
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Investigation into udder characteristics, mastitis and milk production in crossbred sheep

OM Yusuf [1*], CM Logan[1], A Ridler[2] and AW Greer [1]

[1]*Faculty of Agriculture and Life Sciences, Lincoln University, Lincoln, New Zealand, PO Box 85084, Lincoln, New Zealand;* [2]*IVABS, Massey University, Palmerston North, New Zealand.*

**Corresponding author:* olasunkanmi.yusuf@lincolnuni.ac.nz

Abstract

Associations between udder characteristics, milk yield, milk somatic cell counts (SCC) and prevalence of mastitis were evaluated in 121 twin-suckled crossbred non-dairy ewes at four, eight and twelve weeks after parturition. Overall, milk production decreased with time, being 1.09 ± 0.04 litres per four hours at week four of lactation, 0.68 ± 0.02 litres at week eight and 0.48 ± 0.01 litres at week twelve with corresponding mean SCC of 0.32 x 10^6 cells mL^{-1}, 0.39 x 10^6 cells mL^{-1} and 0.28 x 10^6 cells mL^{-1}, respectively. Incidence of mastitis was 12.7%, 9.8% and 8.9% for weeks 4, 8 and 12, respectively. Of the 20 individuals that displayed SCC indicative of mastitis, only 5 had elevated SCC at more than one sampling time. No consistent association was observed between SCC and visual scores for udder depth, udder distention, degree of separation or teat placement (P>0.05 for all). Milk volume and weight of lamb was greater for ewes with an udder depth of 3 compared with 4 with no other associations evident (P>0.05). Overall, the incidence of subclinical mastitis was low but present in this flock with the udder characteristics assessed here providing poor indicators of either mastitis or milk production.

Keywords: Somatic cell counts; mastitis; udder characteristics; intra-mammary infection

Introduction

Intra-mammary infections (IMI) can lead to clinical and sub-clinical mastitis in lactating ewes (Gelasakis et al. 2015), causing mild to excruciating pain and impacting their productive performance and welfare state. Mastitis has financial implications for farmers through the treatment of infected animals, increased replacement rates and reduced lactation yield due to loss of function in one or both udder halves, which may hinder lamb growth (Arsenault et al. 2008; Grant et al. 2016; Huntley et al. 2012). According to Spanu et al. (2011), somatic cell count (SCC) is a predictor of udder health in cow and sheep, and many reports have described varying levels of SCC in sheep milk. Romeo et al. (1996) discovered low SCC ($\leq 185\times10^3$ mL^{-1}) in IMI-free ewes while higher SCC ($> 400\times10^3$ mL^{-1}) have been widely linked with clinical and subclinical mastitis in lactating ewes (Kern et al. 2013; Persson et al. 2017; Zafalon et al. 2016).

In a study of one large flock in New Zealand (NZ), the incidence of clinical mastitis was observed to be around 5% in ewes on pasture (Peterson et al. 2017) while an English study has reported that sub-clinical mastitis (SCM) may affect over 50% ewes in a flock (Green et al. 2016). Risk of mastitis is known to be influenced by environmental conditions which predicate potential exposure to infective micro-organisms, ewe age, feed type, number of suckling lambs and udder characteristics (Arsenault et al. 2008; Larsgard & Vaabenoe 1993; Pereira et al. 2014; Waage & Vatn 2008). However, there are only a few NZ studies that have investigated udder characteristics as a measuring tool to monitor mastitis in crossbred ewes. This can be likened to the reports that discovered low incidence of mastitis (0.6 – 1.7%) in NZ (Clarke 1972; Quinlivan 1968) as farmers' inspection of non-dairy ewes are very often infrequent as opposed to the daily evaluation in dairy ewes. Less is also known about the threshold somatic cell counts or impact of mastitis in crossbred-lamb production where the effect on product quality *per se* is less evident, as milk is consumed by the lamb. The objective of this study was to determine the incidence of mastitis (clinical and sub-clinical) in crossbred sheep and to evaluate the impact on milk and lamb production and the suitability of various udder assessments to provide an indicator of clinical and sub-clinical mastitis.

