Efficacy of a reduced mulesing wound size on breech strike risk parameters and wound healing in Merino weaners

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Abstract

Objective To compare the effect of a conservative mulesing wound size and the modified 'V' standard mules on breech strike parameters and wound healing in Merino ewe weaners.

Design Two separate trials were performed on Merino ewe weaners (6-8months) in the Southern Tablelands of NSW. Animals were randomly assigned to one of two treatment groups; modified 'V' standard mules (NMAP) (n=100) and the conservative (CONS) (n=100).

Methods In both trials, sheep were weighed and scored for key breech strike risk parameters (breech wrinkle and breech cover) prior to and following mulesing treatment. Wounds were photographed at Day 0 and Day 28 relative to mulesing and analysed using digital planimetric software to obtain measurements of wound surface area (WSA, cm^2) and contraction rates as an indication of healing.

Results In both trials the CONS treatment resulted in a smaller WSA at Day 0 and Day 28 relative to mulesing ($P < 0.001$). The CONS treatment removed significantly less tissue ($P = 0.018$). Both treatments resulted in a reduction of breech wrinkle and breech cover scores ($P < 0.001$). The NMAP treatment resulted in lower breech scores following treatment ($P < 0.001$).

Conclusion The CONS treatment is beneficial for animal welfare outcomes as WSA is reduced. Both treatments generate an adequate reduction in breech wrinkle and breech cover in order to reduce the risk of breech strike, however the greater reduction in breech parameters from the NMAP treatment suggests that a selective approach to mulesing is required.

Keywords: mulesing, breech strike, breech cover, breech wrinkle, wound surface area

Abbreviations: WSA, wound surface area; BSA, body surface area; BCOV, breech cover; BRWR, breech wrinkle; NMAP, standard 'v' modified mules; CONS, conservative mules

Introduction

Flystrike is a significant health, production and welfare challenge for the Australian wool industry. Breech strike is the most common form of flystrike and is typically initiated by an infestation of *Lucilia cuprina* larvae in the perineal region.[1-2] The total cost of flystrike has a significant financial impact on the Australian wool industry exceeding $280 million annually for prevention, control and treatment.[2] Breech strike accounts for over half of this cost.[1]

Breech strike risk is determined through a series of indicator traits. Sheep with a large amount of faecal soiling in the perineal region (dag) are significantly predisposed to breech strike.[2-4] Wetting of the wool surrounding the anus and vulva with urine also increases the risk of breech strike.[2-3] Breech cover (BCOV), the amount of bare area surrounding the perineum, and breech wrinkle (BRWR), the degree of skin folds over the tail, perineum and hind legs, influence dag and urine build up.[2-3] The optimal ratio of breech strike indicator traits is 2:2:3 for BRWR:DAG:BCOV.[4] Above this ratio, the risk of strike is significantly increased. Scoring of these traits is on a one to five scale with five being the maximal and least desirable expression of a trait.[3-4] It has been suggest that a reduction in each risk factor by as little as one score can halve the risk of breech strike.[5]

Mulesing, the surgical excision of wool bearing skin and skin folds from the breech and tail region of Merino sheep, has been the primary method for the prevention of breech strike since its development in the 1930s.[6-7] The procedure tightens the skin in the perineal and tail regions to reduce breech wrinkle and stretch the natural bare area around the anus and vulva.[6] This permanently reduces the susceptibility to flystrike through a reduction in faecal build up and wetting.[6-7] Mulesing has been well documented as a painful procedure.[8] The uptake of a commercially available topical anaesthetic, Tri-Solfen® (Bayer Animal Health Australia, Pymble NSW), by approximately 70% of Merino producers has improved welfare,[8-9] however concern remains regarding the lack of science influencing mulesing standards.[10-11] Genetic selection for flystrike resistance is the long term industry goal for prevention. The heritability of breech strike indicator traits have been determined, however it will take 10-15 years before such phenotypes are incorporated into the national Merino flock.[12-14] Alternative practices to mulesing are in development and to date have had limited effect on reducing risk parameters or have had challenges with practical application.[15-16] Consequently, mulesing remains as the most common and effective method of preventing breech strike.

The Code of Practice for the Welfare of Sheep states that mulesing should be performed with the minimum number of cuts suitable to the individual for flystrike protection.[16] Given the move towards a plainer bodied flock, assessment of the necessity for the current modified 'V' standard mules is required. The National Mulesing Accreditation Program is currently undergoing review, which represents the opportunity to refine the existing mulesing procedure to meet industry best practices.[18]

The objective of the current study was to compare the effect of a smaller, conservative mules to the modified 'V' standard mules on wound healing and breech risk parameters. The outcomes of this study will also provide a scientific basis to refine industry best standards.

