*Mastitis—the Continuing Efforts Toward Control

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Over the years and in all parts of the world the imperative for improved mastitis control grows stronger and stronger. The call for control becomes louder primarily because of an increased understanding of the high production losses which inevitably accompany mastitis in dairy cows. It is no longer feasible or even possible to absorb these losses as a normal cost of production and dairymen or production units which continue to allow these losses are certain to fail sooner or later.

Production Losses

Although losses occur from costs of treatment, higher replacement costs, loss of mastitis milk or milk containing drugs, etc., the greatest losses occur from reduced production due to subclinical mastitis in infected quarters. When production of quarters positive to the California Mastitis Test (CMT) were compared to CMT negative quarters, production was reduced up to 42% in the positive quarters (8). When comparisons were made using total milk (bucket milk) from the cow, losses were up to 25% of total production (Table 1) (6,9). Percentage losses applied to bucket milk can also be applied to the total dairy production milk (tank milk) since both samples represent mixed milk. Therefore, by reference to Table 1 the total herd production loss would be about 10% if the bulk tank CMT score is 2 and about 25% if the bulk tank CMT score is 3.

In a study of 962 quarter pairs it was shown that relative yield was reduced by 35% in quarters infected for three months or more and by 13% in quarters with transient infections (Table 2) (19). When infections were successfully treated at drying off, yield in the affected quarter was normal in the next lactation period.

In a three-year study of 24 herds averaging 13,400 lbs. of milk per year the production of cows with one infected quarter averaged about 1,500 to 1,700 lbs. less than production in uninfected cows (Table 3) (21). When we consider that it is common for 50% of the cows to be infected in 50% of the quarters, even in herds not considered to have a mastitis problem, and that the bulk tank milk of many herds is still CMT 1 or higher it must be recognized that herd production losses from unrecognized subclinical mastitis are frequently 10-15% and sometimes higher.

Cost of Mastitis

Loss of milk from chronic subclinical mastitis accounts for the greatest losses from mastitis. The annual cost per cow in herds at different production levels is estimated at current U.S. prices for tank milk scoring CMT-Trace (300,000 cells/ml), CMT 1 (±900,000 cells/ml), and CMT 2 (±2,700,000 cells/ml) (Table 4). The dollar savings per cow in the herd from reducing the cell counts on tank milk are also shown.

Treatment costs are significant, due primarily to loss of milk for sale during treatment and during the withdrawal period essential to allow disappearance of antibiotic residues. This is estimated for a 100-cow dairy at different treatment rates (Table 5).

Total increased income from mastitis control for herds at different production potentials has been estimated for a change in CMT score from 2 to trace (Table 6).

Although these costs are calculated in U.S. dollars under current conditions, it is an easy matter to convert them to other local production and cost figures.

Milk Quality

The nutritive value of milk is reduced by subclinical mastitis because lactose and casein values are reduced and albumin, globulin and salt levels increase (Table 7). Such milk is also less desirable for cheesemaking. *Streptococcus agalactiae* numbers may exceed permissible bacteria counts. Milk from herds with mastitis problems frequently have illegal leukocyte counts and are likely also to have antibiotic residues. In many areas the marketing of poor quality milk is no longer permitted and if quality milk is to be produced, mastitis must be prevented. Control of mastitis is therefore required so that quality milk can be marketed.

Milking Management and Milking Machines

We cannot develop these themes in the short time before us today but I do wish to emphasize just a few points.

1. Good milking requires that the procedure fits the cow's physiological characteristics. It is important to obtain a strong oxytocin release and letdown response prior to onset of milking. It is important to avoid extraneous noise, excitement or rough treatment if good milking is to be achieved. Pain and excitement stimulate epinephrine release which inhibits oxytocin. It is important that the cow be milked out quickly and well as the maximum letdown response

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Table 1
Production Losses From CMT Reactor Cows

CMT Score	Percent Loss From CMT Negative: Bucket Milk CMT Avg. Loss for Cow		Quarter Milk CMT Avg. Loss for Qtr.
T	6*	5**	6***
1	10	11	19
2	16	16	30
3	25	21	42

*D.M. Gray and O.W. Schalm; Davis, CA.
**R.C.W. Daniel, Biggs and Barnum; Guelph, Canada.
***T.T. Forster, Ashworth and Luedecke; Pullman, WA.