Materials and methods

Experimental design

The study was conducted at the LincolnSheep unit, Lincoln University, Canterbury, New Zealand with the approval from and in accordance with the Lincoln University Animal Ethics Committee, application No LUAEC 2017-17.

The lactation yield, milk somatic cells counts and udder characteristics of 121 crossbred (predominantly Coopworth) twin-suckled ewes were assessed during lactation. The ewes lambed in a period of three weeks and were stratified by lambing dates into paddocks. Within 24 h of parturition, lamb weight was recorded and lambs were tagged and matched to dam. Each week during lactation, ewes which had lambed in that week and their lambs were moved into a separate paddock, providing three cohorts of ewes, each with a similar lambing date. For each cohort, at four weeks, eight weeks and twelve weeks after parturition, ewes were assessed for lactation performance and udder characteristics (described below) in addition, ewe live weight and body condition score and lamb weights were recorded.

Ewe udder assessment

At each assessment time the following udder characteristics were recorded as described by Casu et al. (2006), Cooper et al. (2013) and Grant et al. (2016). The presence of lesions or inflammation on the teats and udder in addition to each teat and udder half palpated and scored for consistency on a scale of 1 to 5 for the teats and 1 to 7 scale for the udder. For the teats: 1 being soft consistency and 5 being that there is teat orifice obstruction or occlusion and for udders: 1 being diffuse soft consistency and 7 being diffuse hard consistency. Teat length and width were measured using digital callipers (Jobmate digital callipers: model – J701-2702, Auckland, New Zealand). Teat placement was assessed on a scale of 1 to 5 with 1 being the downward pointing teats (and closer to the udder's lowest point) and 5 being the teats are farther away from the lowest point of the udder. Udder depth was recorded on a scale of 1 to 5 with 1 being the glands are hanging below the hock level and 5 being that the glands are hanging high and tight to the belly. Udder suspension was recorded on a scale of 1 to 5, with 1 being the udder width at attachment to the belly is transversely narrower than the depth while 5 being the attachment width is much larger than the udder depth. Degree of separation was recorded on a scale of 1 to 5, with 1 being that there is no visible division of the udder halves and 5 being that the glands are clearly divided into two halves. Udders were also scored for symmetry (yes/no).

Milk production and somatic cell counts

Milk production was assessed using the oxytocin method as described by (Bencini et al. 1992). At each time, each cohort of ewes were allocated into batches of 10. For each batch of 10 ewes the lambs were removed and the ewes were milked out using a milking machine (DeLaval Type DVP170/340/EF-601516001-TJ Tumba, Sweden) and the time of first milking recorded. After four hours the ewes were administered 1.0 mL of oxytocin (0.0167mg/mL at 10IU mL^{-1}, Kela N.Y. Hoogstraten, Belgium/batch number - 26824A10) intramuscularly and after 1 minute milked again using a sheep-calibrated herd testing sampler (C0180 and C0001, supplied by Livestock Improvement Corporation Ltd LIC; Christchurch, New Zealand). The milk sub-samples were analysed at LIC to determine SCC, milk fat, protein and lactose by MilkoScan (Foss Electric, Hillerød, Denmark). The weight of the sub-samples was multiplied using the formula: milk volume in grams (as retrieved from LIC) ÷ nozzle size = milk litres/day to calculate milk production during the four-hour period. Following the second milking the lambs were returned to their dams and animals were returned to graze pasture.

Statistical Analysis

Data were analysed using GenStat 18 (VSN International Ltd: Hemel Hempstead, United Kingdom). Data were classified into above or below SCC threshold of 400,000 cells mL^{-1} (Arsenault et al. 2008, Huntley et al. 2012, Kern et al. 2013). The relationships among milk production, SCC and udder characteristics were analysed using analysis of variance (ANOVA), and the means were separated with Fisher's least significant difference (LSD) test at points of significance. Milk-production data from one cohort of animals was not assessed at week 4 due to laboratory error and were subsequently not included in the analysis. At week 12, the sub-samples from 65 animals were insufficient for milk composition and SCC analysis, and subsequent comparisons from these animals were excluded from the results. One ewe at week 4 displayed clinical symptoms of hard udder, was subsequently treated with antibiotics and removed from the study.

