Mastitis in cows milked in an automated or conventional milking system in New Zealand

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ABSTRACT

The viability of automated milking systems (AMS) for pasture-based dairying has been studied in New Zealand in the past four years. Automatic milking differs from conventional milk harvesting systems (CMS) in a number of ways, which may impact on udder health. These include fewer machines/cow, distributed vs. batch milking, variable milking intervals, automatic udder health monitoring systems, and pre and post-milking teat sanitation procedures. Three seasons of data from two pasture-based research farms that milked cows with either a two unit AMS or a 30 bail rotary CMS were compared. Quarter milk samples were collected routinely from all cows for bacteriological analysis during the 2002-03, 2003-04 and 2004-05 seasons, with sampling occurring throughout lactation and at detection of clinical mastitis (CM) cases. The number of cows in the AMS herd ranged from 94 to 196 and in the CMS herd, from 289 to 324 across the seasons. Clinical mastitis affected 7, 11, and 15 cows/100 cows/season in the AMS herd and 24, 23 and 14 cows/100 cows/season in the CMS across the three seasons, with *Streptococcus uberis* isolated from approximately 50% of CM cases from both herds. Prevalence of *S. uberis* post-calving averaged 8% of cows for the AMS and 16% for the CMS across the three seasons. We compared several indicators of udder health between an AMS and a CMS herd managed under pastoral conditions.

Keywords: mastitis; automated milking system; prevalence

INTRODUCTION

The adoption of automated milking systems (AMS) as a milk harvesting option for New Zealand dairy farmers has been explored by the Greenfield Project in recent years (Woolford & Jago, 2002; Jago *et al.*, 2002; Jago *et al*., 2004). When implementing automatic milking in pasture-based farming systems, the goal of maximising the daily harvest of milk from each AMS units has been achieved by reducing milking frequency and increasing the number of cows milked per unit (Jago *et al.*, 2004). This approach and the replacement of human labour with sensors to detect changes in milk quality, along with differences in the on-farm management of cows in the Greenfield AMS, may affect the udder health status of the herd in several ways. Reducing the number of milking units to harvest the milk may increase the risk of cows being infected by contagious pathogens such as *Staphylococcus aureus* or *Corynebacterium bovis* if hygiene standards are not maintained. However, previous investigations found that the prevalence of CM or intramammary infection (IMI) for cows milked once a day did not differ greatly from those milked twice a day (Lacy-Hulbert *et al.*, 2005), under New Zealand conditions. Different methods are used by the two systems to detect clinical mastitis (CM). The CMS is reliant on visual observation by the milker to detect CM, whilst the AMS relies on the in-line detection of infected quarters by changes in electrical conductivity of milk (Woolford *et al.*, 1998) and changes in milk yield, since the AMS does not require constant visual supervision.

Understanding the implications of AMS in terms of the health and welfare of dairy cows is an important consideration when developing new management systems. Overall, few changes have been reported in the udder health of dairy cows milked by AMS systems compared to CMS systems (Hillerton *et al*., 2004). On some European farms, an increase in bulk milk somatic cell count (BMSCC) has occurred following the introduction of AMS. However, Hillerton *et al.* (2004) reported that this response was variable between herds. The impact of AMS on udder health in pastoral dairying systems is unknown.

The objective of this study was to examine the bacteriological information observed in two farms managed under a CMS or AMS. A gross comparison across the two systems allowed identification of udder health indicators that could be used for benchmarking AMS in pasture-based systems.

MATERIALS AND METHODS

Farm layout and udder hygiene management

The AMS and CMS were located at two established Dexcel research farms located on the outskirts of Hamilton.

Farm layout and herd management for the AMS has been described in detail elsewhere (Jago *et al.*, 2002; Jago *et al*., 2004) and at present 160 cows are milked with two Merlin (Fullwood, England) robotic milking units off a 58 ha area. In the AMS, cow's teats were washed before milking by an automated brush system sanitised with a chlorhexidine-based sanitizer (Hibitane, Ecolab), as described in Jago *et al*. (2006). After milking, teats were sprayed with an iodine-based teat sanitizer (Teatguard Plus, Ecolab) at the dilution recommended by the manufacturer, and there was an immediate back-flush of the teat cups with cold water (10 litres/min) after every cow milking. The milking plant was washed automatically three times every 24 h and also after milking any cow that was receiving antibiotic treatment for mastitis. The external surfaces of the AMS were cleaned daily.

