12 Use Individual Cow Cell Counts for management decisions

Individual cow cell counts (ICCCs) are the concentration of somatic cells (white blood cells and epithelial cells) passed in milk from all four quarters of each cow and reported as cells/mL. On the day of herd recording, samples are taken from each cow throughout her milking using an in-line meter.

With the exception of milk culture, ICCCs are considered to be the best method of determining whether cows have subclinical mastitis (Holdaway et al 1996).

Some other methods of detecting subclinical mastitis are described in the 'Cow-side mastitis tests' FAQ sheet.

Cows regularly shed a small number of cells in their milk. In mid lactation, normal milk can contain 20,000-200,000 cells/mL. About 98% of these are white blood cells (e.g. 79% macrophages, 16% lymphocytes, and 3% neutrophils), and the remaining 2% are cells that line the ducts of the udder (Lee et al 1980).

Somatic cell response to mastitis infection

When bacteria invade the udder, passing the natural defence mechanism of the teat canal, the next line of defence relies on white blood cells. Cells recruited from the circulation by chemical signals (chemotaxins) in response to this invasion, engulf and destroy the bacteria with strong enzymes, and help repair damaged tissue.

The number of cells in the milk of infected cows can increase from 100,000 to 100,000,000 cells/mL within a few hours in peracute clinical cases (Blowey and Edmondson 1995). There is a concurrent change in the types of cells present, with neutrophils contributing more than 90% of the cells in milk in cases of active infection.

In an individual cow the level and pattern of the cell count increase is affected by the number of quarters infected, and the type of bacteria causing the infection. For example Escherichia coli infections are mostly short-lived and cell counts rise sharply and then decline over 2-3 weeks. In contrast, Staphylococcus aureus often persists as subclinical infections and cell counts from infected quarters rise and fall cyclically throughout lactation (see graphs on the following page).

The Victorian Mastitis Research Group (1992) found the lactational average ICCC for cows subclinically infected with major mastitis pathogens was 3.8 times higher (at 623,000 cells/mL) than uninfected cows or cows infected with minor pathogens.

Confidence – High

Extensive research and field experience has shown that ICCCs are a valuable tool to monitor mastitis status, assess management decisions in herds and individual animals, and to solve problems in herds with high bulk milk cell counts.

Research priority – High

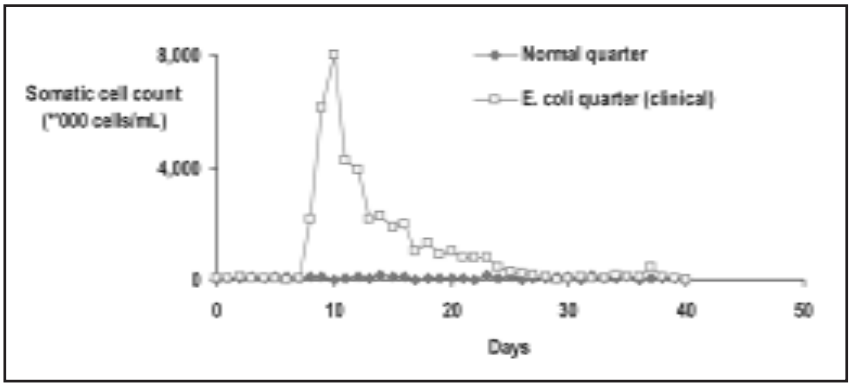
There would be great benefit in further development and application of herd mastitis summaries based on ICCCs. This would provide farmers who milk record with reliable information (for example on the spread of mastitis) in a timely and simple format.

Facilities for advisers to use more detailed analyses during herd investigations (such as simple data download and appropriate software for analysis) would also be beneficial.