Materials and methods

All trial protocol was conducted under prior approval from the University of Sydney Animal Ethics Committee (Protocol #5832).

Animal management

Two trials were performed on Merino ewe weaners of 6-8 months of age from two commercial fine wool properties in the Southern Tablelands of NSW. All sheep were undergoing mulesing as per routine farm management, and had been previously hot-iron tail docked, ear notched and ear tagged at 6 weeks of age. In both trials sheep were randomly allocated to one of two mulesing treatments: (1) conservative mules (n=100); (2) standard 'V' modified mules (n=100).

Trial 1 was conducted on Farm 1, near Taralga, NSW, in autumn of 2015. Two weeks prior to mulesing, 200 ewe weaners were crutched (wool removed from breech and tail) in preparation for breech scoring and to allow crutching wounds to heal prior to mulesing. On the day of mulesing, sheep were mustered and drafted into a holding yard. Sheep were ear tagged, weighed using an electronic sheep handler (Clipex® Sheep Handler, Clipex, Brisbane QLD) and scored for BCOV and BRWR as described below. Each animal was then placed in a mulesing cradle and a contractor performed the mulesing procedure. The same contractor performed both treatments. The tissue removed was weighed using electronic scales (Salter Spacesaver Kitchen Scale No.1075). A topical ointment of canola and tea tree oil was sprayed onto each wound as per the farm's routine practice.

Trial 2 was conducted on Farm 2, near Marulan, NSW, in winter of 2015. Two weeks prior to mulesing, 200 ewe weaners were tagged, weighed and assessed for dag and urine scores, as below, using an electronic sheep handler (Hdale Engineering Ltd, Model no: CWC RC). All sheep were crutched two weeks prior to mulesing. On the day of mulesing, sheep were yarded and drafted into a holding yard. Sheep were restrained in a VE conveyor machine, with the hind legs of the sheep secured into leg hooks. BCOV and BRWR scores were assessed, as described below. A contractor then performed both mulesing treatments. The tissue removed was weighed using electronic scales (Salter Spacesaver Kitchen Scale No.1075). Tri-Solfen® (Bayer Animal Health, Pymble, Australia) was topically applied to each wound surface as per best practice protocol.

Treatments

Modified 'V' standard mules (NMAP) This procedure was performed as per the current industry guidelines.[19] An average of six excisions were performed with sharpened mulesing shears disinfected with clorhexidine (Hibitane®, Coopers Animal Health, Baulkham Hills, Australia). Four crescent shaped flaps were excised starting in alignment with the natural bare perineal skin and extending down the hock (cuts 3-6 in Figure 1). Two strips of skin were then removed from the wool bearing skin along the base and side of the tail (cuts 1-2 in Figure 1). The excisions from the breech joined those taken from the tail, however a 'V' shaped area of wool remained at the base of the tail to protect the skin from sun damage.

Conservative mules (CONS) A total of four excisions were made using disinfected, sharpened mulesing shears. A single crescent shaped strip of skin was excised from both sides of the breech region (cuts 3-4 in Figure 2). The two tail strips were removed as per the modified 'V' standard mules (cuts 1-2 in Figure 2). The excisions from the breech joined those taken from the tail and the same 'V' shaped area of wool remained at the base of the tail.

Breech strike risk parameter scoring

Breech parameter scoring was conducted immediately prior to mulesing (Day 0) and at 2 months post treatment (Day 56). Scoring was performed as per the Visual Sheep Scores Guide,[21] where parameters are allocated a score of 1-5 with 5 being the maximal and least desirable expression of the trait. BRWR, the degree of skin wrinkle at the tail, perineum and hind legs was assessed (Figure 3). BCOV, the amount of bare area surrounding the perineum and breech area was also assessed (Figure 4). Dag and urine stain scores were assessed through the Visual Sheep Score Guide 2 weeks prior to mulesing, at crutching (Figure 5).

Wound area and healing

Wounds were digitally photographed immediately after mulesing (Day 0), prior to topical anaesthetic or ointment application, and again 28 days (Day 28) after mulesing. A 30 cm ruler was held above the wound against the wool to act as a scale, and animal identification number was also included in the image. Digital planimetric analysis software (PictZar® CDM, BioVisual Technologies L.L.C. New Jersey, USA) was used to measure wound surface area (WSA) in cm^2 for each image. The program used the scale to calculate pixels per cm. An assessor manually shaded the wounds within the program to obtain the WSA. A percentage change in WSA over 4 weeks was obtained from the program (Figure 6). All wounds were analysed by the same assessor, who was blind to the treatment protocol at the time of performing the assessments.