The CMS was a 30 bail rotary dairy that milked around 340 cows off a 90 ha area. There was minimal udder or teat cleaning before milking, with only very dirty teats receiving washing prior to milking. All teats were sprayed manually with an iodine-based teat sanitizer after milking (Teatguard Plus, Ecolab). At dry-off, all lactating animals in both systems received a long-acting dry-cow antibiotic.

In the CMS, a gland was diagnosed with CM when farm staff observed abnormal changes in milk appearance. Stripping of cows for signs of mastitis occurred using indirect indicators such as clots on the filter sock, elevated BMSCC or high individual cow somatic cell count (SCC) results. Each CM case was recorded and a milk sample was collected using standard methods (National Mastitis Council, 1999) for bacteriological analysis before treating with antibiotic. In the AMS, CM was diagnosed by in-line sensors that monitored changes in single quarter electrical conductivity, in addition to similar indicators of mastitis used in the CMS. Once identified as potentially clinically infected, the cow was listed for drafting in the following milking for manual udder assessment, aseptic milk sampling and treatment. For both CMS and AMS, only those milk samples that were not contaminated were included in the analysis.

Milk sample collection and bacteriological analysis

To identify mastitis pathogens, milk samples were collected aseptically from each gland and analysed for bacterial pathogens using standard microbiological procedures (National Mastitis Council, 1999). Cows were sampled at the following times: between one and ten milkings after calving, at three and five months into lactation, and at dry-off. A cow was considered to have a subclinical infection when one or more glands were positive for a bacterial species, without abnormal physical changes in milk appearance.

Bulk milk somatic cell count (BMSCC) and descriptive analysis

Records of BMSCC were obtained from each farm from December 2002 to May 2005. Descriptive statistics were calculated for each milking system and lactation season using GenStat Release 8.1. (VSN International, Oxford, England). In all mastitis-related instances, data are presented as either the proportion of cows, the number of CM cows/100 cows/season, or CM cases/100 cows/season. This was primarily an observational study and variable confounding factors such as changes in cow numbers per season, number of cows sampled at each occasion, farm management policies, replication of bacteriological sampling, and occurrence of multiple infections in some cows made data unsuitable for more rigorous statistical analysis.

RESULTS

Udder health

The proportion of healthy, uninfected cows per season ranged from 69% to 82% in the AMS and between 71% to 83% in the CMS (Table 1). The mastitis pathogens most commonly isolated from infected glands in both systems were *Streptococcus uberis* and coagulase-negative staphylococci (CNS) spp. (Table 1). The average seasonal prevalence of *S. uberis* was 6% of cows for the CMS and 4% for the AMS. The prevalence of *S. uberis* was highest in the post-calving period for both systems, averaging 8% of cows for the AMS and 16% for the CMS. As the seasons progressed and herd size increased, the prevalence of *S. uberis* in the AMS increased at the post-calving sampling, and reached the levels found in the CMS post-calving. The prevalence of CNS per season ranged from 6 to 18% of cows in both systems.

TABLE 1: Prevalence of mastitis pathogens in an automated milking system (AMS) and a conventional milking system (CMS) at different periods of lactation across three lactation seasons. Uninfected cows were those that had no infection in any glands at the time of sampling.