Table 2
Response of Quarter Milk Yield to Infection as Compared in 962 Paired Quarters

Infection Status	Yield Loss As Compared to Opposite Quarter	Yield Next Lactation Following Successful Dry Cow Therapy
Infection Lasting > 3 months	-35%	100% Normal
Infection Lasting < 3 months	-13%	100% Normal

R.S. Morris. Aust. Vet. Jour. 49:153, 1973.

Table 3
Pounds Lost Milk Production/Cow/Year Due to One Infected Quarter

	Lactation Number 1	2	3
Staphylococci	1700	1632	1694
Str. Agalactiae	1892	1448	1780
Other Streptococci	1932	1232	1553
Coliform	1670	1329	1421
Other Bacteria	1885	1265	1630

Natzke, et al., J. Dairy Sci. 55:1256, 1972.

lasts only about five minutes.

2. Milking machine systems, properly designed and used, can be a great help to mastitis control. On the other hand, milking systems poorly designed, poorly maintained and poorly operated can be the major underlying cause behind mastitis problems in a herd. The first step in a mastitis control program therefore should be an evaluation of milking management and of the milking machine system itself.

Milking systems have changed significantly over the past 20 years, although the principles of operation have remained fairly constant. Most changes have been directed toward increasing the capacity of the system for transporting larger volumes of air and milk with greater vacuum stability.

New installations are not necessarily well-designed. This is more likely to be true outside of major dairy areas which have immediate, strong and knowledgeable interaction with the milking machine manufacturers. Developing countries may be at a disadvantage in this respect in that both sellers and users of milking equipment may be far from knowledgeable people regarding equipment design and use. There is a special problem in areas where machines of low capacity have been installed and production is later increased by introduction of improved breeding stock, better nutrition and better cow management. Higher producing cows under these conditions run a high risk of mastitis which could severely reduce the benefits of better breeding and management. One should not blame the cows if this happens, the fault may well lie with the milking machines and milking management. Certainly there are many areas where inadequate milking machines hinder mastitis control.

A general discussion of machine milking and minimum system specifications is available (18). A more recent publication with more detailed information especially suitable for larger herds is in press (33). A useful bulletin on milking machines is also available in Spanish (34). Unless really expert help is available for analysis of milking machine function, the veterinary practitioner may have to learn to make these evaluations himself. It may be the only way to really solve a mastitis problem. For this, he will need such equipment as a vacuum gauge, a vacuum recorder, and a carpenter's level and must know how to use them.

3. We have long understood that milking machines act as fomites to carry infection on teat cup liners from one cow to another during milking. This is illustrated in Figure 1, which shows coliform bacteria from a swab taken before milking from the end of a teat of a quarter in the early stage of coliform mastitis. Swabs taken after milking show all teats contaminated with coliform bacteria (Figure 2) (13). A swab of a teat cup liner taken after milking shows the heavy population of bacteria after milking and the decrease after backflushing (13). Automated backflushing systems are being investigated which may reduce transfer of infection by this means (Figure 3) (4,5,13).

Milking machine action is also responsible for impacts of milk droplets which can carry infection directly through the teat canal (28). This is likely to occur near the end of milking in the presence of cyclic and irregular vacuum fluctuations (17,28). It appears that this occurs when small droplets in the unfilled short milk tube are propelled by upward movement of air as the liner opens (27).

More recent work has shown that air admission between the teat and the liner or inflation, which is most often seen near the end of milking, may be the most common machine-related factor associated with new infection rate (23). This may occur without obvious signs of air admission and may be the principle way in which milking machines actively promote infection. Bacteria-laden moisture or particles are apparently drawn down along the side of the teat to the claw and then enter a connecting short milk tube where they impact on a teat end and predispose to in-

Table 4. Production Loss in Dollars Per Cow @ $10.00 per Cwt for Milk

Potential Animal Production (Pounds per Year)	Production Loss CMT 2 per Cow (Pounds)	Dollar Loss CMT 2 per Cow	Dollar Loss CMT 1 per Cow	Dollar Loss CMT Trace per Cow	Dollar Savings CMT 2 to CMT Trace	Dollar Savings CMT 1 to CMT Trace
8,000	1,200	$120	$ 80	$ 40	$ 80	$ 40
10,000	1,500	150	100	50	100	50
12,000	1,800	180	120	60	120	60
14,000	2,100	210	140	70	140	70
16,000	2,400	240	160	80	160	80
20,000	3,000	300	200	100	200	100