Results

Prevalence of high SCC and distribution

The mean SCC and distribution of animals above and below the threshold of 400,000 cells mL^{-1} and their associated milk volumes at each time are given in Table 1. Overall, 16.5% ewes had a SCC ≥400,000 cells mL^{-1}, indicating mastitis, at one or more times throughout the study. Of these, none had high SCC at all of the three sampling times, five ewes at two times and 15 ewes at one time, with corresponding incidences of 12.7%, 9.8% and 8.9% at weeks 4, 8 and 12, respectively.

Association between udder characteristics, SCC and milk production

Mean SCC for the udder characteristic scores where P≤0.4 are given in Table 2. No ewes exhibited udder palpation score of 6 or 7. Presence of lesions and/or inflammation was evident in 15.7% of the animals at one or more times. Fourteen cases were recorded at week 4 while nine and three ewes were recorded at weeks 8 and 12 respectively. Overall, of the parameters assessed, the significant associations with SCC were only observed for teat placement (TP) and teat palpation at week 12 (P=0.002 and P=0.046 respectively) while no association was recorded at week 4 and 8 (P>0.05 for all).

Mean milk yields for the udder characteristic scores where p≤0.4 are given in Table 3. Overall, milk production was greatest at week 4 with 1.09 litres per 4 h, then declined to 0.68 litres per 4 h at week 8 and 0.48 litres at week 12. For the traits of teat length (TL), teat width (TW), udder palpation, teat palpation, udder symmetry and udder suspension there were no association with milk yield at any time (P>0.05 for all). Milk yield was affected by udder depth (P=0.01), with udder depth (UD) score 3 being the greatest *viz*, 1.27 ± 0.070 litres compared with UD score 4, *viz*, 1.04 ± 0.041 litres at week 4 but these were not evident at week 8 and 12. For udder degree of separation (DS) at week 8, DS score 4 had greater milk yield than DS score 3 (P=0.008) although this was not observed at weeks 4 and 12 (P>0.05).

Association among SCC, milk production and lamb growth

Mean lamb LWs were 4.56 kg, 12.16 kg, 20.20 kg and 27.99 kg at birth, weeks 4, 8 and 12 respectively. The association between the LW, SCC and milk yield were not significant throughout the sampling periods (P>0.05 for all). There was no differences in liveweight gain (LWG)

Table 1 Mean somatic cell count (SCC) and distribution of ewes above and below the threshold of 400,000 cells mL^{-1} at weeks 4, 8 and 12 of lactation and previous sampling time for weeks 8 and 12 in relation to milk yield per 4 h and lamb liveweight gain for each twin-suckled lamb per previous four-week period.

Week	SCC threshold	Previous SCC threshold	n	SCC (x 10^6 cells mL^{-1})	Milk yield (litres per 4 h)	Lamb weight gain (kg per 4 weeks)
4	Above		10	1.68	1.07 ± 0.10^{a}	7.26 ± 0.56^{a}
	Below		69	0.12	1.09 ± 0.04^{a}	7.82 ± 0.20^{a}
8	Above	All	10	3.06	0.52 ± 0.05^{a}	7.22 ± 0.46^{a}
		Above at week 4	4	2.92	0.50 ± 0.07	6.78 ± 0.81
		Below at week 4	6	3.16	0.53 ± 0.07	7.52 ± 0.57
	Below	All	92	0.11	0.70 ± 0.02^{b}	7.30 ± 0.14^{a}
		Above at week 4	5	0.09	0.78 ± 0.16	7.70 ± 0.68
		Below at week 4	60	0.11	0.69 ± 0.03	7.24 ± 0.15
12	Above	All	5	1.78	0.45 ± 0.03^{a}	13.01 ± 2.03^{a}
		Above at week 8	1	0.74	0.42	17.00
		Below at week 8	3	2.28	0.47 ± 0.06	10.32 ± 2.16
		Above at week 4+8	-	-	-	-
		Below at week 4+8	4	2.04	0.46 ± 0.04	12.01 ± 2.28
	Below	All	51	0.14	0.49 ± 0.01^{a}	10.74 ± 0.57^{a}
		Above at week 8	3	0.17	0.41 ± 0.02	`13.93 ± 0.32
		Below at week 8	30	0.13	0.49 ± 0.01	9.31 ± 0.70
		Above at week 4+8	-	-	-	-
		Below at week 4+8	30	0.13	0.49 ± 0.01	9.31 ± 0.70