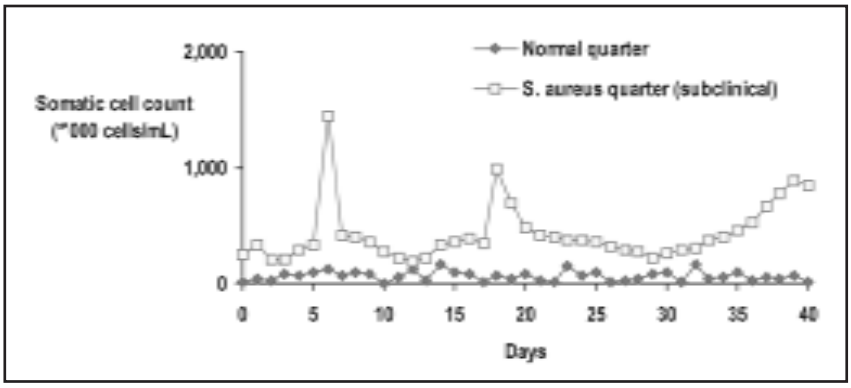
Additional methods of dealing with high ICCC cows (such as identifying which groups of cows it is cost-effective to treat during lactation) would be useful.

Dohoo and Meek (1982) recommend that at least five ICCCs are used to determine the status of cows during a lactation.

Example cell count response in a quarter with clinical mastitis due to *Esherchia coli*



Example cell count response in a quarter with subclinical mastitis due to *Staph aureus*



Factors affecting somatic cell counts

The major factor affecting milk cell count is intramammary infection (Harmon 1994, Schepers et al 1997). Although other factors are often suggested as causes of observed increases in cell count, few have a significant impact. The comprehensive review article by Harmon (1994) gives a good summary of the factors other than infection that may influence cell count, and clarifies some misconceptions regarding changes in cell count.

Regardless of mastitis status, cows may have elevated cell counts around calving and at the very end of lactation. Increased milk cell counts are a normal immune response as mammary tissue changes in preparation for calving. Cell numbers decline quickly after calving in uninfected quarters. Sheldrake et al (1983) demonstrated that all quarters, regardless of infection status, had elevated cell counts immediately postpartum, but those quarters with no infections, or with minor pathogen infections showed a rapid decline in cell count. Cell counts in uninfected cows should be well below 300,000 cells/mL by five days post-partum (Reneau 1986).

Generally, cell count increases with advancing age and stage of lactation. However, Eberhart et al (1979) showed that if cows are separated into groups by infection status little change in cell count occurs for uninfected cows, either as they age or during late lactation. Increased counts at the end of lactation, specifically in low producing cows, may result from a constant number of cells being passed from udder tissue into a decreasing milk volume. Older cows with high cell counts are more likely to have subclinical mastitis infection because they have experienced more days in the milking shed.

Although stresses of various types have been implicated as causing increases in cell counts, attempt to induce changes experimentally or by using corticosteroids have had modest or no effect (Harmon 1994). Similarly, there is no evidence that other 'stressors' such as stray voltage or oestrus significantly influence somatic cell counts.

Increased white blood cell counts arising from other diseases do not generally increase cell counts in the milk.

During lactation ICCCs vary within a day, both within and between milkings (usually low in the morning and higher at night). This normal variation during each day is the main influence on cell counts in cows that do not have mastitis.

Benefits of using ICCCs

ICCCs collected regularly are used to identify cows with subclinical mastitis. This information enables farmers and their advisers to:

- estimate the prevalence of mastitis in herds;
- estimate the new infection rate or spread of infection in the herd;
- consider selective Dry Cow Treatment as a strategy – providing there are at least three ICCC records for each cow during the current lactation;
- identify cows with persistent infections for culling;
- assess the contribution of individual cows if there are problems with high bulk milk cell counts (BMCC);
- determine an appropriate milking order – where subclinical and clinical cases of mastitis are milked last;
- assess the mastitis status of purchased cows; and
- investigate outbreaks of mastitis in the herd.

Technote 14 discusses alternative Dry Cow Treatment strategies.

Technote 21 discusses purchasing cows.

Critical ICCC thresholds

ICCCs are composite milk samples collected from all four quarters. A count above 250,000 cells/mL in milk suggests that a cow is infected in at least one quarter. This threshold provides a reasonable division between cows with and without mastitis especially when applied in mid-lactation (Holdaway et al 1996), and has been used over the past 20 years.

A disadvantage of pooling milk samples from all quarters is that it dilutes high cell count milk with milk from uninfected quarters and increases the likelihood of missing an infected cow, however the ease and minimal cost of using herd test samples outweigh this disadvantage. Cell counts vary during milking, with foremilk and strippings higher than composite samples, so hand-collected samples taken from individual quarters cannot be compared with herd test samples.