Average production = 46 lb./day = 14,000 lbs./305 day/year. D.E. Jasper

Table 5
Estimated Costs for Treating Clinical Cases
@ $10.00/Cwt. in a 100 Cow Dairy

Per Week	Clinical Cases Per Month	Per Year	Percent Per Year	Treatment Cost Per Year
0.12	0.5	6	6%	$ 120 - 150
0.23	1.0	12	12%	240 - 300
0.46	2.0	24	24%	480 - 600
1	4.3	52	52%	1040 - 1560
2	8.6	104	104%	2080 - 2600
3	12.9	156	156%	3120 - 4680

Average production = 46 lb./day = 14,000 lbs./305 days/year. D. E. Jasper

Table 6
Dollars Returned by Mastitis Control
@ $10.00/Cwt.

Potential Production Pounds per Year	Dollars Received per Cow From: Increased Milk Production[1]	Reduced Treatment Expense[2]	Reduced Replacement Expense[3]	Increased Income: Dollars per Cow in Herd	Dollars per 100 Cow Herd
8,000	80	20	20	120	12,800
10,000	100	20	23	143	14,300
12,000	120	20	25	165	16,500
14,000	140	20	27	187	18,700
16,000	160	20	30	210	21,000
20,000	200	20	35	255	25,500

[1]By reducing the bulk tank CMT from 2 to trace.
[2]By reducing treatments from 2 cases per week to 1 case per 2 months.
[3]By reducing replacement of low producing cows from 10 to 5 cows per year.

fection. Therefore, every effort should be made to see that teat cups seat and fit well on the teats, that teat cups neither crawl nor drop off and that teat cups do not admit air between the liner and the teat skin. There will be many observations on this aspect of infection transfer in the coming few years and perhaps ways will be found to control it.

4. Unconventional Milking Systems. While important steps are being made in the perfecting of the conventional milking machine and its operation, others are exploring unconventional systems of milking. Among these are two systems which do not use teat cup liners, the swinging vacuum system from New Zealand (24) and the PME system from Germany (29). Both of these systems were expected to reduce transfer of infection between teats but both caused an increase in transfer and in new infection rate (15,16,32). This has stimulated additional attention to aerosol movement in the teat cup and cluster which may benefit all machines in the long run.

Modifications in the PME system to a PKME system, including reintroduction of pulsation, but located in the mouthpiece only, and four separate long milk tubes leading to the milk pipeline, appear to have solved the cross infection problem (30). Use of four separate long milk tubes is also being explored for use with conventional machines in California (3).

Infectious Causes

Streptococcus agalactiae and *Staphylococcus aureus* are still the principal causes of mastitis in most areas. However, mastitis due to these organisms can be controlled and eliminated from dairy herds by good management and treatment programs.

It has come as a surprise to many to sometimes find mastitis still to be a problem in herds with *Streptococcus agalactiae* and staphylococcal mastitis problems. A major cause of this is mastitis due to environmental organisms such as *Streptococcus uberis, Streptococcus fecalis* and the coliform or Enterobacteriaceae organisms.

Table 7
General Changes in Milk Composition
Associated with Elevated Somatic Cells

Measurement	Normal Composition (%)	Change* from Normal (%)	Reason
Decrease:			
Casein (total)	2.8	82	decreased synthesis
Lactose	4.7	85	decreased synthesis
Fat	4.2	88	decreased synthesis
Total solids	13.1	92	decreased synthesis
Increase:			
Whey protein (total)	0.8	162	leakage from blood
Chloride	0.091	161	leakage from blood
Sodium	0.044	136	leakage from blood
pH	6.6	105	leakage of alkaline components

*Examples of normal values and changes reported in various studies.

From: Current Concepts of Bovine Mastitis, Second edition, 1978. National Mastitis Council, 30 F St. N.W. Washington D.C. 20001.

Table 8
The Response (% eliminated) of Infection Treated with Cloxacillin
When Treatment was Given at Various Times

Type of Infection	% Responding when treated in: Lactation (clinical)	Lactation (sub-clinical)	At Drying Off (sub-clinical)
S. aureus	25	40	65
S. agalactiae	85	>90	>95
S. dysgalactiae	90	>90	>95
S. uberis	70	85	85
No. of quarters treated	2,000	600	2,750

From F. H. Dodd. Proc. No. 28, Post-Graduate Committee in Veterinary Science, 280 Pitt St., Sydney, Aust., 1976.