For means of milk production and lamb liveweight gain within each sampling time for all samples above or below the threshold, those with different superscripts are significantly different (P<0.05).

Table 2 Mean log10 somatic cell counts (SCC) for each of the udder and teat characteristic scores at week 4, 8, and 12 of lactation.

Score or presence								
Week 4	1	2	3	4	5	No	Yes	**P**
Udder symmetry						5.31 ± 0.127	5.09 ± 0.053	0.065
n						20	59	
Week 8								
Udder palpation	5.08 ± 0.048	5.02 ± 0.116	5.24 ± 0.112	5.65 ± 0.464	-	-	-	0.087
n	80	15	3	4	-	-	-	
Udder inflammation/ lesion						5.07 ± 0.044	5.44 ± 0.321	0.062
n						96	6	
Udder degree of separation	5.28 ± 0.148	5.05 ± 0.076	5.16 ± 0.078	4.96 ± 0.787	4.98 ± 0.085	-	-	0.230
n	20	38	20	14	10	-	-	
Week 12								
Teat Palpation	5.16 ± 0.057^{a}	5.13 ± 0.063^{a}	6.13^{b}	-	-	-	-	**0.046**
n	48	7	1	-	-	-	-	
Teat placement	-	6.55^{b}	5.09 ± 0.043^{a}	5.16 ± 0.084^{a}	5.26 ± 0.170^{a}	-	-	**0.002**
n		1	23	24	8			

Within rows means with different superscripts are significantly different (P<0.05). Only those udder and teat characteristics with a P ≤ 0.4 are shown

between lambs that came from ewes with high or low SCC (using a threshold of 400,000 cells mL^{-1}) as shown in Table 1. There was no relationship between SCC and lamb growth (data not shown). For the udder characteristics of DS, SU, and udder symmetry, there was no association with the LWG (P>0.05 for all) except at week 4 (UD: P=0.02) where mean LWG was 7.32 kg for UD score 4 (compared with 8.95 kg, 8.35 kg and 8.79 kg for UD score 2, 3 and 5 respectively), and at week 8 (TP: P=0.04) where the mean LWG was 7.28 kg for TP score 3 compared with 8.95 kg, 8.35 kg and 8.79 kg for TP score 1, 2 and 5, respectively.

Table 3 Mean milk production (litres per 4 h) for each of the udder and teat characteristic scores at week 4, 8, and 12 of lactation.

