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ECONOMIC LOSSES TO NEW YORK'S DAIRY SECTOR DUE TO MASTITIS

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ABSTRACT

Mastitis is a major cost for the dairy sector, leading to an estimated loss of $177 per cow from reduced milk production, treatment and increased culling. When quality and yield loss for the processing sector are added, the cost to the New York industry is nearly $200 million annually.

This paper evaluates two promising new technologies, a bactericidal protein treatment and a vaccine. Both have shown effectiveness in preliminary trials against a major source of infection. Assuming that further development will allow products effective against the major bacterial source of infection, the products are projected to save the New York industry $18.7 and $50.9 million annually, respectively. The bactericidin will reduce or replace antibiotic usage, a desirable goal in the opinion of many, but the vaccine promises to reduce the significant management currently required to control the disease.

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Heiko Frick and William Lesser[1]

Introduction

Mastitis has been considered the number one dairy disease for many years. Although much research effort and funds have been spent to gain knowledge of the etiology and control of mastitis, the disease remains a substantial problem. Indeed, little real advance has been made in mastitis control following the advent of antibiotics and improved management practices going back to the World War II era. Now biotechnology promises treatment breakthroughs which could reduce mastitis levels substantially and be a major economic boon to dairy farmers and milk processors. This paper analyzes two promising new developments, the use of bacterial proteins and of a mastitis vaccine. The economic implications of these new developments are evaluated in the latter sections of the paper. To set the stage for that analysis, the earlier sections contain a review of the mastitis literature, culminating in a projection of the costs of mastitis to the New York dairy sector in 1988.

Etiology of Mastitis

Mastitis is an inflammation of the udder's milk secreting tissue caused by bacterial infections. The four most common bacteria - Staphylococcus aureus, Streptococcus agalactiae, Streptococcus dysgalactiae, and Streptococcus uberis - cause 90-95% of all infections[30]. The first two bacteria types are contagious and are spread by infected cows; the latter two are present in the environment and on the cow's body (tongue, mouth, skin). Another form of environmental bacteria, E. coli, is found in bedding.

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Udder infections are characterized by a three step sequence[5]:

a) Contamination of teat end by pathogen,

b) Penetration of teat orifice and teat canal,

c) Establishment within mammary gland tissue.

The cow's natural defenses against bacterial entrance into the teat are (1) through closing the teat canal tightly with the teat sphincter muscle, and (2) by layers of keratin lining the teat canal. Nevertheless, bacteria may gain entrance by colonizing, injury, and mechanical propulsion from milking machines. Once inside the udder, the bacteria are in a favorable growth environment.

Mastitis is a difficult cattle disease to control. It cannot be eradicated and can prevent dairy cows from reaching their full genetic potential. A major treatment breakthrough came in 1945 through the widespread use of penicillin. Since then all advances have been through improved hygiene and management practices. By 1968 dry cow therapy and teat dipping had gained widespread acceptance through its dual mechanism: treatment of lactating cows at drying off with antibiotics to reduce the duration of mastitis and prevent new infections, and daily post-milking teat dipping to reduce infection rates.

Dairy scientists have long recognized the severity of the disease but quick and easy farm milk tests were required to convince farmers of the nature of the problem. Mastitis has been endemic but was not recognized as a problem at low levels of infection. The advent of the somatic cell count (SCC) has enabled farmers to determine the degree of infection of their herds. The SCC is a measure of white blood cells (leukocytes and neutrophils), the natural defense mechanism against infection, in milk in addition to the normal number of epithelial (glandular) cells. Most measures of SCC are made on bulk tanks because of the expense of individual tests, but increasingly whole herds are monitored on a per cow basis. Using the SCC, general levels of subclinical and clinical infections have been identified, as described in Table 1.

Table 1: Levels of Infection as Measured by SCC

SCC/ml	infection	cell types	
< 100,000	normal milk	85% epithelial -	15% white blood
500,000	subclinical	48% " -	52% " "
> 1,000,000	clinical	26% " -	74% " "

Source: 2

At less than 100,000 cells no infection is evident. As the SCC increases the likelihood of infections increases; a clear distinction between uninfected[33] and subclinically infected cows is reported between SCC's of 150,000 to 214,000. These levels are subject to high cow-to-cow variations. Subclinical mastitis is not evident to farmers but clinical mastitis is recognized by clotted milk, body heat, redness, and swelling and pain in the udder.

An inherent problem in the analysis of SCC is that milk of cows with clinical symptoms is usually separated from the bulk tank, resulting in a lower (biased) inference of the degree of herd infection from bulk tank SCC samples. Although the SCC has been refined as a measure of likelihood of infection, the classification of a clinical case of mastitis is still predominantly based on visual signs. This is due in part to only a 70% accuracy in measuring contagious mastitis infections by milk culture[22].

White blood cells contain proteases, lipases, and phospholipases which break down two important milk components, casein and milk fat, into smaller compounds that are more readily lost into whey during cheesemaking. Infections also damage the mammary epithelial tissue and result in greater plasma leakages from blood vessels. Blood plasma also contains lipolytic and proteolytic enzymes which similarly break down milk protein and fat. Lipase increases milk rancidity[28].

Contagious Mastitis

Contagious mastitis (Staphylococcus aureus and Streptococcus agalactiae) were responsible for 45% and 44% respectively of all infections in a Mississippi State survey[35a]. Contagious infections occur during milking when bacteria are spread through contaminated washing and drying cloths, wash water, hands of operator, and milking machines. Because these infections are passed from animal to animal they can be eliminated from a herd. The Ohio Agricultural Research and Development Center Herd (OARDCH) had been Streptococcus agalactiae free for seven years and Staphylococcus aureus only existed at a 1% level[37]. In Denmark Streptococcus agalactiae has been reduced to 1%; other bacteria infect 35% of the cows[29]. During the late fifties and early sixties the New York State Mastitis Control Program had herd infection rates of 23% Streptococcus agalactiae and 13% Staphylococcus aureus[34]. (Participation in this program was mandatory for excessively poor producers but many better-than-average producers joined voluntarily).