An approximated body surface area (BSA) was calculated using the formula described by Bennett (1973) where total body surface area (m^2) = $0.094B^{0.67}$ (where B is sheep weight in kg).[20] A comparison of WSA as a percentage of BSA (WSA:BSA(%)) was calculated and compared across treatment and time.

Statistical analysis

Data was tested for normality using the Anderson-Darling Test for normality (5%). All data analysed followed a normal distribution and therefore, did not need to be transformed.

Weight of tissue removed (g), WSA and WSA:BSA were analysed using a restriction maximal likelihood regression (REML) in Genstat® 16th edition (VSN International Ltd, Hemel Hempstead, UK). The response variable of 'weight of tissue removed' was fitted against treatment, farm and potential interactions. For the WSA and WSA:BSA analysis, the response variables were analysed by fitting the effects of treatment, time, farm and potential interactions. Where there was a significant effect or interaction, pairwise comparisons were conducted using least significant differences (LSDs) from the model.

As the breech scores were ordinal data they were analysed using ordinal logistic regression (OLR) in ASReml® v3 (VSN International Ltd, Hemel Hempstead, UK) to account for uneven intervals between scores. The fixed effects were treatment, time, farm and their interactions. Pairwise comparisons to assess the differences within treatment/time were made using z-values calculated from the SEDs and presented as probability plots. Tag was included in all models as a random effect to account for any inter-animal variation.

Results

Tissue removed

There was a significant treatment x farm interaction for weight of tissue removed ($P = 0.018$). The mean weight of tissue removed for the CONS treatment was significantly smaller than the NMAP at both Farm 1 (85.14 ± 1.72 g vs 113.73 ± 1.72 g) and Farm 2 (46.17 ± 1.73 g vs 66.54 ± 1.75 g) (Figure 7).

Wound area and healing

Wound Surface Area There was a significant treatment x time interaction for WSA ($P < 0.001$). The NMAP treatment resulted in a larger WSA than CONS on both Day 0 and Day 28 (Figure 8). There was a significant reduction in WSA from Day 0 to Day 28 for both CONS (87.62 ± 1.25 cm^2 vs 17.25 ± 1.25 cm^2) and NMAP (150.82 ± 1.25 cm^2 vs 29.53 ± 1.26 cm^2) treatments (Figure 8). Both treatments resulted in an 80% reduction in WSA over the 28 days.

There was a significant farm x time interaction for WSA ($P < 0.001$). The NMAP treatment resulted in a larger WSA than the CONS at both Farm 1 (83.58 ± 1.32 cm^2 vs 52.27 ± 1.31 cm^2) and Farm 2 (96.77 ± 1.34 cm^2 vs 52.6 ± 1.33 cm^2) (Figure 9). There was no significant difference in the WSA of the CONS treatment between the two farms, however the NMAP treatment resulted in a significantly larger WSA at Farm 2 (Figure 9).

Wound Surface Area: Body Surface Area There was a significant interaction of treatment x time on WSA:BSA(%) ($P < 0.001$). The NMAP treatment resulted in a greater WSA:BSA(%) at both Day 0 and Day 28 (1.71 ± 0.01 vs 0.33 ± 0.01) than the CONS (0.98 ± 0.01 vs 0.20 ± 0.01) (Figure 10). For both treatments there was a significant reduction in WSA:BSA(%) over the 28 days (Figure 10).

There was a significant interaction of farm x time on WSA:BSA(%) ($P < 0.001$). WSA:BSA(%) was significantly greater for the NMAP treatment compared to the CONS treatment for both Farm 1 (0.95 ± 0.01 vs 0.60 ± 0.01) and Farm 2 (1.08 ± 0.01 vs 0.58 ± 0.01) (Figure 11). For the NMAP treatment, WSA:BSA(%) was significantly greater on Farm 2 compared to Farm 1 (1.08 ± 0.01 vs 0.95 ± 0.01) (Figure 11).

Breech strike risk parameters

Breech wrinkle The mean BRWR scores for Day 0 and Day 56 are presented in Table 1. There was a significant interaction of time x treatment for BRWR (P < 0.001). Both the CONS and NMAP treatments resulted in a significant reduction in BRWR (- 0.57 vs - 0.92) (Figure 12). Prior to treatment, the CONS treatment group had a lower mean BRWR than the NMAP group (P < 0.001) (Figure 12). Following treatment the NMAP treatment had significantly lower BRWR scores than the CONS treatment (P < 0.001) (Figure 12). BRWR differed significantly between farms, with Farm 1 having higher mean BRWR scores than Farm 2 (P < 0.001) (Figure 13).