A cow is classed as infected or uninfected according to her highest (or peak) cell count taken during the lactation. In Australia, where Staph aureus and Strep uberis are the main pathogens, cows are allocated an 'infected' status if their ICCC ever exceeds 250,000 cells/mL and it is assumed that they remain infected throughout the lactation irrespective of the value of subsequent ICCCs. For example, in the Tasmanian Dairy Industry Authority report below, all cows would be considered infected for the rest of the lactation after recording a cell count above 250,000 cells/mL despite having some subsequent counts below 250,000 cells/mL.

Excerpt of a cell count history report

TDIA

Tasmanian Dairy Industry Authority

Cellcount History Report

		Mean*	14/05/99	04/99	03/99	02/99	01/99	12/98	11/98	10/98	05/98	6/04/98
601	8601	283	1222	782	296	203	818	685	186	9		216
730	8730	441	746	649	520	488	238	231	1991	167	448	277
742	8742	791	1879	783	1699	329	895	1574	731	754	529	284
817	8817	145	139	153	235	103	145	454	165	100	79	90
835	8835	355	483	198	221	1456	709	198	87	178	502	944

There is often a good deal of discussion about the most appropriate threshold to nominate for ICCCs. Like any diagnostic test, the ability of an ICCC to predict whether a cow has mastitis depends on the accuracy of the test at a nominated threshold and the prevalence of mastitis in the herd.

The test accuracy reported by the Victorian Mastitis Research Group (1992) is consistent with overseas studies. For example, at the 250,000 cells/mL threshold:

- a Canadian study estimated test sensitivity to be 71.7% and specificity to be 75.4% when diagnosing prevalent mastitis infections due to major pathogens (Dohoo and Leslie 1991); and
- the test accuracy in three New Zealand herds had a sensitivity range of 38-82% and a specificity range of 64-97% (Holdaway et al 1996).

As described above cell counts can be used for a range of management decisions such as identifying infected cows for culling or selecting a Dry Cow Treatment strategy. It is likely that use of different thresholds would be appropriate, depending on the economic consequences of the errors (i.e. missing infected cows or erroneously picking clean cows) (Victorian Mastitis Research Group 1992). However, in practice it is very difficult to apply different thresholds to different herds or for different management decisions, and the universal use of 250,000 cells/mL is a simplification that has worked well in the field.

Accuracy of mastitis diagnosis at drying-off using various ICCC thresholds* (Victorian Mastitis Research Group 1992)

Peak ICCC threshold (cells/mL)	TEST SENSITIVITY Cows with mastitis above the ICCC threshold (%)	TEST SPECIFICITY Uninfected cows below the ICCC threshold (%)
100,000	95.5	37.5
150,000	91.3	55.9
200,000	83.5	66.8
250,000	75.7	74.1
300,000	68.2	80.3
350,000	61.0	84.5
400,000	56.5	86.8

* The study involved 768 uninfected cows and 333 cows with mastitis based on 2 out of 3 positive cultures.

Linear scores

Herd improvement organisations and dairy scientists overseas often convert ICCC to 'linear scores'. The conversion is mathematical and turns a measure of concentration (cells/mL) into a scale from 0 to 9. The advantages of using linear scores are that:

- They are easily understood – for example score 2 represents a low cell count and score 6 represents an extremely high cell count.
- Transformed data has some statistical advantages for analysis.

Use of linear scores to report ICCC has not been widely adopted in Australia.

Method used to transform ICCCs to linear scores

Data manipulation	Example ICCC of 250,000 cells/mL
Divide ICCC ('000) by 100	250/100 = 2.5
Natural log transformation	0.916291
Divide this value by 0.693147	1.32537
Add 3 to the result	4.3

12.1 Consult your veterinarian or factory field officer for advice on management of cows contributing high numbers of cells to the vat, if Bulk Milk Cell Count premiums are being lost or you are approaching penalty levels.

It is possible to predict the BMCC using the milk yield and ICCC of individual cows. A BMCC and average herd ICCC taken on the same day do not always report the same value. Differences are usually explained by:

- Milk from some cows being withheld from the vat.
- The range of accuracy of the machine measurements. They are likely to underestimate counts when individual cow milk samples contain more than 800,000 cells/mL (for example due to the clumping of cells).