Staphylococcus aureus can be controlled only with penicillin (a 70% reduction appears possible over 3 years) but not eradicated from a herd. Streptococcus agalactiae on the other hand can be eradicated. Several steps may be followed to reduce the spread of infection. These include udder washing with a sanitizing solution, and drying with individual paper towels. Milk equipment and milkers' hands are important means of spreading contagious bacteria. Few milkers wear rubber gloves and dip them into a sanitizing solution because it is inconvenient. Changes in milking equipment have resulted in better liner design to avoid milk cup slipping and better pulsator and controller action to decrease the stress on the teat sphincter and reduce the likelihood of bacteria being propelled into the teat towards the end of milking.

Only 40% of all infections are serious enough to be recognized as clinical and treated with antibiotics during lactation[6]. Milk from antibiotic-treated cows must be withheld for 36-96 hours, depending on the antibiotic. The success rate of lactation treatment is estimated at 40-70%, as it is effective primarily for Streptococcus agalactiae[22,33]. Dry cow therapy (treating all 4 quarters of each cow at drying off) has proven more successful than lactation treatment with an estimated success of 70-98%[22]. Treatment efficacy data obtained from a New York field experiment showed lactation treatment response as follows: Staphylococcus aureus 28%, Streptococcus agalactiae 86% - dry treatment: Staphylococcus aureus 64%, Streptococcus agalactiae 100%. Milk loss to an infected quarter is estimated at 25-60% over a lactation with only 5% compensated from the opposite uninfected quarter.

Environmental Mastitis

Streptococcus dysgalactiae, Streptococcus uberis, and E. coli are ubiquitous in the cow's environment and serve as a common source of infection. They are extremely heterogeneous, each group including several species and strains. Infection-level data are sketchy. During the late fifties and early sixties the New York State Mastitis Control Program had herd infection rates of 13% for Streptococcus non-agalactiae[34]. Two to three decades ago the frequency of E.coli was 2-3% of mastitis infections. In the OARDCH, streptococcal infections never exceeded 5% of quarters and coliform infections ranged between less than 1% to a maximum of 3% of quarters[37].

Simultaneous infections of Streptococci and coliform comprise a small percentage of all environmental infections. Streptococcal infections peaked in summer and fall, accounted for 30.2% of all clinical infections in the OARDCH, exhibited clinical symptoms in 53% of all cases, had an average duration of 17.0 days, and responded to antibiotic treatment 41.7% of all times. Coliform infections peaked during the summer, accounted for 31.8% of all clinical infections in the OARDC herd, exhibited clinical symptoms in 81% of all cases, had an average duration of 9.1 days, and responded to antibiotic treatment 22.4% of all times. Treatment effectiveness data for New York were as follows[22]: lactation treatment: Streptococcus dysgalactiae 90%, Streptococcus uberis 72% - dry treatment: Streptococcus dysgalactiae 98%, Streptococcus uberis 88%. Since the symptoms of environmental mastitis are more likely to be clinical than for contagious mastitis, farmers are more aware of the problem and more likely to respond through management changes.

Dry cow therapy has an effect on Streptococci but not on coliform. With the eradication of Streptococcus agalactiae and the reduction of Staphylococcus aureus it is feared that the prevalence of environmental mastitis will increase[37]. Poorer hygiene because of denser housing is the basis of the concern. Monitoring environmental bacteria through SCC has not proven reliable[37]. Teat dip and dry cow therapy (TDDCT) practice is least effective against the group E. coli. The rate of infection is higher in the late dry period with elevated levels of both Streptococci and coliform during the immediate prepartum period. Suggested control methods are entirely based on better hygiene and sanitation. That is, successful immunization does not yet exist.

Apart from infection levels, the SCC can be influenced by age of cow (increase of 100,000 cells each lactation), the stage of lactation (high at calving and drying off and low during mid lactation), season (higher in summer), and stress level[25].

Costs of Mastitis - Literature Survey Results

Infection Levels and Lost Milk Production

Past studies have identified a relationship between infection levels and lost milk production, a major source of costs associated with mastitis infections. Several standards have been devised for reflecting the relationship between infection levels and milk production losses. The most commonly used is the California Mastitis Test

(CMT) which classifies the degree of infection into five categories: N-Negative, T-Trace, and 1, 2, 3. Table A-1 in the Appendix indicates the relationship between the CMT, SCC and lost milk production. Losses run from close to zero for a SCC below 100,000 to 25 percent for a SCC close to three million. One aspect of lost milk production is the reduction of the lactation cycle by 16.6 +/- 8.4 days[27].

In recent years the Linear Score has emerged as a more common method of relating infection levels to losses in milk production. Appendix Table A-2 summarizes the relationship between the Linear Score (LS) and production losses. The LS runs from 1 to 9.

These composite tables mask the great variability in the relationships found in individual studies. The variability is traceable in part to the differences between comparisons of affected/unaffected quarters in the same animal and infected/uninfected udders of different animals. No conclusions as to the bacterial agent can be made from average SCC levels, particularly when the level is below 200,000 [32].

Discarded milk applies only to cases of clinical mastitis. Natzke calculates it by using a milk production level of 60 lbs, multiplies this by average withholding time of 5 days, and a $10/cwt value of milk which results in a cost of $30/clinical case. He assumes an average rate of clinical cows of 1.25 in a 100 head herd. Dobbins calculates it by using the milk production level at infection (35 lbs vs 45 lbs for healthy cows), multiplies this by average withholding time of 4 days, average number of infections per cow per year, and $10.50/cwt value of milk.