Milking System	Lactation Season	Timing	Cows (n)	Proportion of Uninfected Cows	Proportion of Infected Cows					
					SU	SA	CNS	CB	EC	Others
AMS	2002-03	PC	52	0.87	0.04	-	0.06	-	0.02	0.02
		R1	66	0.71	0.03	-	0.17	0.08	-	0.02
		R2	46	0.61	0.02	0.02	0.22	0.2	-	0.02
		DO	63	0.57	0.03	-	0.17	0.21	-	0.02
		Average		0.69	0.03	0.01	0.16	0.12	0.01	0.02
	2003-04	PC	138	0.82	0.09	0.01	0.08	0.01	0.01	0.01
		R1	128	0.8	0.04	0.01	0.10	0.05	-	0.01
		R2	53	0.81	0.02	0.02	0.09	0.06	-	-
		DO	166	0.63	0.04	0.04	0.14	0.18	-	0.01
		Average		0.77	0.05	0.02	0.10	0.08	0.00	0.01
	2004-05	PC	182	0.82	0.10	0.02	0.03	-	0.01	0.01
		R1	175	0.84	0.02	0.03	0.06	-	-	-
		R2	157	0.83	0.02	0.03	0.06	0.01	0.01	-
		DO	162	0.79	0.03	0.03	0.10	0.01	-	0.01
		Average		0.82	0.04	0.03	0.06	0.01	0.01	0.01
CMS	2002-03	PC	287	0.62	0.18	0.01	0.21	-	0.02	0.02
		R1	191	0.76	0.04	0.03	0.15	-	-	0.02
		R2	183	0.72	0.05	0.03	0.17	0.01	-	-
		DO	257	0.73	0.02	0.04	0.18	0.04	-	-
		Average		0.71	0.07	0.03	0.18	0.01	0.01	0.01
	2003-04	PC	323	0.76	0.14	0.01	0.09	-	-	0.01
		R1	218	0.83	0.03	0.01	0.11	-	-	-
		R2	203	0.87	0.02	0.01	0.08	-	-	-
		DO	202	0.79	0.03	0.02	0.11	-	-	0.01
		Average		0.81	0.06	0.01	0.10	0.00	0.00	0.01
	2004-05	PC	273	0.74	0.15	-	0.10	-	-	0.01
		R1	128	0.89	0.03	0.01	0.05	-	-	-
		R2	136	0.85	0.03	0.01	0.09	0.01	-	-
		DO	219	0.85	0.02	0.03	0.07	-	-	-
		Average		0.83	0.06	0.01	0.08	0.00	-	0.00

PC = post-calving; R1 = three months in milk; R2 = five months in milk; DO = dry-off; SU = *Streptococcus uberis*; SA = *Staphylococcus aureus*; CNS = Coagulase-negative staphylococci; CB = *Corynebacterium bovis*; EC = *Escherichia coli*; Other = other pathogens

TABLE 2: Incidence of total clinical mastitis (CM) and CM by different mastitis pathogens, in cows milked in an automated milking system (AMS) and a conventional milking system (CMS) across three seasons.

Milking System	Lactation Season	Cows (n)	CM cows/ 100 cows	Pathogen (number of CM cases/100 cows)						Not Sampled
				SU	SA	EC	DY	Other	Sterile	
AMS	2002-03	94	7.4	1.1	5.3	1.1	0.0	0.0	3.2	7.4
	2003-04	196	11.2	6.6	2.0	0.0	0.0	1.5	2.0	3.6
	2004-05	184	15.2	8.7	3.8	1.1	0.0	1.6	2.7	5.4
	Average		11.3	5.5	3.7	0.7	0.0	1.0	2.6	5.5
CMS	2002-03	289	23.9	13.1	2.1	0.3	1.0	2.4	9.0	2.8
	2003-04	324	22.5	15.1	1.9	1.5	0.3	3.1	9.3	5.6
	2004-05	288	13.9	9.7	0.3	0.0	0.3	1.4	2.4	2.1
	Average		20.1	12.6	1.4	0.6	0.5	2.3	6.9	3.5

SU = *Streptococcus uberis*; SA = *Staphylococcus aureus*; EC = *Escherichia coli ;* DY = *Streptococcus dysgalactiae;* Other = other pathogens; Sterile = no bacterial growth was observed.

Across both systems, *Staphylococcus aureus* affected a maximum of 4% of cows at any sampling point. In the AMS, the presence of *S. aureus* was sporadic in the first season, but became more consistently observed in the second and third seasons, affecting on average 2.8% of cows in the third season (Table 1). In the CMS, the prevalence of *S. aureus* decreased from 2.6% of cows in the first to 1.3% in the third season (Table 1). The minor pathogen, *Corynebacterium bovis* was more prevalent in the AMS than the CMS. In the AMS, a relatively high prevalence was observed in late lactation in the first and second seasons, affecting up to 21% of cows, but dropped to 1% in the third season. For the CMS, *C. bovis* was rarely observed (Table 1). Finally, there was no apparent difference in the prevalence of *Escherichia coli* or other pathogens between the two milking systems.