A BMCC represents the total number of somatic cells in the vat divided by the total litres of milk. Although the BMCC gives an overview of milk quality in the herd, cell counts from individual cows are generally required to diagnose and manage mastitis problems in herds.

The ICCC (cells/mL) and litres of milk of each cow can be used to calculate the total number of cells each cow is estimated to be contributing to the bulk milk tank (litres*ICCC*1,000). A number of herd improvement centres are able to provide advisers with a mastitis cell count file (as a text file) that details each cow's production and cell count for the last several years. This file can be imported into Excel (or a similar spreadsheet) and the data then easily manipulated. For example:

- The cows can be ranked in order of the number of cells they each contribute to the BMCC.
- The effect on the estimated BMCC can be calculated if a number of the higher cell count cows are left out of the vat.

Once this information is available, a number of options can be explored to manage high BMCC.

Diverting milk from the vat

It can be profitable to divert milk from high cell count cows away from the vat. This requires that the payment for vat milk with a lower BMCC exceeds the value of the volume of milk that is withheld. This must be determined by a calculation that can be easily set up on a spreadsheet (see opposite page).

Diverting milk from high cell count cows away from the vat is a short-term strategy and not a long-term solution to mastitis problems. Nevertheless, it is:

- an important option to be considered when a farm's BMCC approaches or exceeds regulatory levels and the milk may be rejected; and
- a consideration for farms exploring ways to achieve and maintain premium payments.

Calculation of the impact of excluding high cell count milk from the vat. In this instance, the milk payment is based on a system where milk with BMCC below 250,000 cells/mL receives 0.5 cents per litre more than milk with BMCC above 250,000 cells/mL.

Step 1 Number of cells passed in milk by two high cell count cows			
	Volume (litres)	ICCC (cells/mL)	Total cells from cow
Cow 1	16 L	3,000,000 cells/mL	16 * 3,000,000 * 1,000 = 48,000 million cells
Cow 2	20 L	1,500,000 cells/mL	20 * 1,500,000 * 1,000 = 30,000 million cells

Step 2 Number of cells in bulk tank after excluding milk from these two high cell count cows		
	Volume (litres)	Total cells in vat
Vat	2,000 L	Vol * BMCC * 1,000 = 2,000 * 275,000 * 1,000 = 550,000 million cells
Vat excluding milk from cows 1 and 2	2,000–20–16 = 1,964 L	550,000 million –48,000 million –30,000 million = 472,000 million cells

Step 3 Impact on final BMCC and milk income by change in milk payment		
	BMCC (cells/mL)	Milk income ($)
Vat	275,000 cells/mL	2,000 L* 26.1 cents/L = $522.00
Vat excluding milk from cows 1 and 2	Total cells ÷ total vol = 472,000 million ÷ 1,964 L = 240,000 cells/mL	1,964 L * 26.6 cents/L = $522.42

In this example, the economic benefit is likely to be minimal (42 cents!). If diverting milk is judged to be economic it is wise to do a 'test run' that involves withholding milk from the selected cows for two days and submitting vat milk to the factory for BMCC testing on these days. It is also important to determine that mastitis is not spreading through the herd because, in this scenario, it will be necessary to continue to divert milk from the vat to maintain BMCC. The next decision is what to with these cows (see below).

Options for dealing with high cell count cows

There is no quick fix for treating high cell count cows (Shephard 1997a). Control of this problem within a herd relies on preventing new infections, using an appropriate dry cow program and an effective culling program. This is frustrating for farmers and advisers, because milking high cell count cows reduces milk quality and potentially leads to mastitis spread.

There are a number of short-term management options that can be implemented when individual cows are identified as contributing high numbers of somatic cells to the vat. The final decision will depend on the number of cows with high ICCC, whether mastitis is spreading through the herd, and the production level and history of individual cows.

Strategic culling

Technote 15 describes issues to consider when culling cows.

Cows that have high cell counts in two consecutive lactations, despite Dry Cow Treatment, should be considered for culling. Culling may be the best option for older cows that have chronic high cell counts where there is little prospect of improvement (for example those with Staph aureus infection), particularly if only small numbers of cows are involved.