Natzke assumed that, at a cost of $20/visit, one in 40 clinical cases is attended by a veterinarian. Dobbins found that in his herds there was an average of two one-hour emergency calls each month for mastitis alone and the veterinary charge was $30/hour.

In Natzke's calculations 2 1/2 tubes of antibiotic are used in each treatment which gives a cost of $2/cow/treatment period. Dobbins found that an average of 5 clinical cases/100 cows occurred each month which were treated twice on 2 quarters.

Natzke stated that extra labor requirements were 75 minutes per cow at a labor cost of $4/hour. Dobbins found that labor cost $2.50/hour and that 15 minutes/day were required per infected cow during the 4-day treatment period.

Natzke gave a range for culling due to mastitis of 9-17%. He continued by assuming a 12% average rate which, at a 25% total culling rate, corresponds to 3 cows/100 head/year. He continued to state that the actual net replacement cost is $367/cow. Dobbins had found that 15 cow/100 head were culled each year for mastitis alone and that the net replacement cost was $260/cow.

Off-Farm Costs

Costs of mastitis to processors include lower quality due to high SCC, reduced fat and antibiotic adulteration of milk. When milk is picked up at the farm (which occurs every 1-2 days), a milk sample is taken to be analyzed for antibiotic contamination, SCC, and milk fat content. Antibiotic analysis requires about 30 minutes during which the milk truck must wait. If the milk tests negative for antibiotics the load will be emptied into larger holding tanks. If it tests positive the milk will be stored separately, the test repeated, and if still positive the milk will be discarded.

Antibiotic in milk presents several problems: the bacterial starter culture for cheese and yoghurt is inhibited, producing dairy products of variable and generally lower quality. Antibiotic contaminated milk and dairy products cannot be sold for human consumption.

High SCC levels cause losses in cheese production even in the absence of antibiotic contamination. The effect can be determined from the Van Slyke formula which establishes a linear relationship between the fat and casein levels of milk and the theoretical yield of cheddar cheese(3). The relationship between the CMT and milk fat loss is summarized in Table 2

Table 2: Relationship between CMT and Milk Fat Losses

CMT	milk fat losses	
study:	A	B
N	0	0
T	2.1%	3.4%
1	2.6%	6.9%
2	5.4%	10.3%
3	10.8%	13.7%
Sources:	A 1	B 29

No decrease in casein is reported up to a SCC of 1,000,000(13). However, as the SCC increases more casein is broken down into smaller compounds. The degree of decomposition cannot be measured with current techniques. Preliminary tests indicate that there is a sudden 1% drop in cheese yield as the SCC surpasses 100,000 due to enzymatic activity. Between 200,000 and 1,300,000 cells the decrease in yield is more gradual, in the range of 1-2%(3). Casein comprises about three quarters of milk proteins(11,23).

Milk Quality as measured by SCC and USDA regulations requires a SCC level below 1,000,000 cells/ml. In New York, if producers continually exceed this threshold they are required to participate in New York's Mastitis Control Program. Producers are encouraged by some buyers to supply milk with low SCCs through premium payment schemes. Processors prefer constant SCCs because products will be more uniform and higher in both yield and quality and have longer shelf lives.

On-Farm Costs

On-farm costs have been broken down into seven categories. Three studies have used these categories to estimate actual costs per cow and year. Blosser (1977) conducted a nationwide survey in which he asked one competent person in each state to give a "judgement" of the costs of mastitis in that state. Dobbins (1977) used data from 31 random herds under the Georgia Quality Milk Program which had started a mastitis control program. Natzke (1976) used the Florida Agricultural Station Experimental herd to keep a detailed account of costs. The following table summarizes losses averaged by cow in herd per year:

Table 3: Average annual cost per cow due to mastitis

	Study		
	A	B	C
1 reduced milk production	$81.32	na	$118.44
2 discarded milk	$12.88	$ 6.13*	$7.72
3 cost of veterinary services	$ 1.97	$ 0.62	$7.20
4 cost of drugs	$ 3.86	$ 2.50	$2.16
5 increased labor	$ 2.28	$ 5.00	$1.50
6 decreased cow sale value 7 incr. cow replacement cost	$ 5.72 $ 9.32	$11.01	$39.00
sum	$117.35		$176.02

Source: A Blosser 4, B Natzke 20, C Dobbins 8 * = interpolated
na-not available

Reduced milk production is estimated by comparing milk production at a given or estimated average herd SCC to a potentially attainable SCC of 100,000. The number of pounds are then multiplied by a $/cwt value of milk. As is apparent from Table 2, the value of reduced milk production is the most important loss category. It should, however, be realized that the actual values may be subject to large errors depending on which research results the loss is based on.

Estimated Current Losses in New York State in 1988

On-Farm Losses

Losses are computed from the same seven categories shown in Table 3. The authors assume a yearly average SCC of 400,000 cells for New York. This is based on a lower limit as indicated by New York DHI records which recorded levels of 373,000 (1986) and 336,000 (1987)[38]. About 25% of New York's cows are registered in DHI. The average milk production for this group was 3,600 lbs higher than the state average which is generally assumed to indicate better management, better feed, and lower mastitis infection levels. In addition, SCC ranges obtained from three large New York cooperatives indicate average levels between 409,000 and 440,000. For another study, monthly SCCs were measured for seven cheese plants in Southern New York/Pennsylvania and six in Northern New York and New England; yearly average counts were 367,000 and 402,000[2].

