BALANCING MASTITIS AND QUALITY

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SUMMARY

The International Dairy Federation definition of mastitis in the dairy cow dates from 1967 and is based partly on the cell count of quarter foremilk exceeding 500,000 cells/ml. It is argued that this is unsustainable with the current knowledge of udder health, technical advances in controlling mastitis and demands for milk quality. It is proposed that a quarter cell count of 200,000 cells/ml should indicate mastitis and that for practical purposes when the whole cow milk cell count exceeds 400,000 cells/ml the milk is abnormal. These changes will reflect widespread industry practice and be supportive of likely international trading standards.

INTRODUCTION

Milk naturally contains body or somatic cells. These are largely leukocytes and some epithelial cells shed from the lining of the mammary gland. The leukocytes are derived from blood with, very simply, polymorphonuclear cells acting as a primary means of defence against an invasion of the mammary gland, macrophages involved more in immune recognition and lymphocytes responsible for immune memory. There is a plethora of evidence suggesting that the truly healthy gland of the dairy cow has a natural level of 100,000-150,000 cells/ml and more than this indicates secretory disturbance (1).

The commonest disturbances would be a new invasion of foreign material especially bacteria, an established infection usually by bacteria and a longer term response often related to damage or impaired secretory function after elimination of infection. It is possible, but uncommon, for a gland to have a cell count of 200,000-300,000 cells/ml in the absence of infection.

Cell count is affected by animal physiology and particularly breed. The effect of age is largely cumulative from previous responses to infection. Various dynamic factors influence cell count. Cell count is briefly high immediately post-partum until lactation establishes but this rarely lasts more than five days and milk is usually not acceptable for sale until four days post-partum. Cell count is affected by milking frequency, being lower in uninfected glands with more frequent milking after accommodation to the change (2). Uneven milking intervals affect cell count although the effect disappears when daily values are calculated. Cell count may also be marginally higher at the end of lactation, as yield decreases, due to lack of dilution, but stage of lactation has no real effect (3).
CELL COUNT AND INFECTION

Milk cell count has been used extensively as an indicator of the infection status of the mammary gland and in 1967 this was included as a component of the definition of mastitis (4). Infection is the major influence on cell count (5) and cell count is used as an indirect indicator of the prevalence of infection (6).

When the Five Point Mastitis Control Plan was introduced in the early 1970s the cell count of UK milk was greater than 600,000 cells/ml. This equated, from field studies, with more than 55% of all cows being infected in one or more quarters. With good mastitis control and market requirements for good quality milk, a cell count less than 150,000 cells/ml, we now have a UK bulk supply of 160,000-170,000 cells/ml but still 10-12% of all cows are infected in at least one quarter.

Figure 1. Assessment of cytological - bacteriological findings in mastitis diagnosis (4)

<table>
<thead>
<tr>
<th>Cell count per ml milk</th>
<th>Pathogenic organisms</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Not isolated</td>
</tr>
<tr>
<td></td>
<td>Isolated</td>
</tr>
<tr>
<td>&lt;500 000</td>
<td>normal secretion</td>
</tr>
<tr>
<td>&gt;500 000</td>
<td>latent infection</td>
</tr>
<tr>
<td></td>
<td>non-specific mastitis</td>
</tr>
<tr>
<td></td>
<td>mastitis</td>
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In 1975 Prof. Tolle recognised at the IDF Mastitis Symposium in Reading (7) that the IDF definition had to be improved to take account of the factors described above. It was clear then to the participants of the meeting that the dynamics of the infection process led to variability of both cell count and bacterial recovery such that latent mastitis and nonspecific mastitis were not useful terms. The threshold levels for cell count were based on a population mean + 2 SD for one measurement of foremilk from an individual quarter. The definition was a guide to diagnosis though 50% of truly infected quarters might at anytime have a cell count less than 500,000 cells/ml (8). It should be noted that strictly the definition applies to mastitis, the inflammatory response, and not necessarily to infection.

The use of cell count and the strict research definition of mastitis based on quarter foremilk, have rightly become part of the assessment of milk quality and this threshold was probably relevant when the bulk supplies of nations involved in extensive milk trading exceeded the threshold of mastitis. There are now significant anomalies possible. The most obvious example is that a bulk supply is unacceptable in many count ries when cell count exceeds 400,000 cells/ml. It is possible that all quarters of all cows in the supplying herd have a cell count 401,000-499,000 cells/ml yet none have mastitis!