Table 9
Occurrence of New Infections

Infections/Week	Weeks	New Infecti	
Dry Period	3	51	17.0
	11	7	0.6
Subtotal	14	58	4.1
Lactation	41	63	1.5

Escherichia coli, Enterobacter aerogenes and *Klebsiella pneumoniae* are the most common of the Enterobacter group of organisms but other members of the group also cause mastitis. Each of these organisms may grow and multiply in the bedding used by cows and may occasionally cause mastitis. When numbers in bedding increase beyond 10^6 the incidence of mastitis due to these organisms also increases (1,2). In a study utilizing sawdust, wood shavings and straw bedding materials, sawdust supported the highest coliform populations, straw supported the least (25). Sawdust has been associated with high counts of Klebsiella and outbreaks of Klebsiella mastitis (22). However, Klebsiella will multiply in other types of bedding as well and other coliforms will grow in sawdust.

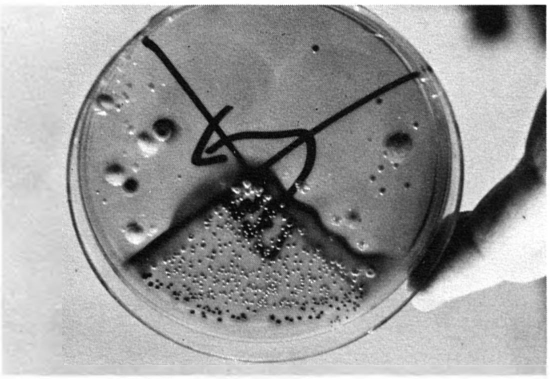
Although sawdust seems particularly suited for supporting large coliform populations, especially Klebsiella, other types of bedding may also. A major factor is contamination by urine and feces which provide moisture, nutrients and an inoculum of *E. coli*. Klebsiella is frequently present in fresh sawdust. Enterobacteriaceae are often present in the environment and all of them need only moist, nutrient conditions and proper temperatures in which to grow.

In our study of corrals we found coliform counts to be much lower in those corrals with a dirt base than in those bedded with sawdust or with chopped cotton stalks. We also found very wet sloppy areas to have lower coliform counts than better looking dry areas. High coliform counts can build up quickly in sawdust even though it still looks new and fresh whereas badly used and soiled sawdust bedding may have much lower counts.

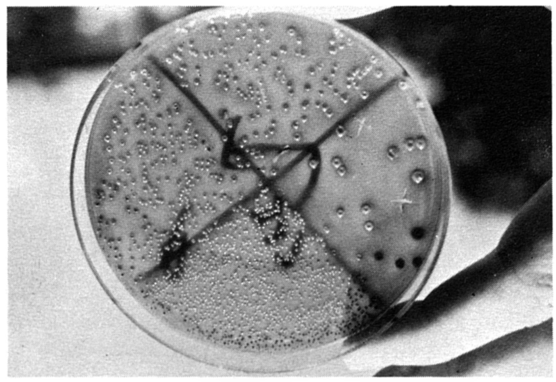
Probably many different bedding materials can be safely used if protected against urine and fecal contamination. This is possible in good free-stall housing situations. It is difficult in open housing where population pressures result in cows crowding together. In one experiment (1,2) no coliform mastitis was found in cows bedded in cubicles on sand. Sand does not support growth of coliform bacteria and where feasible may be a very desirable bedding material.

At other times coliform bacteria may build up on improperly cleaned and sanitized milking equipment (10,14). Old inflations with cracks are hard to clean and may be a source of infection.

Control of mastitis from coliform and other environmental organisms starts with population control in the environment and continues with good milking



Before



After

Figures 1 and 2. McConkey agar plate cultures of teat end swabs taken before and after milking from a cow with early coliform mastitis in one quarter.

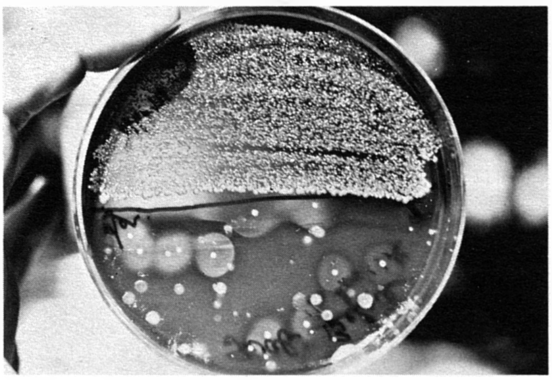


Figure 3. Blood agar culture of liner swabs taken before (top) and after (bottom) back flushing with water containing Rapidyne (25 ppm).