For the calculations in this study, milk production losses are based on SCCs. From Table A-1, a 9% loss in milk production is obtained when the SCC is 400,000. At a 12,401 lbs per cow average production for New York, a 9% reduction in milk production is equivalent to 1226 lbs, which corresponds to $143.69/cow/year at a projected Federal order #2 blend price for 1988 of $11.72[16] per cwt. For comparative purposes, which lend support to the given calculations, the reduced milk production at an average linear score of 4 is given (compare to Table A-2). At a linear score of 4 it is estimated that 1,200 lbs/lactation or 1,138 lbs/year less milk is produced. Translating these figures by using Table 4, it can be concluded that the degree of subclinical infection is in the vicinity of 50% of all cows in New York. This relationship measures the level of subclinical infections since milk from clinically infected cows usually does not enter the bulk tank.

Table 4: Relationship of SCC and Per Cent Cows Infected

Bulk Tank SCC	Per Cent Cows Infected Pennsylvania study	Cornell study
0- 99,000	6%	5%
100,000-199,000	17%	12%
200,000-299,000	34%	33%
300,000-399,000	45%	38%
400,000-499,000	51%	58%
500,000-599,000	67%	53%
over 600,000	79%	61%

Source: 28

For the next five loss categories the following assumption applies: the occurrence rate (first time and subsequent infections) is set at 5% per month (i.e. 5 cows exhibit clinical mastitis symptoms and are treated in a 100 head herd each month). At a 6.6 day duration interval, the total number of days/year that milk is discarded in a 100 cow herd is 396 days. This 5% value is justified by considering the range indicated by other studies. The upper range is derived from a six year study of clinical mastitis in a 1500 cow herd in Florida that had an average number of 2.2/100 (st.d. 0.7) cows with clinical cases at any point in time[23]. Hence for a 100 cow herd the total number of cow days with milk discarded is 803 (2.2x365 days) a year. That is twice the level assumed for this study for an occurrence rate of 10%/month. The average duration of milk withheld was 6.6 days[20]. A lower bound is given by a study on selective New York DHI herds which participated in a regular veterinary program at Cornell University. It was found that an incidence level (number of first time clinical infections) of 9.3% prevailed[10]. This level compares to 16.8% in Ontario[9]. When applying another study which gives a relationship between mastitis occurrence in a lactation and parity (number of calves the cow has had) for Holstein cows, the incidence rates of these two studies translate into occurrence rates of 1.7% and 3.7%[19]. It must be noted that these lower bounds apply to better-than-average herds.

Discarded milk is set at 40 lbs/day (12,401 lbs production/305 day lactation period) while the infection is acute and the cow is being treated. Since there are 396 days/year in a 100 cow herd during which milk is discarded, the loss of milk which is non-usable is equivalent to 158 lbs per cow/year or $18.50/cow/year at $11.72/cwt. This milk is fed to calves, reducing milk replacer costs by $9.48 (1 lb of replacer for 10 lbs of milk at $30 per 50 lbs of replacer). The net cost of discarded milk is $9.08/cow/year ($18.50-9.48).

Cost of veterinary services is based on 60 (5 x 12 month) clinical incidents a year. An estimated 10% of clinical cases are treated by veterinarians at an average cost of $30 per case[7]. The resulting cost is $1.80 per cow/year.

Cost of drugs used is calculated by assuming a $1.00/treatment tube administered twice to an average of three quarters in 60 cows. The cost per cow and year is $3.60.

Increased labor required to milk and treat mastitic cows separately is estimated at 1/2 hour for each case per day for 6.6 days. Total days is assumed again at 396 days. Labor cost is taken at $4.00 an hour. The resulting cost per cow and year is $7.92.

The difference in decreased sale value per cow for slaughter and cost of a replacement is estimated at $275/culled cow[18]. This is based on an average slaughter price of $42/cwt, an average slaughter weight of 1350 lbs and a replacement cost of $850. New York DHI records indicate a cull rate attributable to mastitis of 4.0% (st.d.3.45)[38]. The average culling/replacement cost is therefore $11.00 per cow and year. Culling and replacement costs vary depending on beef prices. During the first half of 1988 they were very high especially compared to the price of milk.

Table 5 summarizes current losses in New York State averaged per cow in herd per year.

Table 5: Milk Losses in New York State due to Mastitis

1	reduced milk production	$143.69
2	discarded milk	$ 9.08
3	cost of veterinary services	$ 1.80
4	cost of drugs	$ 3.60
5	increased labor	$ 7.92
6	decreased cow sale value	$11.00 (6 and 7 combined)
7	incr. cow replacement cost	
	sum	$177.09

Source: see text

The estimated total loss of $177.09/cow is comparable to earlier estimates given in Table 3; only reduced milk production and culling/replacement costs vary significantly from the earlier studies. The higher loss value today appears attributable to two factors: higher milk output per cow increases total loss per cow and a higher price of milk magnifies the physical loss.

Independently of this study, researchers at Ohio State University collected data on herds in Ohio to calculate the cost of mastitis(15). They concluded that 80% of the total results from decreased milk production. In their calculations they arrived at an average of 1,200 lbs of milk lost/cow/year compared to 1,226 lbs used in this study. The cost/cow/year was $186.13, based on a milk price of $12.60/cwt.

A loss of $177.09/cow/year corresponds to $151,943,220 for the New York's entire dairy farm sector when multiplying the per cow loss by the January 1, 1988 USDA inventory estimate of 858,000 cows in New York State(17).

Off-Farm Losses

Off-farm losses apply to the milk processing industry. More milk is processed in New York than is produced there. As a result losses to the processing industry are based on a larger volume.

Milk adulterated with antibiotics is the most apparent loss which occurs at the processing stage. Farmers generally do not receive payments for such milk. From a survey conducted for this study the weighted adulterated milk losses are estimated at 0.1% of milk receipts. Given that milk received at New York dairies in 1986 was 14,884,751,000 lbs[26] and the projected blend price is $11.72/cwt, losses due to antibiotic adulteration amount to $1,750,000 in total. Milk testing for adulteration is a cost which processors incur but is not applied in this study.