IS THE THRESHOLD OF 500,000 CELLS/ML STILL RELEVANT?

The threshold of 500,000 cells/ml is clearly not relevant and has not been for a considerable time. In the EU, bulk milk for sale is required to have a cell count less than 400,000 cells/ml. This translates into at least one of every four quarters possibly being infected (6) and mastitic, yet the
milk from these cows is still saleable. A recent survey of national milk quality levels (9) has shown that many IDF member countries now have a national average of approximately 250,000 cells/ml or better in the bulk supply. Within many of these countries buyers encourage individual producers, by financial incentives, to supply milk with a cell count less than 150,000 cells/ml.

It is almost certain that all quarter milk with a cell count less than 100,000 cells/ml contains no micro-organisms derived from the udder. There are temporary situations at the beginning and end of the lactation when this may be true for a higher cell count too. Usually cell count is raised in response to infection and it is almost certain that when cell count exceeds 200,000 cells/ml bacteria derived from the udder can be found. Typically these bacteria are existing in a commensal relationship, in a balance between excessive bacterial growth and overt stimulation of immune defence - pathogenesis. It is irrelevant whether the bacteria are ‘minor’ pathogens or ‘major’ pathogens. The gland is unhealthy and the milk is abnormal. When cell count exceeds 400,000 cells/ml then the balance is upset and the gland is truly diseased.

A grey area exists when cell count may be 100,000-400,000 cells/ml when bacteria are not isolated. This condition is usually induced by an infection that has been resolved and is a state of recuperation or results from longer-term damage to secretory tissue.

These thresholds indicating health, infection and disease are taken from various studies and are approximate. They could be refined but will not be significantly wrong. They need to be considered in terms of the health of the cow, the image of a healthy product and what can be achieved, practically. When whole country bulk milk supplies can average approximately 100,000 cells/ml, for example by Austria and Switzerland, then they are achievable (9).

**SHOULD THE CELL COUNT THRESHOLD DEFINING MASTITIS BE CHANGED?**

The thresholds should be changed because progress in management to control infection, acceptable standards of milk quality and scientific refinement of diagnosis and measurements, mean that the threshold of 500,000 cells/ml is both wrong and unsustainable.

A practical level, relevant to research, quality payments and mastitis control, is necessary. It needs to be based on whole quarter milk and not foremilk, to cope with quality measurements and to be relevant to upcoming automated screening systems, for example real-time in milking systems. It also needs to be easily related to whole udder milk as much management use is now made of readily available and frequently obtained individual cow milk cell counts. Various thresholds are currently in use including

- **milk acceptability** - national standards based on levels such as 400,000 or 500,000 cell/ml for bulk supplies
- **milk quality** - payment thresholds for bulk milk at 150,000, 250,000, 400,000 cells/ml etc.
- **milk loss** - recognition that yield losses start when quarter cell count exceeds 200,000 cells/ml
mastitis control - levels for intervention, based on monthly individual cow cells count start at 200,000 cells/ml.

However, there is no evidence that any particular cell count *per se* has any significant effect on human health save that the higher the cell count then the greater the risk of contamination with pathogens and antibiotic residues, and the suspicion that the raw food is produced under poorer standards of hygiene.

The original definition to indicate mastitis was a quarter foremilk value largely for research purposes. A refined value is necessary for this purpose and a value is necessary for quarter whole milk, cow whole milk and the bulk supply in this more advanced dairy industry. The levels cannot be absolute to individual samples. They must cope with various forms of error by calculation from necessary repetition of measurements and averaging of values. Suitable methods are already in place in many countries for bulk supplies where rolling geometric means are employed, individual cow cell counts are used in advising mastitis control by examining sequential samples, and quarter cell counts are used in mastitis diagnosis by consideration of sequential or duplicate samples. Agreement of means and uniform adoption would be a useful agreement and recommendation.

The problems to resolve and agree are

- the threshold levels indicating mastitis and acceptable milk quality at quarter, cow and bulk supply levels
- the sampling frequency and averaging methods to be employed
- the tolerance acceptable on the thresholds.

The consideration may need to take account of the physiological and dynamic influences described earlier. However, there is evidence suggesting that physiological effects are of little consequence in truly uninfected cows (3). Certain other factors should perhaps be excluded. The effect of milking interval would tend to disappear naturally when daily values are calculated. Milking frequency is usually not a problem except for once daily milking and then there is other evidence of secretory disturbance to suggest that the milk is abnormal, and possibly, unacceptable in other ways (10). Seasonality and stress affect cell count in some situations but the major effects are from risk of infection due to increased exposure and so such effects on cell count are most likely to indicate poorer health. Allowance should not be made (11).