Score or presence								
Week 4	1	2	3	4	5	No	Yes	P
Udder palpation	1.06 ± 0.043	1.18 ± 0.064	0.87 ± 0.003	1.03 ± 0.258	-	-	-	0.316
n	50	24	2	3	-	-	-	
Udder symmetry	-	-	-	-	-	1.00 ± 0.069	1.12 ± 0.041	0.127
n	-	-	-	-	-	20	59	
Udder depth	-	0.79 ± 0.175[a]	1.27 ± 0.070[b]	1.04 ± 0.041[a]	0.97 ± 0.130[a]	-	-	**0.010**
n	-	2	21	50	6	-	-	
Week 8								
Teat Palpation	0.69 ± 0.026	0.65 ± 0.034	0.95	-	-	-	-	0.335
n	73	28	1	-	-	-	-	
Teat inflammation/ lesion						0.68± 0.022	0.50 ± 0.047	0.145
n						99	3	
Teat placement	-	0.67 ± 0.039	0.71 ± 0.034	0.68 ± 0.041	0.54 ± 0.044	-	-	0.237
n	-	22	49	23	8	-	-	
Udder palpation	0.69 ± 0.024	0.71 ± 0.050	0.46 ± 0.032	0.48 ± 0.062	-	-	-	0.060
n	80	15	3	4	-	-	-	
Udder symmetry	-	-	-	-	-	0.55 ± 0.048[a]	0.70 ± 0.023[b]	**0.028**
n	-	-	-	-	-	12	90	
Udder Suspension	0.51 ± 0.045	0.75 ± 0.063	0.69 ± 0.035	0.65 ± 0.033	0.68 ± 0.066a	-	-	0.208
n	5	17	37	30	13	-	-	
Udder degree of separation	0.60 ± 0.039[a]	0.70 ± 0.034[a]	0.61 ± 0.040[a]	0.71 ± 0.056[ab]	0.86 ± 0.082[b]	-	-	**0.008**
n	20	38	20	14	10	-	-	
Week12								
Teat inflammation/ lesion						0.49 ± 0.011	0.40 ± 0.015	0.076
n						53	3	
Udder depth	-	-	0.57 ± 0.075	0.48 ± 0.012	0.47 ± 0.025	-	-	0.141
n	-	-	3	38	15	-	-	
Udder Suspension	0.48 ± 0.043	0.53 ± 0.029	0.47 ± 0.014	0.47± 0.018	0.49 ± 0.049	-	-	0.387
n	3	10	23	13	7	-	-	
Udder degree of separation	0.46 ± 0.017	0.47 ± 0.021	0.49 ± 0.022	0.50 ± 0.026	0.58 ± 0.041	-	-	0.231
n	9	18	18	8	3	-	-	

Within rows means with different superscripts are significantly different ($P<0.05$). Only those udder and teat characteristics with a $P \leq 0.4$ are shown

Discussion

This study investigated aspects of SCC, and milk production in relation to udder characteristics and mastitis in crossbred ewes using a combination of linear udder scoring and measurements. Similar approach have been used in dairy ewes (Casu et al. 2006, Casu et al. 2010, De la Fuente et al. 1996). Casu et al. (2006) reported that this approach had a high level of repeatability across lactations and, upon presumption, this may show some effects in suckler ewes. There appears to be few previous reports of SCC and its association with lamb production in crossbred ewes. The sample size in this study was relatively small, as only twin-bearing ewes were considered throughout the experiment, with only 121 individuals and 242 lambs. Further to this, some milk production data is missing, in one instance through means outside of our control as a result of laboratory error, and in the other instance, due to the unforeseen complication of insufficient milk production for a large enough sub-sample to be collected using the herd-testing equipment. As such, given the limitations within this dataset, this can be considered a preliminary investigation into the relationship between SCC and milk and lamb production in crossbred ewes and the incidence of sub-clinical mastitis, which has not previously been widely reported in New Zealand flocks (Peterson et al. 2017).

Overall, high SCC levels across the sampling periods were inconsistent. Despite over 16% of individuals recording SCC above the threshold of 400,000 cells mL^{-1}, few individuals had elevated SCC on consecutive occasions. As antibiotic treatment was only administered to one ewe at week 4, this indicates a very high rate of self-cure of IMI. It is possible that this high rate of self-cure may have been assisted by frequent lamb suckling but specific evidence for this is beyond the scope of the current study. Overall, the incidence of elevated SCC observed here compares favourably with the previously reported incidences of clinical mastitis in cross-bred and hill sheep in New Zealand of around 5% with sub-clinical infections estimated to be three-fold (Peterson, et al. 2017, Rattray et al. 1982). However, it is evident the incidence of elevated SCC is dynamic and may vary depending on the time of measurement. In the current study all animals were stratified by lambing date and assessed at a similar time in lactation, as such, the environmental conditions that may have potentiated exposure to IMI-causing pathogens (Klaas & Zadoks 2017) may not have been present equally across each cohort, making comparison of the incidence in relation to stage of lactation more difficult to assess. Importantly, higher SCC was not generally associated with lower milk production. At both weeks 4 and 12, those ewes which were above the 400,000 cells mL^{-1} threshold has no penalty in milk production. By contrast, at week 8 those with a SCC above the threshold appeared to have their milk production reduced by 25%. However, interestingly, this was not reflected in differences in lamb growth. Although this needs to be repeated across different environments, the results of the current study indicate that the greatest impact of sub-clinical mastitis on milk production may be around mid-lactation. However, a majority of ewes did not, at any time, display elevated SCC or show any signs of udder or teat inflammation, suggesting that the incidence of elevated SCC in crossbred ewes is relatively low.