Losses to the cheesemaking industry can be broken down into two categories: 1) lost fat production due to a decrease in fat yield and 2) damage due to enzymatic breakdown. At a SCC level of 400,000 an averaged fat loss of 3.5% can be interpolated from Table 2. Lipolytic breakdown has not yet been quantified but proteolytic breakdown at 400,000 cells is in the vicinity of 2% reduced cheese yield.

Losses may be computed as follows: at an average fat production level of 3.66%[38, 39], a 3.5% loss is equivalent to an absolute percent fat reduction of 0.13% or 19,350,000 lbs. Applying the butterfat price differential, this loss of 0.13% butterfat translates into a dollar value of about $30,000,000 (based on 14,884,751,000 lbs of milk at $11.72 and 3.66% butterfat compared to the same quantity at $11.92 and 3.79% butterfat).

In calculating cheese losses resulting from proteolytic decomposition, a 2% difference in production at 450,000,000 lbs of cheese produced in New York amounts to 9,000,000 lbs annually. The cheddar cheese price for 40 lbs blocks quoted at the National Cheese Exchange is used as an indicator for losses to cheese manufacturers. For 1988 this average is expected to be about $1.15/lb. Losses to the cheesemaking industry are hence around $10,350,000/year.

Losses due to inconsistent quality are too ephemeral to be quantified but are a considerable concern to processors. For fluid milk, significant correlations have been found between SCC and flavor scores but these two cannot be quantified for this study[13]. Table 6 summarizes the quantifiable losses:

Table 6: Summary of Economic Losses in 1988 to New York's Dairy Sector

On Farm	$ 151,943,000
Milk Adulteration	$ 1,750,000
Reduced Fat	$ 30,000,000
Reduced Cheese	$ 10,350,000
Total	$ 194,043,000

Source: see text

Bactericidal Protein Treatment

Background

The application of biotechnology to mastitis treatment is opening up new avenues of prevention and control which may have important implications. These bacterocidins consist of enzymes and other bactericidal proteins. They act as catalysts and are very specific to a single chemical reaction. For mastitis treatment, bacterocidins can be either infused into the udder (in the same way as antibiotics) or used in solutions (such as teat dips). The general characteristics of this treatment are the same in both cases. Although most work to date has been done on enzymic proteins to control Staphylococcus aureus, research with bactericidal proteins against other organisms suggests that the conclusions drawn are general. The authors proceed therefore by extrapolation the research results to all mastitis-causing organisms.

Bacterocidin lyse (kill) targeted organisms rapidly by damaging the cell wall. They are produced naturally by bacteria as a means of population control. These proteins are larger molecules than antibiotics and are expected to persist in the udder for longer periods of time. Unlike antibiotics, the rapid action of bacterocidins reduces the likelihood of an induced resistance in target and non-target organisms. In the longer term, however, resistance will develop and new bacterocidins will need to be identified.

Bacterocidins used for mastitis treatment are non-toxic to other organisms. This allows their inclusion into food products under FDA health regulations, which implies that treated lactating cows or dry cows which calve prematurely need not have their milk withheld, as would be the case with antibiotics in subclinical treatment.

Effectiveness

Early research results indicate that these bacterocidins are comparable to antibiotic treatment and twice as effective as penicillin treatment for first time infections in heifers. Combining bacterocidins and antibiotics produces a synergistic reaction which may prove very significant. Use of combinational bactericidal protein provides similar bacterial synergism. Treating cows with one of these combined products is likely to prove more effective. Combinations appear to require lower concentrations which may reduce expenses involved with treatment. The milk exclusion for such a product would require a shortened withholding of one day, as compared to 6.6 days with antibiotics. Milk would be withheld for very high SCCs (>1,000,000) or abnormal secretion but not due to toxicity.

The specificity of enzymes means that specific bacterocidins will have to be prescribed by veterinarians who are able to determine the organism causing the infection. This is in contrast to broad spectrum antibiotics which require no prescription for use to control mastitis. The cost of a veterinary diagnosis could make enzyme use non-cost-effective compared to antibiotics. However, the combination of bacterocidins into a single medication would allow the products to be sold as non-prescription drugs. It is assumed the cost of the protein treatment will be similar to that of currently-used antibiotics to insure that the initial adoption will occur. Farmers must perceive this treatment method as economically competitive with antibiotic alternatives. The adoption of enzymes is expected to be slow initially until the treatment can be sold as a non-prescriptive drug. However, with new specific diagnosis such as Pro staph and Elisa incorporated into routine management, specific treatment may prove to be effective and affordable.

Implications

Replacing antibiotics with enzymes have the following expected effects on New York's dairy industry:

Milk production per cow would increase slightly because treatment effectiveness is increased for first time infections. No data are yet available to estimate this impact. The cost of discarded milk is reduced from $9.08/cow to $1.38/cow when milk is withheld for only one day during treatment.

The cost of drugs is not anticipated to change. All current marketing investigations indicate that price competitiveness with antibiotics will be necessary for successful adoption. Bacterocidin administration should be similar to antibiotics.

Labor requirements are decreased slightly to the extent that first time infections can be treated effectively during lactation and eliminated.

Cow replacement costs are not anticipated to change.

The benefits for the processing sector can be captured very quickly. Milk will not be adulterated and testing will therefore be unnecessary. This saving should be attributed to the new treatment but cannot be quantified readily. Enhanced fat production will be modest and noticeable only to the degree that first time infections are eliminated. Losses in cheese manufacturing should not occur if no antibiotics are used. Enzymes are organism-specific and should not inhibit starter cultures and do not cause casein or fat decomposition.

Table 7 summarizes the effects on New York's industry. On farm losses would be reduced by $7.70/cow/year or $6,606,600 for all of New York's cows. Off farm losses would be reduced by $12,100,000. Proportionately, processors would benefit more (65%) compared to farmers (35%). It should therefore be expected that the milk processing industry will promote the use of enzymatic treatment for mastitis control.