Drying-off cows

High ICCC cows can be dried off and treated with Dry Cow Treatment. Although they will not contribute milk for the remainder of the season, they may be cured and will be productive in future lactations. This may be the best option for heifers, and for cows nearing the end of their lactation that have had low cell counts in previous lactations.

Drying-off individual quarters

The Rapid Mastitis Test, electrical conductivity meter or quarter sampling and culture can be used to determine whether infection is isolated to only one quarter.

Technote 4.13 describes how to permanently dry-off a quarter.

Drying-off individual quarters may be the best option for cows with a single infected quarter that are likely to be culled at the end of their current lactation. Simply ceasing to milk the affected quarter results in drying-off for the current lactation. Permanent drying-off can be achieved by infusing chemicals that destroy the milk-producing tissue.

There are several disadvantages of drying-off only one quarter. The first is that there is always the possibility of accidentally milking the affected quarter into the vat! In addition there is less prospect of the quarter being cured prior to the next lactation as an individual quarter cannot be treated with Dry Cow Treatment during lactation, or infused with Dry Cow Treatment at the end of lactation when it is already involuted.

Whether or not this strategy impacts on the BMCC depends on the number of cells that the affected quarter is contributing to the bulk tank.

Quarter milkers

'Quarter milkers' are sometimes used in the United States to prevent high somatic cell count milk, attributable to a single quarter, from reaching the bulk tank. An example of a quarter milker is the Quality Milk Isolator (RJB Company, California), which attaches to the claw piece in the shed and redirects milk flow from the affected quarter into the isolator.

Although quarter milkers are labour intensive and not commonly used in Australia, their use may be indicated when a high producing cow is affected so that milk from her good quarters is not lost to the vat. It is emphasised that quarter milkers should NEVER be used on any cow receiving antibiotics as cross contamination between treated and untreated quarters can occur.

Treating individual cows during lactation

Many studies have shown that it is not economic to routinely treat high cell count cows with antibiotics during lactation and the Countdown Downunder Farm Guidelines for Mastitis Control reflect these observations.

Although up to 60% of infections may be eliminated from treated quarters (Wilson et al 1972, Mwakipesile et al 1983), the possible benefits of reduced cell count and increased milk production are outweighed by costs. The costs of treating lactating cows are associated with purchasing antibiotic, withholding milk, and the diagnostic methods and errors of selecting cows for treatment (McDermott et al 1983).

In a recent study of 462 cows (from 50 commercial dairy farms) with ICCC above 500,000 cells/mL during the first month of their lactation, Shephard (1997b) reported that there was no economic benefit in cows treated with intramammary (cloxacillin) and systemic (erythromycin) antibiotics compared to untreated cows. Similar findings have been reported at lower ICCC thresholds. Of 111 cows on seven New Zealand farms suspected to have mastitis, Douglas et al (1997) found no significant difference in cell counts between cows given intramammary antibiotic (cefuroxime) and untreated cows, and the cost of treatment was estimated to be NZ $4.87 per quarter. In this study, suspect cases of subclinical mastitis were determined using ICCC and 44% of the treated cows had been incorrectly diagnosed as infected (at ICCC thresholds of 120,000 cells/mL for first lactation cows and 150,000 cells/mL for older cows).

Although it is generally not economic to treat high cell count cows during lactation, treatment may be cost-effective in circumstances where cows are likely to have a high cure rate and are inexpensive to identify. Two examples where treatment during lactation may be strategic are:

- heifers with Staph aureus infection (Sol et al 1997); and
- cows with Strep agalacatiae infection. Strep agalactiae is sensitive to commonly used intramammary products, especially penicillin, and cure rates are typically greater than 90%. (Note, however, the key to control of Strep agalactiae outbreaks is to stop the spread of infection.)

Technote 5 briefly describes management of Strep agalactiae outbreaks.

Using milk from high cell count cows to feed calves

The option of feeding high cell count milk to calves might offer a frustrated farmer some solace but should be carefully considered.

Apart from a documented account of the transfer of Strep agalactiae to group reared heifers (Johnson 1947) there has been no other scientific publications to support or refute suggestions that feeding high cell count milk to calves increases the risk of mastitis in heifers.