**WHAT LEVELS?**

Absolute values can be suggested from existing scientific knowledge but in many situations these will be difficult to accept for historical and cultural reasons. They are all achievable and practical. Indicators for quarter and cow cell count levels are in Figure 2.

**Figure 2.** Suggested relationship between average milk cell count, udder health and milk quality
This suggestion is based on no new information but rather changes the definition of mastitis to what is scientifically supportable and away from a threshold based on a description of what occurs in milk production. The suggestion includes compromise in taking account of the grey areas so allowing for errors in determining the cell count, dynamic effects of physiology and infection, and population effects.

The quarter milk thresholds may be easily applied to research and evaluation of efficacy of therapeutics. The cow milk thresholds are valuable for mastitis control strategies and managing bulk milk quality. No suggestion is made for bulk milk quality as this is a commercial value but it is clear in terms of product quality, value and image that the threshold must be close to 200,000 cells/ml. When the cell count from a cow exceeds 400,000 cells/ml the infected quarter has a cell count of 1,000,000 cells/ml or greater, irrespective of a yield depression (Table 1). This means that this milk is grossly abnormal and that it should not be consigned as a food under much current legislation (10).

### Table 1. Predicted quarter cell counts (‘000 cells/ml) when an uninfected quarter has a cell count less than 200,000 cells/ml, the infected quarter yield is 30% or less than the whole udder yield and for a whole cow cell count up to 1,000,000 cells/ml

<table>
<thead>
<tr>
<th>Uninfected quarter cell count</th>
<th>Quarter yield</th>
<th>Cow cell count (‘000 cells/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>200</td>
<td>400  500  600  700  800  900  1000</td>
</tr>
<tr>
<td></td>
<td>250</td>
<td>1430 1760 2100 2360 2760 3100</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>1600 2100 2600 3100 3600 4100 4600</td>
</tr>
<tr>
<td>150</td>
<td>30%</td>
<td>1100 430 600 730</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1600 480 650 930</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>2000 850 1100 2100</td>
</tr>
<tr>
<td>200</td>
<td>30%</td>
<td>860 320 480 650</td>
</tr>
<tr>
<td></td>
<td>20%</td>
<td>1400 400 650 930</td>
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<tr>
<td></td>
<td>10%</td>
<td>2000 650 1150 1650</td>
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<table>
<thead>
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<th>Cow cell count (‘000 cells/ml)</th>
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<tr>
<td>20%</td>
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<td>10%</td>
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The conclusion from this is that milk should not be acceptable in the bulk supply if the cow has a cell count of greater than 400,000 cells/ml. It is difficult to argue otherwise. The situation is even worse where cows have a cell count of more than 1,000,000 cells/ml and the secretion from the infected quarter is likely to be self solid. Practical limitations have to be made as it is often difficult to detect the individual infected quarter quickly. There is a need for better mastitis detection and not least in more automated systems where there is no compliance with the legal requirement to 'inspect the appearance of the milk'. Chronic cases are readily identifiable from individual cow cell counts and here the goalposts have already changed. The National Milk Records threshold has been applied to separate cows above and below 200,000 cells/ml for some time. This is a highly relevant threshold in line with suggestions here and in common use in good mastitis control programmes.

It may be necessary to tolerate milk from cows with a cell count of 200,000-400,000 cells/ml going in the bulk tank but it has to be appreciated that very many of these cows are infected. There is no way that consigning 'milk' from a cow with a cell count greater than 400,000 cells/ml, likely to have a quarter cell count of 1,000,000 cells/ml, is compliant with milk hygiene requirements. This secretion is physically abnormal. It is exudate.

SUMMARY

It is timely to redefine the threshold for quarter milk cell count for the dairy cow indicative of mastitis, probable infection and abnormal milk. It is proposed that this should be 200,000 cells/ml. Tolerance is needed for practical purposes, to cope with the frequency of measurements, accuracy of measurements and transitory effects such that a whole cow milk value of 400,000 cells/ml is proposed. Notwithstanding these values milk cannot be consigned for sale if it is physically abnormal. Considerable scientific information is available to support these proposed thresholds but this should be reviewed fully. It is unlikely that these proposed definitions will have a major impact on bulk milk supplies involved in trade but they are supportive to the suggestion for a world standard for bovine milk cell count (13).

REFERENCES