These savings for New York State alone appear to be substantial enough to conclude that an effective bacterocidin treatment, which could be sold as a non-prescription drug, could largely replace antibiotics nationwide. It is estimated that in the U.S. $25 million are spent annually on antibiotics to treat mastitis. Some antibiotics may still be used to achieve the synergistic effect but manufacturers of antibiotics would face significant cut backs in demand for use in the treatment of mastitis. Other groups concerned about the widespread introduction of antibiotics into the food chain would also be expected to support non-antibiotic substitution. Bactericidal protein however must be subjected to a full review by the FDA, USDA and other regulatory agencies prior to their commercial availability. This should be a relatively straight forward process as these proteins are naturally occurring. Biotechnology only provides an economical means of production. However the required development and testing means these products' commercialization remains in the future.

Table 7: Summary of Economic Savings in New York as a Result of Bacterocidin Treatment

On farm	$ 6,606,600
Off farm	$ 12,100,000
Total	$ 18,706,600

Source: see text

Mastitis Vaccine

Background

Antibiotics and bacterocidins are useful predominantly to treat infected cows. Treatment implies a cow will have gone through a subclinical period, with the associated economic losses, before the infection becomes apparent and therapy is initiated. After treatment the cow is as susceptible as before and prevention of reinfection continues to be dependent on careful management practices.

For decades the search has been underway for an effective immunization against mastitis. The gland's immune response presents a special problem in the type and levels of antibody able to cross into the udder, and the difficulty of determining antigens effective in stimulating resistance to the numerous udder pathogens have proven insurmountable. Recently, a new method for retaining the surface capsule of Staphylococcus aureus has been perfected that has been shown to be effective in both the laboratory and in a limited number of field trials. Cows immunized with a capsule-rich vaccine have heightened resistance to infection by that organism.

Effectiveness

To date, a vaccine has been shown effective only for Staphylococcus aureus, a leading source of contagious mastitis. This is an attractive target organism as it is possible to eliminate S. aureus from a herd. For the purpose of this analysis it is assumed that similarly effective vaccines can be developed for the other contagious and environmental forms of mastitis infection. Protection against environmental infection is particularly important as it cannot be eliminated from the environment. There is some concern opportunistic environmental bacteria will flourish in the absence of contagious forms although this has not necessarily been the case with S. aureus free herds.

Data on the effectiveness of the existing vaccine are limited due to the few field trials conducted to date. Laboratory trials do indicate increases in antibody titers and concomitant reductions in SCC[27,11]. Field data interpretation is more complicated than laboratory designs since field tests permit the cooperating dairyman to continue with normal management practices. In the highly infected herds typically used for these tests -- high to insure an adequate number of infected quarters to give meaningful results -- control is often limited and heavy culling is used routinely. Heavy culling combined with the introduction of mastitis-free animals means that the control group in a successful immunization test will understate the degree of infection in the initial population.

The data which are available suggest a decline in the bulk tank SCC of about 150,000. (187,000 in the Norcross and Kenny test[27] and 130,000 in the Norwegian trial[11]). In New York, using the 400,000 SCC average adopted above, the level would decline to about 250,000.

Implications

Loss reductions in the seven on-farm loss categories can be summarized as follows:

The decline in SCC level from 400,000 to 250,000 corresponds to a reduction in production loss of about 2% (Table A-1). In terms of linear scores, the improvement is from 5 to about 4 (Table A-2). This corresponds to an increase in milk production per cow of 250 pounds a year, or $29.30 at $11.72/cwt*. For all of New York this saving is $25,139,400.

The increase in antigen production is expected to prevent new infections and reduce clinical signs. Since only clinical cases need be treated with antibiotics, no milk should have to be discarded. Vaccination can produce an elevated SCC level for the first two days following administration, but the levels are not sufficiently high to necessitate discarding milk. For practical application and best response, vaccination is recommended just prior to calving. This provides protection during a high risk period and when SCC are not of concern. The savings are estimated at $9.08 per cow or $7,790,640 for New York State.

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*Based on year (365 days to 240 lactation days) adjustment and assuming a herd of 25% first year and 75% second and beyond lactation cows.

The costs of veterinary services, drug costs and labor are not expected to change on average. The costs of the vaccines are not known at this time, but they must be competitive with existing products to be viable in the low-profit dairy sector. The rate of culling is likely to decrease through the prevention of new infection and fewer clinical cases. However, since the magnitude of such a shift is uncertain it is not quantified here.

Off-farm loss reductions will also be substantial. With a SCC level of 250,000, fat losses during milk processing should decline from 3.5% to about 2.75%, or for the New York herd from 19,350,000 pounds to 15,000,000 pounds. Adjusting milk prices for the butterfat differential with 3.69% butterfat gives a price of $11.77/cwt, or 5^{c} higher. At 11,884,751,000 pounds of milk produced in New York this is a $5,900,000 gain.

Reduced infection and clinical cases will reduce the use of antibiotics, effectively increasing cheese yields. The same gains as for the enzyme technology are assumed, namely $10.35. These figures are summarized in Table 8 and give a total annual savings of $51 million. In this case farmers would benefit much more than processors - roughly 65% versus 35%. Savings due to immunization are more than 2.5 times the savings associated with the bacterocidin treatment and reflect the potential of an effective low cost vaccination. However, due to the preliminary nature of vaccine production, these figures must be considered as very tentative.

Table 8: Summary of Economic Savings in 1988 for New York as a Result of Mastitis Vaccinations

On Farm	
Increased milk production	$ 25,139,400
Discarded milk	7,790,640
Off Farm	
Elimination of milk adulteration	1,750,000
Increased fat composition	5,900,000
Increased production	10,350,000
TOTAL	50,930,040

Source: see text

Summary and Conclusions

Mastitis clearly remains a major cost to the New York dairy industry. Available data suggest a sub-clinical infection level of about 50 percent. At these levels of infection the costs of lost milk production are substantial -- an estimated $143 per cow in 1988. Including all costs associated with clinical infections the amount rises to about $177 per cow annually, or $150 million for New York state. When associated losses at the processing level are added the total approaches $200 million annually.