12.2 Consider milking chronically infected cows last to avoid contaminating other cows.

Technote 8.3 discusses milking order and mastitis.

12.3 Watch for evidence of spread of infection in the herd by checking the percentage of cows and heifers with increased cell counts each month.

ICCCs can be used to monitor the status of herds with successful mastitis control and to investigate mastitis outbreaks (Ryan 1992). Routine analyses offered by a number of herd improvement organisations are used to:

- alert people to the spread of contagious mastitis, specifically when there is a high rate of new infections in heifers that were pathogen-free at calving;
- examine the rate of spread of infection by determining the age groups of affected cows and the number of cows crossing the critical threshold (250,000 cells/mL) in a given time period;
- identify cows to be sampled for milk culture; and
- identify cows to be milked last or run as a separate milking herd.

Repeated ICCC measures help to identify cows that do not have mastitis, and chronically infected cows with consistently high cell counts or cyclical peaks in cell counts. Changes in ICCC status are also very informative as they suggest:

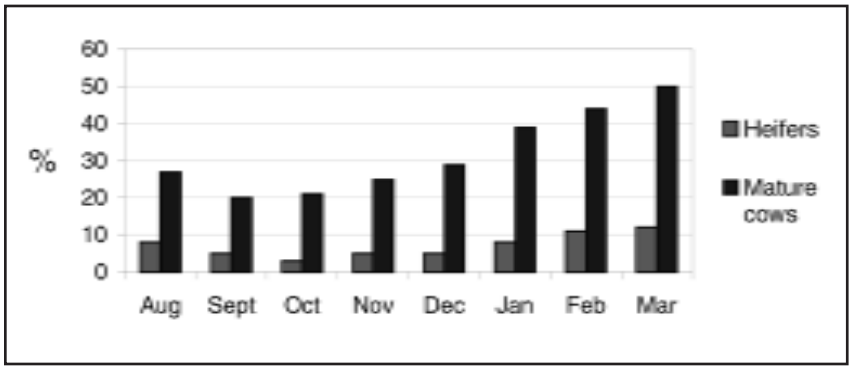
- new infections – in cows with ICCC previously below the threshold.
- cures during the dry period – in cows with previously high ICCC that dropped below the threshold in their next lactation either as a result of treatment or self-cure.

A high incidence of mastitis in heifers indicates the spread of new mastitis infections in the herd. Conversely, a high mastitis rate in older cows but not in heifers suggests that the infection is not spreading through the herd (see the graph below). As a guide, heifers are considered to have a high incidence of mastitis when more than 20% have a peak cell count above 250,000 cells/mL at the end of their first lactation.

In cows with *Staph aureus* infections, changes in mastitis status should be assessed between lactations because fluctuations in ICCC are expected within a lactation.

Scattergraphs

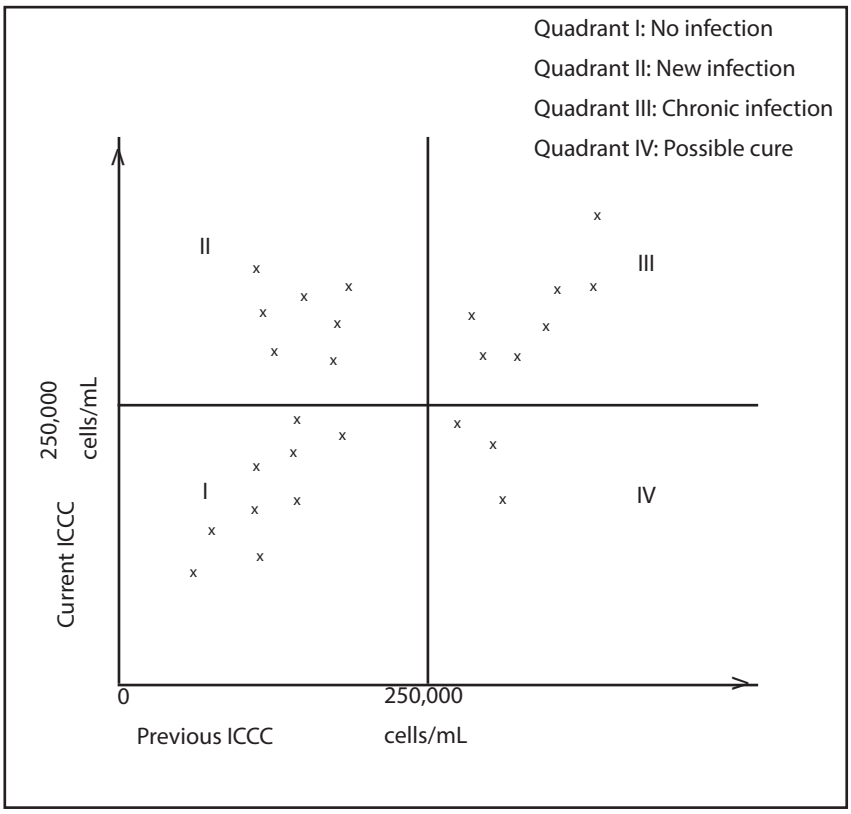
A high mastitis rate in older cows and a low rate in heifers suggests the infection is not spreading