Clinical mastitis

Clinical mastitis affected 7, 11, and 15 cows/100 cows/season for the AMS and 24, 23 and 14 cows/100 cows/season for the CMS (Table 2). For CM caused by *S. uberis*, the average prevalence across the three seasons was 5.5 CM cases/100 cows for the AMS and 12.6 for the CMS. In both systems, the majority (60%) of *S. uberis* CM occurred in the first month after calving. For CM caused by *S. aureus*, the average prevalence across the three seasons was 3.7 cases/100 cows for the AMS and 1.4 for the CMS. Sterile mastitis, whereby no bacterium was isolated from the CM sample, averaged 2.6 CM cases/100 cows in the AMS, but was higher (9.2 CM cases/100 cows) during the first two seasons of the CMS. At the same time, the number of CM cases that were not sampled was slightly higher in the AMS (5.5 CM cases/100 cows) than the CMS (3.5 CM cases/100 cows).

There were large differences in the age structure of the herd in each system (Table 3). There was a higher proportion of heifers in the CMS (35%) compared to the AMS (9%), when averaged across the three seasons, whilst animals four years and older represented 76% in the AMS and 44% of the CMS herd. Across both systems, *S. uberis* was particularly evident amongst cows four years and older, affecting 11% of animals. However, for two-year old animals, *S. uberis* affected on average 8% of CMS heifers but only 1% of heifers in the AMS. Infections by *S. aureus* IMI were more frequently observed in animals four years and older in both systems, affecting approximately 4% of cows.

TABLE 3: Age structure (proportion) of herd milked by an automated milking system (AMS) or a conventional milking system (CMS) across three seasons and prevalence of cows affected by *S. aureus* or *S. uberis* intramammary infection (IMI) in each milking system.

Milking System	Lactation Season	Cows (n)	Age Structure			*S. uberis* IMI cows			*S. aureus* IMI cows		
			2 yo	3 yo	4+ yo	2 yo	3 yo	4+ yo	2 yo	3 yo	4+ yo
AMS	2002-03	92	0.08	0.20	0.73	0.00	0.00	0.09	0.00	0.00	0.01
	2003-04	186	0.16	0.12	0.73	0.02	0.01	0.12	0.00	0.00	0.05
	2004-05	179	0.04	0.13	0.82	0.01	0.02	0.13	0.00	0.00	0.07
	Average		0.09	0.15	0.76	0.01	0.01	0.11	0.00	0.00	0.04
CMS	2002-03	299	0.45	0.15	0.40	0.11	0.02	0.14	0.02	0.01	0.05
	2003-04	334	0.23	0.35	0.43	0.07	0.02	0.09	0.01	0.00	0.02
	2004-05	291	0.37	0.18	0.48	0.07	0.04	0.08	0.01	0.01	0.02
	Average		0.35	0.23	0.44	0.08	0.03	0.10	0.01	0.01	0.03

TABLE 4: Average bulk milk somatic cell count (BMSCC) and proportion of bulk milk tank consignments (BMTC) observed across different BMSCC categories in three seasons in an automated milking system (AMS) and a conventional milking system (CMS).

Milking System	Lactation Season	BMTC (n)	BMSCC Mean (± StDev)	BMSCC Range (x 1000 cells/ml) Proportion of BMTC			
				<100	101-200	201-399	>400
AMS	2002-03	81	151 ± 51	0.07	0.84	0.07	0.01
	2003-04	179	194 ± 76	0.05	0.60	0.34	0.01
	2004-05	219	187 ± 71	0.05	0.59	0.33	0.02
	Average			0.06	0.68	0.25	0.01
CMS	2002-03	80	220 ± 52	0.00	0.41	0.58	0.01
	2003-04	243	145 ± 41	0.12	0.79	0.09	0.00
	2004-05	210	136 ± 52	0.24	0.66	0.10	0.00
	Average			0.12	0.62	0.26	0.00

Bulk milk somatic cell count (BMSCC) trends

The seasonal BMSCC for the AMS ranged from 151,000 to 194,000 cells/ml and from 136,000 to 220,000 cells/ml for the CMS (Table 4). The number of bulk milk tank consignments that attracted penalties (>400,000 cells/ml) were more frequent for the AMS in the third season, involving four consignments, whereas only one or two existed in previous seasons.