Breech cover The mean BCOV scores for Day 0 and Day 56 are presented in Table 2. There was a significant time x treatment interaction for BCOV (P < 0.001). Both the CONS and NMAP treatments resulted in a significant reduction in BCOV scores (- 1.67 vs - 2.11) (Figure 14). On Day 56 the NMAP treatment had significantly lower BCOV scores than the CONS treatment (Figure 14). BCOV was significantly different between the farms, with Farm 2 having lower scores (P < 0.001) (Figure 15).

Discussion

The results from this study show that significant reductions in tissue removed, WSA and WSA:BSA(%) can be achieved through the CONS treatment. The reduction in the number of excisions used in the CONS treatment is reflected in the amount of tissue removed. The amount of granulation tissue required increases as wound size increases.[22] This prolongs the time required for epithelisation, extending wound healing times.[22-23] Mean wound contraction rates between the two treatments were the same, however the NMAP treatment had a larger WSA at Day 28. Our results are in alignment with previous studies that identified that a larger initial wound took longer to heal.[22-23] The increased healing time for the NMAP treatment is due to the larger surface area requiring an increased amount of granulation tissue to close the wound. The extended time for the NMAP treatment to completely heal increases the risk of injury to the wound, contamination and wound strike.[22-23] The Code of Practice for the Welfare of Sheep supports the idea of a reduced wound size suggesting that mulesing should be performed with the minimal number of excisions required to adequately reduce breech strike risk.[16]

A smaller wound size is advantageous to animal welfare outcomes. The CONS treatment had a significantly smaller WSA:BSA(%) which is linked to wound healing. An increased WSA:BSA(%) in small animals has a negative impact on normal physiology and can alter the metabolic rate.[25] The response of inflammation and the requirement for granulation and re-epithelisation increases with greater WSA:BSA(%).[22-23] The use of pain relief has been shown to improve wound contraction rates in lambs.[33] Combining the CONS treatment with pain relief will alleviate pain and has the potential to further improve wound healing .

The amount of tissue removed and WSA varied between the two farms. As different contractors were used at the two farms, the exact cause of this variation is inconclusive. Given the differences in the flock phenotype between the two farms, it is hypothesised that the increase in BRWR resulted in an increased amount of tissue being removed with each excision. In support of this theory, the initial WSA from the CONS treatment at both farms was not significantly different, eliminating the difference in the size of the excisions as a cause.

Farm 2 had been selecting for a reduced level of wrinkle in the flock phenotype as a part of the breeding objectives for the enterprise. This resulted in a difference in the initial breech scores between the two properties. There is insufficient information regarding the effect of initial breech scores on treatment outcomes. The results from this study suggest that higher initial scores result in a smaller reduction of breech parameters following mulesing regardless of treatment (Table 1-2). The reduction of higher scores is important given the exponential increase in breech strike risk with each score.[21] This outcome supports the need for selective mulesing, where sheep with higher expressions of risk parameters are treated with a larger mules.

Breech strike risk parameters are important in determining the risk of strike. It has been identified that BRWR should be no higher than score 2 and BCOV score 3.[4;12] An increase in breech scores beyond this significantly increases the risk of strike through moisture and faecal build up.[4;12] The NMAP and CONS treatments both resulted in a significant reduction of BCOV to within the ideal range. As BCOV influences the amount of dag and urine staining, this is a significant finding. Previous research has proposed that for treatment to be considered successful BCOV should be reduced by 1.5 scores.[13] Both the NMAP and CONS treatments achieve this, however the NMAP treatment reduces BCOV to a greater extent. As the outcome of mulesing is related to the granulation and epithelisation process for skin contraction, the larger wound size was expected to result in a larger reduction of BCOV.[22] The CONS treatment reduced BRWR scores, although the mean BRWR remained above the optimal level for strike. A previous study outlined that a reduction in a risk factor by as little as one BRWR score can halve the incidence of strike.[26] Consequently, the CONS treatment, despite resulting in BRWR scores above optimal, is able to significantly reduce strike risk.