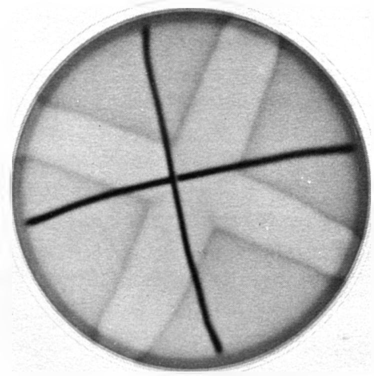


Figure 5. A blood agar plate streaked with β-hemolysin ready for inoculating four milk samples.

Figure 6. A blood agar plate streaked with β-hemolysin after inoculation and incubation. *Streptococcus agalactiae* colonies are surrounded by a Camp reaction within the zone of β-hemolysis.

sanitation and good milking systems properly operated.

Mycoplasma bovis and several other mycoplasma species cause mastitis generally characterized by sudden onset, marked reduction in milk secretion, or almost complete agalactiae, often purulent secretions, and variable swelling and edema of the udder (11). The course of the disease is highly variable and may last for weeks or months. It is capable of spreading rapidly from cow to cow at milking time.

Treatment has not been of much value and control efforts are directed toward isolation of infected cows away from non-infected cows following culture diagnosis. Several herd cultures may be necessary before an outbreak is stopped. In areas where mycoplasma mastitis exists, infection is often introduced into a herd by purchase of cows. It is generally recommended that new stock be tested for mycoplasma mastitis before it is mingled with the rest of the herd.

Diagnosis

A good diagnosis is still essential to wise handling of a mastitis problem. A very fine and inexpensive diagnostic manual is available (20). In this as elsewhere (26), the basic diagnostic medium is an agar plate containing 5% of washed cow red blood cells. We use a quarter plate for quarter samples, a half plate for composite cow samples and an entire plate for bulk tank milk samples. Prior to streaking the culture plate with 0.01 ml of milk, it is useful to make one or more streaks across the blood agar with a solution of crude staphylococcal β-hemolysin (Figure 5) (12,31). By using this method the Camp reaction on streptococci and hemolytic patterns on staphylococci can be observed on primary plates (Figure 6). Mycoplasma and some other organisms need special media and growth conditions.

Control

In the typical herd with a streptococcal and staphylococcal infection problem, the hygiene-dry cow therapy program devised at Reading in England offers the best approach (7). In the case of heavy streptococcal infection, all such cows should initially be treated. Because of poor cure rates during lactation quarters infected with staphylococci are best treated during the dry period (Table 8).

Treatment during the dry period is highly effective for streptococci and reasonably effective against staphylocci. Furthermore, it prevents much of the infection that occurs during the first three weeks of the dry period (Table 9).

At the beginning of a control program in infected herds, every quarter of every cow should be treated at drying-off time. After a high level of control is attained and little or no streptococcal or staphylococcal mastitis exists, some system of selective dry cow therapy may be in order such as treatment of only those cows with a high CMT or positive cultures during the preceding lactation, and/or quarters positive to culture a week before drying.

Hygiene in a Control Program

In order to reduce new infection rates, dipping of teats in a disinfectant solution has been advised (7). In streptococcal and staphylococcal infected herds this practice reduces new infection rates by about 50%. The most common teat dip has been 0.5 to 1.0% iodophore. Other products were 0.5% chlorhexidine and 4% hypochlorite. Teat spraying has also been used but problems in uniform application have been common. Teat dipping is still considered the most important deterrent to new infections in the average herd.

However, teat dipping is not helpful in preventing mastitis due to environmental organisms such as *S. uberis* or the coliform bacteria. In order to provide better protection against these infections as well as against conventional infections and unusual infections such as mycoplasma, further work is underway on premilking sanitation and mechanization of hygienic practices including backflushing of teat cup clusters (5,13).

Clearly, mastitis is not yet controlled. But, with the intriguing developments in management, equipment designs and function, environmental management and sanitation, we have some reasonable hope that mastitis will not be the problem in the future it has been in the past.

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