A BMSCC <200,000 cells/ml was achieved in 90% of bulk milk consignments for the AMS in the first season, and for the CMS in the second and third seasons. However, season to season trends were difficult to determine as only part season data were available for the first season.

DISCUSSION

Udder health

The aim of this study was to report bacteriological data obtained from dairy herds milked within a CMS or AMS, and to grossly compare both systems so that udder health targets could be identified for benchmarking AMS performance in pasture-based systems. Good udder health is a highly desirable outcome for any milking system, as mastitis not only affects animal welfare, but also influences milk production, milk quality and cow longevity. This survey showed that in both systems, between 70-80% of cows were free of udder infection across all seasons.

Data on prevalence of IMI caused by different pathogens across a complete lactation is sparse in New Zealand. However, *S. uberis* is the most common mastitis pathogen found in well-managed dairy herds. Its prominence was also evident in this study, and averaged across the three seasons, the prevalence of *S. uberis* mastitis was similar for both systems. However, the incidence of CM immediately post-calving was twice as high in the CMS vs. the AMS, which may reflect the lower proportion of heifers in the AMS herd. Heifers tend to be more susceptible to *S. uberis* mastitis than older cows (McDougall, 1999; McDougall, 2002). A higher prevalence of infection by the contagious minor pathogen *C. bovis* was observed in the AMS compared to the CMS and may be a result of differing efficacy of teat sanitising applications between a manual and automated system (Hillerton *et* al., 1995). It has been suggested that *C. bovis* prevalence could be used as an indicator of the quality of teat spray application (Pankey, 1989).

The prevalence of *S. aureus* mastitis was below 5% of cows for both herds, which is the level that should be expected in well managed herds (LIC, 2001). The retention of infected cows to increase herd size may have been the cause of increasing levels of *S. aureus* infections observed in older cows in the AMS. More than 90% of the *S. aureus* infections, observed in AMS cows, occurred in cows that were four years or older, and which made up on average 76% of the cows across the three lactations. Conversely, the proportion of cows that were four years or older in the CMS was 44% and the prevalence of *S. aureus* mastitis amongst these cows was 5% in the first season and 2% in the last two seasons.

More comprehensive data exist on the incidence of CM found in New Zealand herds. The average incidence rate of CM was reported to be 13.6 cows/100 cows/annum across 129 dairy herds (McDougall, 2002). Averaged across the three seasons, the incidence of CM for the AMS was half of that observed in the CMS, but in the third season, the CM incidence rate for both systems was similar to the level reported by McDougall (2002). The pathogen *S. uberis* was most commonly isolated from CM in both systems, which is consistent with data reported by McDougall (2002). As not all CM cases were sampled across both systems, a definite measure of the pathogens responsible for the infections could not be concluded. However, uncertainty remains as to the number of CM cases which were not sampled and which may have changed the incidences reported in this paper. There are few recommendations about the number of CM cases to be expected in well managed dairy herds, but a realistic farm goal would be to have less than 14 cows/100 cows/annum suffering CM.

The BMSCC did not differ greatly between both systems. During the study period, cows were milked twice daily in the CMS but the milking interval varied from once a day to over twice daily for individual cows in the AMS (Jago *et al*., 2002; Jago *et al.*, 2004). Previous data reported by this group (Lacy-Hulbert *et* al., 2005) indicated that once-a-day milking should have no detrimental effects on udder health, but elevations in BMSCC can be observed related to milk volume. Data from Europe indicated that for some farms there was an increase in BMSCC following the change from CMS to AMS (Hillerton *et al.,* 2004). The BMSCC was variable across seasons for both the CMS and AMS herds and no clear trend has emerged from these data. This paper demostrated that acceptable standards of milk quality in terms of BMSCC can be achieved with pastoral AMS, and that parameters of udder health of cows milked within this system were similar to those observed in a herd milked in a CMS which followed the recommended best practice procedures. The infection status in the AMS has clearly changed

over time perhaps reflecting the increase in herd size, replacement policy and age structure of the herd.

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