samples they failed to reach 50 hours, whilst the average period of sweetness of all the samples was 86 hours as compared with 96 hours in the case of the sterile unit.

¹ Ministry of Agriculture (1926), *Miscellaneous Publications*, No. 43, p. 14.

It has always been assumed that because of rapid deterioration of the rubber it is not possible to sterilise rubber and metal in contact with one another. In the case of the teat cups and liners of the Alfa Laval Machine, this was done on all occasions (except twice per week) for a period of six months. The life of the liners was certainly reduced by this treatment but not to such an extent as to make the practice economically impossible, particularly in view of the advantages of steam sterilisation. It was found that if the teat cups and liners were separated after each milking, and the latter steam sterilised out of contact with metal their effective life was reduced from 200 to about 170 working hours. When the teat cup and liners were steam sterilised together the life of the liners was about 120 working hours. The other rubber parts not being in a state of tension suffered surprisingly little when sterilised.

Therefore, in machines from which it is not difficult to remove and replace the teat cup liners (this is now the case with the machine under test) there is no reason why steam should not be successfully used as a sterilising agent, without seriously shortening the life of the rubber parts, provided these are of good quality.

It must be pointed out that all the utensils used in handling milk taken by machine must be sterilised, the cows kept clean and the necessary precautions taken to avoid contamination during stripping, so that clean milk from the machine may not be contaminated subsequently.

Dairy Husbandry Aspect.

Of not less importance than the hygienic efficiency of a mechanical milker is its ability to milk cows in such a way that the animals themselves, the milk yields and the composition of the milk are not adversely affected.

Although amongst milk producers it is generally conceded that the actual process of milking by machine is satisfactory, it is commonly believed that the percentage of fat in the milk is less than that of milk taken by hand. Observations were, therefore, made during the course of the experiment on the points which are of practical importance.

Behaviour of the cows.

With young cows, whether first or second calvers, no difficulty whatever was experienced in milking by machine. This was also true of the majority of old cows but in one case fluctuations in the yield compelled the resumption of hand milking. In some cases it was found that cows with short teats milked better by machine than by hand. Careful observations over a long period did not reveal any abnormal turgidity of the teats. Although during the experiment several cows suffered in one or more quarters from mild mastitis, in no case was there any evidence of the carriage of infection from animal to animal by the teat cups.

Rate of Milking.

Observations of the rate of milking were made during the experiment and it was found to be substantially the same as in good hand milking.

Quantity of strippings.

The actual quantity of strippings which have to be milked by hand was variable, but in many cases was very small. The average quantity was $\frac{3}{4}$ lb. per cow per milking.

At 192 observed milkings the total quantity of strippings amounted to 5.93 per cent. of the total milk yield.

Percentage of Fat.

The average percentage of fat in the total milk obtained at 192 milkings was 3.83, a figure which is satisfactory for a herd in which Shorthorn cows largely predominated.

The average percentage of fat in the strippings was 7.71, which shows that although the quantity of strippings might appear small it is essential not to rely on the machine to remove the whole of the milk from the udder.

Total Yields.

The yields of those cows which completed a lactation period whilst being milked by machine was found to be quite satisfactory, heifers yielding 5000 lb. and upwards and older cows 9000 lb. or more.

It was not found possible because of the experimental nature of the work to make accurate calculations of the amount of labour involved in running the machine and of the cost of upkeep, but it was obvious that in a herd of sufficient size, even when the labour necessary for cleaning is included, a considerable saving might be expected.

SUMMARY.

This experiment has demonstrated that it is possible consistently to produce milk containing small numbers of bacteria and of good keeping quality by the use of milking machines.

It has been shown that the milking units and their rubber components may be successfully sterilised by steam.

The pipe lines have been shown to be a possible source of heavy contamination, and means of preventing this have been described.

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