Dag and urine scoring have been shown as important traits in determining breech strike risk.[3-4;12-14;] The ability to accurately obtain measurements for these parameters is limited. As experienced at Farm 2, scouring events provide challenges to the accurate scoring. These parameters were removed from the trial as over 60% of the flock was scouring at the time of assessment. The presence of dags prevents accurate urine scoring as the colour and moisture is obscured.[21] Consequently, breech wrinkle and cover were used as the sole parameters for assessing the effectiveness of the treatment. The timing of this study prevented observations on the incident of strike, given the seasonal nature. All trial sheep will be monitored to identify the effect of treatment on breech strike incidence.

BCOV and BRWR determine the level of dag and urine build up, as it is the skin folds and wool that trap the faeces and moisture.[3-4;12-14] Urine results in wetting and moisture build up of the skin and wool, increasing dermatitis due to *Pseudomonas* sp. and rendering the sheep more susceptible to strike.[27-28] The importance of dag varies with different environment.[3;12;14;29-30] Temperature, humidity and seasonal rainfall variation alter the expression of dags.[3;12;14] In environments with lower dag scores, BRWR, BCOV and urine are the main predictors of strike.[3;12;14] There is a need to validate the CONS treatment in a wide range of environments to ensure adequate protection against strike is achieved.

The Visual Sheep Score Guide is widely used throughout the wool industry despite being highly subjective and often having animals scored between scores. The assessment of BRWR through a wrinkle count and BCOV through the measurement of bare area has previously been used.[31] BRWR counts remain subjective as variation in the length and tightness of wrinkles occurs. Where applicable, the objective assessment of breech parameters will result in more accurate analysis and reduce variation between scoring. The use of digital planimetry software to map wounds is the most accurate method with 3.9% average error[32] and has previously been used to map wound healing in sheep.[33] There is scope to utilise this method of analysis to determine BCOV objectively in future studies.

Anecdotal evidence suggests that mulesing sheep as weaners has benefits to welfare and animal management. Lambs appear to mother up better at marking in the absence of mulesing and have a reduced ability to recover from mulesing than weaners. The two farms involved in this study routinely mules sheep as weaners, despite this being in contrast with The Code of Practice.[16] Lambs have a smaller body surface area than weaners, which would result in an increased WSA:BSA(%) for wounds of the same size. Body condition also varies between lambs and weaners. As weaners are larger and more developed, less energy is required for skeletal growth, improving the ability to store excess energy as fat reserves. Body condition scoring is independent of frame size[24] and is more likely to influence wrinkle scores than live weight alone. Animals with an increased amount of condition have a greater amount of fat coverage,[24] increasing the surface area of the skin. Future studies should include body condition scores to determine the influence of this on treatment outcomes.

It has been shown that BRWR and BCOV phenotypes vary increasingly with age.[12;21] The full variation of breech scores is important in genetic selection against breech strike. Restricting the age at which mulesing can be performed on an animal could prove detrimental to genetic selection, as the variation and ability to select against traits is reduced in lambs.[12]

The next phase of investigation will study the effect of the conservative treatment in a wider range of environments and establish if age has an effect on the outcomes of the two treatments. The findings from this study provide new information and are supportive of the use of the conservative mules over a range of flock phenotypes. The conservative mules treatment has improved welfare outcomes through the smaller initial WSA and WSA:BSA(%). The conservative treatment generated a significant reduction in breech strike risk parameters in order to reduce the risk of breech strike, however this study emphasised the need for a selective mules with varying phenotypes.

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References

1. Sackett D, Holmes P, Abbott K, Jephcott S, Barber M. Assessing the economic cost of endemic disease in the profitability of Australian beef cattle and sheep producers. In: Final report – Animal Health and Welfare (Project code AHW.087), Meat and Livestock Australia, North Sydney, 2006.
2. Australian Wool Innovation Ltd. Managing Breech Flystrike. http://www.wool.com/globalassets/start/about-awi/publications/managing_breech_flystrike_june_2011.pdf. 2011. Accessed June 2015.
3. Greeff JC, Karlsson LJE, Schlink AC. Identifying indicator traits for breech strike in Merino sheep in a Mediterranean environment. Anim Prod Sci 2014;54:125-140.
4. Lindon G. Key messages and RDE priorities. In: AWI Breech strike R&D Technical Update, Australian Wool Innovation, Sydney, Australia, 20 August 2014. http://www.wool.com/globalassets/start/on-farm-research-and-development/sheep-health-welfare-and-productivity/sheep-health/breech-flystrike/r-and-d-update/20140820_15_awi_rnd_tech_update_gl_key_message_priorities.pdf Accessed May 2015.
5. Horton B. A method for estimating the economic value of changes in the risk of breech strike. Anim Prod Sci 2013;53:1126-1133.
6. Beveridge WIB. The origin and early history of the Mules operation. Aust Vet J 1984;61:161-163.
7. Beveridge WIB. The Mules Operation: Prevention of blowfly strike by surgical measures. Aust Vet J 1935;11:97-104.