Overall, the udder scores reported here appeared to provide poor indicators of both milk quality and udder health. Although several significant associations were reported, they were inconsistent across time points and did not appear to provide a useful or consistent predictor of potential SCC or milk production. In part, this was surprising as UD has been reported to have a strong relationship with milk production in ewes (Casu et al. 2000; Labussière 1988). This was only apparent in the current study in ewes with UD score 3 having heavier lambs at weaning than UD score 4 which contrasts with results of Casu et al. (2006) and Green, et al. (2016) who reported UD score 4 as optimal. Perhaps more surprising was the apparent lack of association between udder palpation score and SCC, although this possibly reflects relatively few animals in which lumps in the udder were reported. Further, the ewes in this study predominantly had teats at TP score 3 and TP score 4 which exhibited lower SCC and rare lesions, which is in agreement with previous reports of lower propensity of teat lesions at TP score 3 due to the preferred angle of the teat to the udder (Cooper 2011; Green et al. 2016). Nevertheless, the lack of consistent association among among scores and milk production and SCC in this dataset provides little basis from which recommendations on optimal udder characteristics can be made. It is clear that the suitability of these assessments needs to be evaluated on a larger, more complete dataset.

Conclusion

This preliminary report indicates a limited effect of elevated SCC on milk and lamb production in crossbred ewes. The incidence of elevated SCC was 16% of individuals and varied throughout lactation, indicating an ability of ewes to self-resolve infections. The impact of SCC on milk yield was only evident at week 8, although lamb growth was not affected. Further, palpation of the udder and visual scoring for depth, degree of separation, suspension and symmetry did not appear to be useful indicators or either SCC or milk production.

Acknowledgements

The authors are grateful to Ivan Barnett, Rebecca Johnson and Martin Ridgeway for their technical assistance. This work was funded by Beef+Lamb NZ. OMY is supported by an NZAID Scholarship.

References

Arsenault J, Dubreuil P, Higgins R, Belanger D 2008. Risk factors and impacts of clinical and subclinical mastitis in commercial meat-producing sheep flocks in Quebec, Canada. Preventive Veterinary Medicine 87: 373-393.

Bencini R, Martin GB, Purvis IW, Hartmann PE 1992. Use of oxytocin to measure milk output in Merino ewes and its effect on fat content. Australian Journal of Experimental Agriculture 32(5): 601-603.

Casu S, Deiana S, Tolu S, Carta A 2000. Linear evaluation of udder morphology in Sarda dairy sheep: relationship with milk yield. Proc Atti VIX Cong Nat, SIPAOC 1: 195-198.

Casu S, Pernazza I, Carta A 2006. Feasibility of a linear scoring method of udder morphology for the selection scheme of Sardinian sheep. Journal of Dairy Science 89: 2200-2209.

Casu S, Sechi S, Salaris SL, Carta A 2010. Phenotypic and genetic relationships between udder morphology and udder health in dairy ewes. Small Ruminant Research 88: 77-83.

Clarke R 1972. Field observations on ovine mastitis. Proceedings of the 2nd Annual Seminar, Society of Sheep and Beef Cattle Veterinarians, NZVA pp 47-54 VetLearn Foundation.