Changes in ICCC status can be readily visualised in scattergraphs (Rapnicki 1997). Scattergraphs are plots of ICCC taken in a previous period (x-axis) against current ICCC (y-axis). By drawing a critical threshold (e.g. at 250,000 cells/mL) on each axis, the graph is divided into four quadrants (see below).

The success of Dry Cow Treatment strategies can be summarised by comparing the current and previous year's cell counts. Similarly, drawing graphs for cows of different parity or stage of lactation may assist investigations of mastitis problems in herds.

Example of a scattergram comparing the peak ICCC in the current season with the previous year (adapted from Stewart *et al* 1995).



Specialist analysis of ICCC in Australia

Some herd improvement organisations and veterinary advisers offer sophisticated analysis of ICCC data. For example the Maffra Herd Improvement Co-operative provides an analysis that can monitor the new infection rate in herds (Shephard 1998). This type of information can be especially helpful to evaluate the progress of control programs and an early warning system if there is increased spread of mastitis in a herd.

Excerpts of a Herd Test Mastitis Control Analysis from a seasonal calving herd in Victoria (Richard Shephard)

New infection rate in your herd:

Test date	% of herd with new infections after last year	New infection rate (per 100 cows per month)
18-Sept-96	24.6%	–
23-Oct-96	17.3%	14.8
20-Nov-96	7.4%	7.9
29-Jan-97	20.3	8.7
3-Apr-97	28.0%	13.1
28-May-97	15.8%	8.6
17-Sept-97	17.4%	4.6
29-Oct-97	6.9%	4.9
10-Dec-97	7.0%	5.0
21-Jan-98	8.6%	6.2
11-Mar-98	7.7%	4.7
15-Apr-98	42.4%	36.4
27-May-98	8.4%	6.0
29-Sept-98	6.0%	1.4
22-Oct-98	2.8%	3.6
26-Nov-98	4.8%	4.1
27-Jan-99	3.3%	1.6

Late lactation last season was not good. This was quite common last year for some reason – cows below 10 litres, feed stress, etc., but this is too many to just ignore.

Think about late lactation management and drying off protocols that you use in your herd, e.g. Are the machines up to it? By the end of the year the liners would be extremely worn in your shed. They may not be providing enough teat massage by this stage.

I have done hundreds of these analyses and if you obtain late lactation new infection rates like these for even one month per year you will find it extremely difficult to hold BMCC down.

Worth making a plan for late lactation.

Existing level of infection in your herd:

Test date	No. cows <100,000 cells/mL	No. cows tested	Percentage of herd <100,000 cells/mL
25-Sept-96	239	288	83.0%
20-Nov-96	308	354	87.0%
22-Jan-97	284	350	81.1%
19-Mar-97	269	350	76.9%
21-May-97	205	334	61.4%
23-Oct-97	304	365	83.3%
17-Dec-97	307	375	81.9%
18-Feb-98	280	366	76.5%
22-Apr-98	272	359	75.8%
20-May-98	218	351	62.1%
21-Oct-98	357	412	86.7%
14-Dec-98	342	406	84.2%

The best herds hover around the 90% mark. This is the cause of your problem this season (and it is not a major problem at that). Aim to increase the % of uninfected cows towards 90% over the next few years so that your BMCC will be around 150,000 cells/mL.

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