8. Sneddon J, Rollin B. Mulesing and Animal Ethics. J Agr Environ Ethic 2010;23:371-386.
9. Windsor PA, Lomax S. Addressing the concerns in control of ovine cutaneous myiosis in sheep in Australia. Aust Vet J 2013;110:165-169.
10. Lee C, Fisher AD. Welfare consequences of mulesing sheep. Aust Vet J 2007;85:89-93.
11. Fisher AD. Addressing pain caused by mulesing in sheep. Appl Anim Behav Sci 2011;135:232-240.
12. Smith JL, Brewer HG, Dyall T. Heritability and phenotypic correlations for breech strike and breech strike resistance indicators in Merinos. In: *Proceedings of the 18th Conference Association for the Advancement of Animal Breeding and Genetics.* Proc. Assoc. Advmt. Anim. Breed. Genet., Barossa Valley, Australia, 2009;334-337.
13. James PJ. Genetic alternatives to mulesing and tail docking in sheep: a review. Aust J Exp Agr 2006;46:1-18
14. Scobie DR, O'Connell D, Morris CA, Hickey SM. A preliminary genetic analysis of breech and tail traits with the aim of improving the welfare of sheep. Aust J Agr Res 2007;58:161-167.
15. Larsen J, Tyrell L, Anderson N. Prevalence of breech-strike in mulesed, clipped and unmulesed Merino hoggets in south-eastern Australia. Aust Vet J 2012;90:158-166.
16. Evans IB, Lawton PW, Sergeant E, Lloyd JB. Effect of plastic occlusive clips used as an alternative to mulesing on breech conformation, body weight and survival of Merino lambs. Aust Vet J 2012;90:88-96
17. Primary Industries Ministerial Council. *Model Code of Practice for the Welfare of Animals – The Sheep*. 2nd edn. CSIRO Publishing, Collingwood, Victoria, 2006.
18. Lomax S, Sheil M, Windsor PA. Impact of topical anaesthesia on pain alleviation and wound healing in lambs after mulesing. Aust Vet J 2008;86:159-168.

19. Bennett JW. Regional body surface area of sheep. J Agr Sci 1973;3:429-432.
20. Gherardi SG, Seymour M. Mulesing for flystrike control, *Farmnote* 1996:46 http://www.hamburger-illustrierte.de/content/htm/tic/2004/12/12/f04696.pdf. 1996. Accessed April 2015.
21. Australian Wool Innovation Ltd and Meat and Livestock Australia. Visual Sheep Scores – research version. http://www.wool.com/globalassets/start/on-farm-research-and-development/sheep-health-welfare-and-productivity/sheep-breeding/visual-sheep-scores/visual_sheep_scores_researcher_version_lr.pdf. 2013. Accessed April 2015.
22. Lepherd ML, Canfield PJ, Hunt GB, Thomson PC, Bosward KL. Wound healing after mulesing and other options for controlling breech flystrike in Merino lambs: observation on gross and microscopic wound healing. Aust Vet J 2011;89;1-2:27-37.
23. Lepherd ML, Canfield PJ, Hunt GB, Thomson PC, Bosward KL. Wound healing after mulesing and other options for controlling breech flystrike in Merino lambs: quantitative and semiquantitative analysis of wound healing and wound bed contraction. Aust Vet J 2011;89;3:61-69.
24. Paveletic MM. Skin and adnexa. In: Slatter DH, editor. *Textbook of small animal surgery*. 3rd edn. Saunders Elsevier, Philadelphia, 2003:25-373
25. Russel A. Body Condition scoring of sheep. In Practice 1984;6:91-93.
26. Horton B. A method for estimating the economic value of changes in the risk of breech strike. Anim Prod Sci 2013;53:1126-1133.
27. Norris BJ, Colditz IG, Dixon TJ. Fleece rot and dermatophilosis in sheep. Vet Microbiol 2008;128:217-230.

28. Bull LB. Some observations on dermatitis of the folds in the breech of sheep and its possible relationship to blowfly strike. Aust Vet J 1931;7:143-148.

29. Scobie DR, O'Connell D. Breech bareness reduces flystrike in New Zealand crossbred Sheep. Anim Prod Sci 2010;50:599-602.

30. Wardhaugh KG, Morton R. The incidence of flystrike in sheep in relation to weather conditions, sheep husbandry and the abundance of the Australian sheep blowfly, *Lucillia cuprina*. Aust J Agr Res 1990;41:1155-1167.