Cooper S 2011. A study of ovine udder abnormalities: Identifying the risk factors for teat lesions. University of Warwick.

Cooper S, Huntley SJ, Green LE 2013. A longitudinal study of risk factors for teat lesions in 67 suckler ewes in a single flock in England. Preventive Veterinary Medicine 110: 232-241.

De la Fuente L, Fernandez G, San Primitivo F 1996. A linear evaluation system for udder traits of dairy ewes. Livestock Production Science 45:171-178.

Gelasakis AI, Mavrogianni VS, Petridis IG, Vasileiou NGC, Fthenakis GC 2015. Mastitis in sheep – The last 10 years and the future of research. Veterinary Microbiology 181: 136-146.

Grant C, Smith EM, Green LE. 2016. A longitudinal study of factors associated with acute and chronic mastitis and their impact on lamb growth rate in 10 suckler sheep flocks in Great Britain. Preventive Veterinary Medicine 127: 27-36.

Huntley SJ, Cooper S, Bradley AJ, Green LE 2012. A cohort study of the associations between udder conformation, milk somatic cell count, and lamb weight in suckler ewes. Journal of Dairy Science 95: 5001-5010.

Kern G, Traulsen I, Kemper N, Krieter J 2013. Analysis of somatic cell counts and risk factors associated with occurrence of bacteria in ewes of different primary purposes. Livestock Science 157: 597-604.

Klaas IC, Zadoks RN 2017. An update on environmental mastitis: Challenging perceptions. Transboundary and Emerging Diseases 65 (Suppl-1): 166-185 https://doi.org/10.111/tbed. 12704

Labussière J 1988. Review of physiological and anatomical factors influencing the milking ability of ewes and the organization of milking. Livestock Production Science 18: 253-274.

Larsgard A, Vaabenoe A 1993. Genetic and environmental causes of variation in mastitis in sheep. Small Ruminant Research 12: 339-347.

Green LG, Grant C, Whatford L, Genever L 2016. Understanding mastitis in sheep. beefandlamb. ahdb.org.uk. 1-16.

Pereira PF, Stotzer ES, Pretto-Giordano LG, Müller EE, Lisbôa JA 2014. Risk factors, etiology and clinical aspects of mastitis in meat ewes of Paraná, Brazil. Pesquisa Veterinária Brasileira 34: 1-10.

Persson Y, Nyman A-K, Söderquist L, Tomic N, Waller KP 2017. Intramammary infections and somatic cell counts in meat and pelt producing ewes with clinically healthy udders. Small Ruminant Research 156: 66-72.

Peterson SW, Nieper B, Collett MG, Grinberg A 2017. Brief communication: An investigation of mastitis in a hill-country sheep flock. Proceedings of the New Zealand Society of Animal Production 77: 114-116.

Quinlivan T. 1968. Survey observations on ovine mastitis in New Zealand stud Romney flocks: 1. The incidence of ovine mastitis. New Zealand Veterinary Journal 16: 149-153.

Rattray P, Jagusch K, Duganzich D, MacLean K, Lynch R1982. Influence of feeding post-lambing on ewe and lamb performance at grazing. Proceedings of the New Zealand Society of Animal Production 42: 179-182.

Romeo M, Esnal A, Aduriz J, Gonzalez L, Marco J, Rubino R 1996. Evolution of milk somatic cell counts along the lactation period in sheep of the Latxa breed. EAAP Publication (Italy) eng no 77.

Spanu C, Berger Y, Thomas D, Ruegg P 2011. Impact of intramammary antimicrobial dry treatment and teat sanitation on somatic cell count and intramammary infection in dairy ewes. Small Ruminant Research 97: 139-145.

Waage S, Vatn S 2008. Individual animal risk factors for clinical mastitis in meat sheep in Norway. Preventive Veterinary Medicine 87: 229-243.

Zafalon LF, Santana RCM, Pilon LE, Júnior GAF. 2016. Diagnosis of subclinical mastitis in Santa Inês and Morada Nova sheep in southeastern Brazil. Tropical Animal Health and Production 48: 967-972.