A literature survey suggests costs have remained near this level for some time, due largely to the limited advances in treatment over the past score of years. Two approaches are dominant: hygienic management practices including "dry cow" treatment at the end of the lactation cycle, and antibiotic treatment during the milking cycle. The latter case requires milk be withheld from human consumption. When milk is inadvertently shipped, the processing industry suffers losses. But even sub-clinical levels of mastitis degregate the quality of the milk and lead to lower cheese yields.

In this environment, technological enhancements are much in demand. Two new approaches have recently been developed and been demonstrated as effective in preliminary field trials. These developments are (1) bactericidal protein treatments and (2) an immunization vaccine. Available data suggest potential savings of $18.7 and $50.9 million annually respectively for the two approaches. These estimates are very preliminary and any number of factors may arise which could reduce the economic returns. One of these factors is the price of the medication itself. But the potential benefits are so substantial that even some technological advance would be a major benefit to New York's dairy sector.

These estimates are based on the new products supplementing existing practices. No product is likely to replace the need for careful herd hygiene so that any decline in careful management practices is likely to negate much of the value of the new products. But, viewed in this environment, the new products are promising additions to the currently available strategies for dealing with the problems of mastitis.

The products, as applied to date, have clear and readily apparent benefits to dairymen. They require no major changes in management practices. Past experience has shown that products with these characteristics are adopted relatively rapidly. Thus the benefits of these products are likely to be seen soon after commercial release. The total savings appear to be much greater when adopting the vaccination treatment. However the distribution of benefits between farmers and processors is very different. One potentially complicating factor is the portion of the benefits from bacterocidin use which accrues to milk processors. Processors will have an incentive to see that these control products are used but no direct involvement in the adoption decision. Adjustments in product pricing which pass part of the processors' benefits back to producers can be helpful in spurring more rapid adoption of these products.

The timing of market readiness for these new products is very uncertain at this point. In cases of both the bacterocidins and the vaccination are directed at only one of the four major sources of mastitis. To be economically effective all or most common bacteria must be controlled by such products. Early results suggest the other forms of bacteria can be controlled in a similar fashion. Nevertheless, even under the most optimistic scenario, it will be a number of years before all the necessary products are developed, the regulatory requirements satisfied and production initiated. Five years would appear to be a minimum time required, at least in the U.S., and a full decade is possible. At that time the dairy sector will have available a significant cost-reducing product, but not one which is likely to have profound ramifications on the structure and location of milk production in the United States.

References

1) Ashworth, U.S., T.L. Forster, and L.O. Luedecke (1987). "Relationship Between California Mastitis Test Reaction and Composition of Milk from Opposite Quarters." J. Dairy Science 50: 1078.

2) Barbano, D. M., R.J. Verdi, and R. Rasmussen (1987). "Influence of Milk Somatic Cell Count on Cheese Manufacturing and Cheese Yield." Paper presented at the 24th Annual Marshall Invitational Italian Cheese Seminar, Madison, Wisconsin, Sept 16-17, 1987.

3) Barbano, D.M. and J.W. Sherbon (1984). "Cheddar Cheese Yields in New York." J. Dairy Science 67: 1873-1883.

4) Blosser, T.H. (1977). "Economic Losses from and the National Research Program on Mastitis in the United States." J. Dairy Science 62: 119-127.

5) Bramley, A.J. and F.H. Dodd (1984). "Mastitis Control. Progress and Prospects." J. Dairy Research, 51. pp 481-512

6) Cassel, E.K. (1978). Factors Affecting the Percent Quarters Infected in a Dairy Herd. M.S. thesis, Cornell Univ. In Roger Natzke. Elements of Mastitis Control (1980).

7) Dinsmore (DVM), Page. Quality Milk Control Program. Personal interview (1988).

8) Dobbins, Charles N. Jr. (1977). "Mastitis Losses." J. American Veterinary Medical Association. Vol. 170. pp 1129-1132.

9) Dohoo, R., S.W. Martin, A.H. Meek, and W.C.D. Sandals. (1982/83) "Disease, Production and Culling in Holstein-Friesian Cows." Preventative Veterinary Medicine, 1: 321-334.

10) Erb, H.N., R.D. Smith, et al. (1985). "Path Model of Reproductive Disorders and Performance, Milk Fever, Mastitis, Milk Yield, and Culling in Holstein Cows." J. Dairy Science 68: 3337-3349.

11) Gudding, R. (1988). "Results from Trials with the S. Aureus Mastitis Vaccine." Mimeograph, Norway.

12) Herrington, B.L., J.W. Sherbon, R.A. Ledford, and G.E. Houghton (1972). "Composition of Milk in New York State". New York's Food and Life Sciences Bulletin No. 18.

13) Janzen, J.J. In G. Munro, P.A. Grieve, and B.J. Kitchen. "Effects of Mastitis on Milk Yield, Milk Composition, Processing Properties and Yield and Quality of Milk Products." Australian J. Dairy Technology. March 1984: 7-16.

14) Janzen, J.J. (1970). "Economic Losses Resulting from Mastitis." A Review. J. of Dairy Science 53: 1151-1161.

15) Lightner, J.K., G.Y. Miller, W.D. Hueston, and C.R. Dorn (1988). "Estimation of the Costs of Mastitis, Using National Animal Health Monitoring System and Milk Somatic Cell Count Data." J. America Veterinary Medical Association 192: 1410-1413.

16) Milk Market Review 88-2. Cooperative Extension. Cornell University.