31. Cuming M. Methodical progress with flystrike control. http://www.wool.com/about-awi/media-releases/methodical-progress-with-flystrike-control/?category=0&year=0&month=0&page=28. 2012. Accessed October 2015.

32. Wendelken ME, Berg WT, Lichtenstein P, Markowitz L, Comfort C, Alvarez OM. Wounds Measured From Digital Photographs Using Photo-digital Planimetry Software: Validation and Rater Reliability. Wounds 2011;23:267-275.

33. Lomax S, Sheil M, Windsor PA. Impact of topical anaesthesia on pain alleviation and wound healing in lambs after mulesing. Aust Vet J 2008;86:159-168.

Appendix 1

Figures

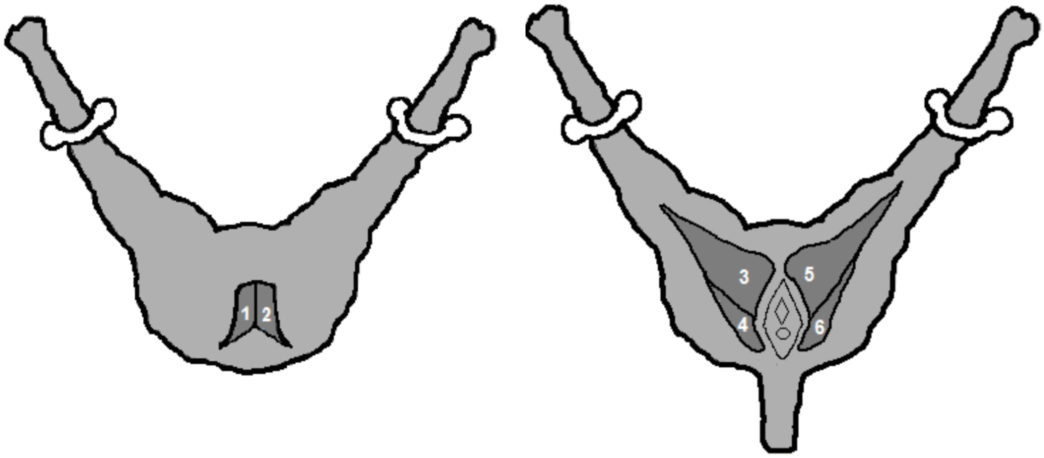

Figure 1. The standard ‘V’ modified mules technique (NMAP) removes the wool bearing skin from the sides and tip of the docked tail through cuts 1 and 2. Tissue is excised from the breech area through four crescent shaped cuts, extending down the hock (cuts 3 to 6). Diagram adapted from Gherardi and Seymour (1996).[19]

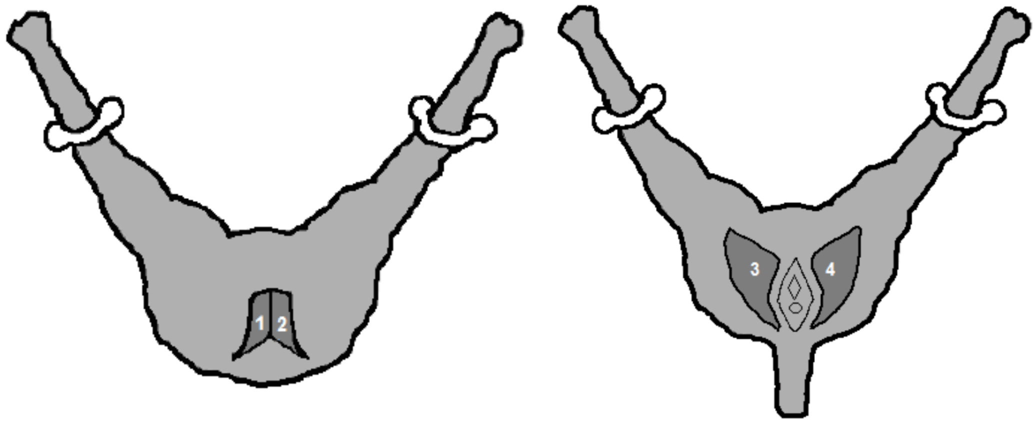

Figure 2. The conservative mules technique (CONS) removes the wool bearing skin from the sides and tip of the docked tail through cuts 1 and 2. Two excisions are taken from the breech region, cuts 3 and 4. Diagram adapted from Gherardi and Seymour (1996).[19]