17) Milk Production, Disposition, and Income Summary, 1987. USDA, National Agricultural Statistics Service, Agricultural Statistics Board. May 1988, Da 1-2(88). Washington, DC.

18) Miller, Henry. Empire Livestock Marketing Coop. Ithaca, NY. Personal interview and Empire Livestock market summaries. (1988).

19) Morse, D., M.A. DeLorenzo, R.P. Natzke, and D.R. Bray (1987). "Occurrence and Reoccurrence of Clinical Mastitis." J. Dairy Science 70: 2168-2175

20) Morse, D., M.A. DeLorenzo, R.P. Natzke, and D.R. Bray (1987). "Factors Affecting Days of Discarded Milk Due to Clinical Mastitis and Subsequent Cost of Discarded Milk." J. Dairy Science 70: 2411-2418.

21) Natzke, Roger P. (1978). Economics of Mastitis Control, Large Dairy Herd Management. University of Florida, pp 577-584.

22) Natzke, Roger P. (1981). "Elements of Mastitis Control." J. Dairy Science 64: 1431-1442.

23) Natzke, Roger P. National Mastitis Council 1986. pp 104-107.

24) Nelson, J.H., T.G. Oleson, and D.M. Irvine. (1974). "Milk and Whey Protein Composition, Distribution, and Cheese Yield of Canadian Cheddar Cheese from Four Milk Clotting Enzymes." J. Dairy Science 57: 598.

25) Nelson, F.E., J.D. Schuh, and G.H. Stott. (1967). "Influence of Season on Leukocytes in Milk." J. Dairy Science 50: 978.

26) New York State Dairy Statistics. 1987 Annual Summary. Dairy Industry Services, Department of Agriculture and Markets.

27) Norcross, N.L. and K. Kenny, (1986). "Evaluation of a Vaccine for Mastitis Caused by Staphylococcus Aureus." Proc. Fourteenth World Congress on Diseases of Cattle. 2: 1094-99.

28) O'Donovan, J., F.H. Dodd, and F.K. Neave (1960). "The Effect of Udder Infections on the Lactation Yield of Milk and Milk Solids." J. Dairy Research 27: 115-120.

29) Philpot, W. Nelson (1984). "Economics of Mastitis Control." Veterinary Clinics of North America: Large Animal Practice - Vol 6, No. 2: 233-245.

30) Philpot, W.N. (1967). "Influence of subclinical mastitis on milk production and milk composition." J. Dairy Science 50: 978.

31) Philpot, W.N. (1984). "Mastitis Management." Louisiana State University Agricultural Center.

32) Quality Milk Control Program (1988). "Mastitis Annual Report." Culture Data Tables 1987-88. Cornell University. Ithaca, NY.

33) Reneau, Jeffrey, K. (1986). "Effective Use of Dairy Herd Improvement Somatic Cell Counts in Mastitis Control." J. Dairy Science 69: 1708-1720.

34) Roberts, Hodges, Fincher, Temple, Brown, Cheney, Johnson, Linquist, Reed, Guthrie (1963). "Studies of the Streptococcus agalactiae Form of Mastitis in Dairy Cattle." J. American Veterinary Medical Association 143(11): 1193-1201. In John Fetrow, Subclinical Mastitis: Biology and Economics. Continuing Education Article # 9 Vol 2, No 11 Nov 1980.

35a) Sears, P.M., M. Fettinger, J. Marsh-Salin. (1983). "Prevalence of Streptococcus agalactiae from Mississippi Bulk Samples and Estimated Economic Impact." Third International Symposium on Veterinary Epidemiology and Economics. (Abstract). Edmondsville, KS: Veterinary Medicine Publishing Co., p. 670.

35) Sears, Philip (DVM, PhD) Quality Milk Control Program. Personal Interview (1988).

36) Shook, G. (1982) in T.R. Smith and W. G. Merrill (1987). "New SCC Report." Animal Science Mimeograph Series No. 107. Cornell University. Ithaca, NY.

37) Smith, K.L., D.A. Todhunter, and P.S. Schoenberger (1985). "Symposium: Environmental Effects on Cow Health and Performance." J. Dairy Science 68: 1531-1553.

38) Smith, T. (1988). New York State Dairy Herd Improvement Data. Special Compilation.

39) Smith, Terry R. (1986). "New York and Northeastern Dairy Herd Improvement Program Summary". Animal Science Mimeograph Series No. 99. Cornell University. p 11.

40) Spurgeon, K.R., Jeng-Jung Yee, and J.H. Martin (1981). "Selection of Milk for Maximum Yield of Cheese and Other Dairy Products." Cultured Dairy Products Journal. Aug.: 5-11.

APPENDIX

Relationship Between Infection Levels and Lost Milk Production

Table A-1:
Relationship between CMT, SCC and decrease in milk production

CMT	SCC	Lost milk production
	140,000 165,000 195,000	5%
Trace	225,000 260,000 300,000 340,000 380,000	8%
1	420,000 465,000 515,000 565,000 620,000 675,000 730,000 790,000 855,000 920,000 990,000 1,055,000 1,130,000 1,200,000	9% to 18%
2	1,280,000 1,360,000 1,440,000 1,525,000 1,610,000 1,700,000 1,800,000 1,920,000 2,030,000 2,180,000 2,280,000	19% to 25%

Source: adapted from 30

Table A-2:
Relationship between Linear Score, SCC and annual lost milk production

Linear Score	SCC	Lbs of milk lost relative to linear score = 2	
		heifers	2+lactation
0	12,500		
1	25,000		
2	50,000		
3	100,000	200	400
4	200,000	400	800
5	400,000	600	1,200
6	800,000	800	1,600
7	1,600,000	1,000	2,000
8	3,200,000	1,200	2,400
9	6,400,000	1,400	2,800

Source: adapted from 36

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