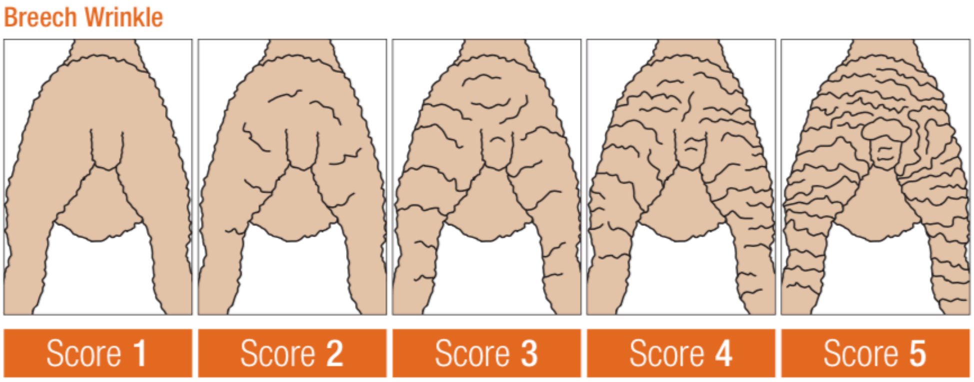

Figure 3. The breech wrinkle (BRWR) scoring system is conducted on a scale of 1-5. A score of 5 is the maximal and least desirable expression of the trait for protection against breech strike. Image from AWI and MLA (2015).[21]

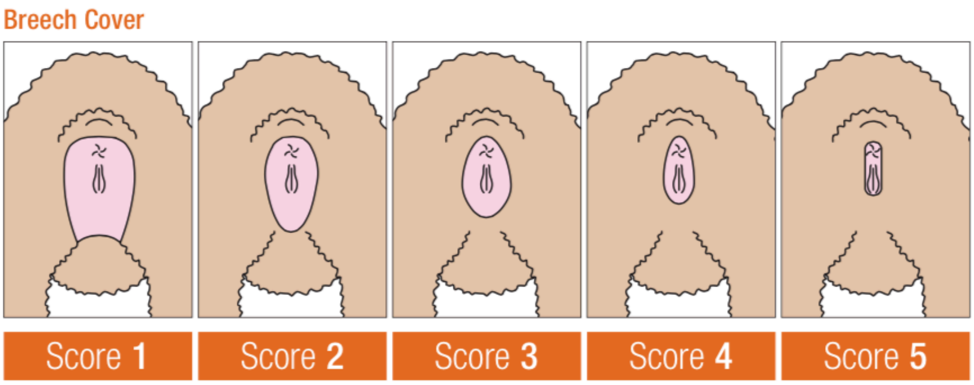

Figure 4. Breech cover (BCOV) is scored on the 1-5 scale as per the visual sheep scored guide. A score 1 sheep has a natural bare area that extends outwards around the anus and vulva, down to the bottom of the breech area (the channel). A sheep with a score 5 has minimal natural bare area. Image from AWI and MLA (2015).[21]

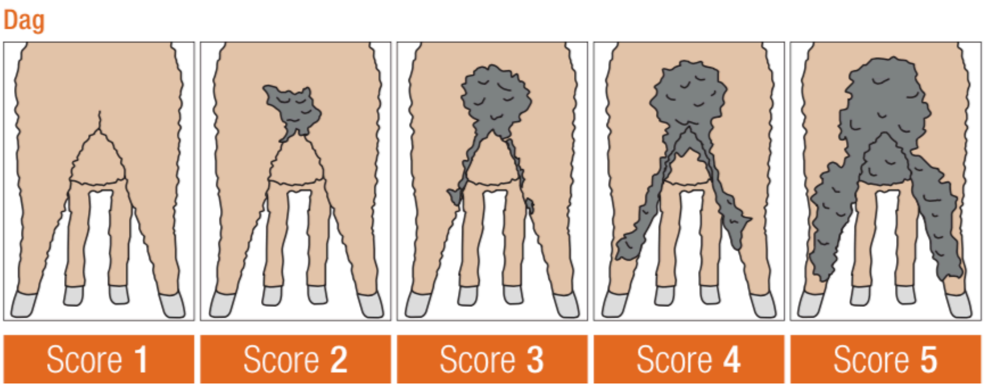

Figure 5. The visual sheep scoring guide scores Dag on a scale of 1-5. A score of 5 is a sheep that has dags extending down the hock to the pasterns. The breech area has extensive dags. A score of 2 or less is optimal for protection against breech strike. Image from AWI and MLA (2015).[21]

University of Sydney Team Pain
PictZar® Wound Measurement Summary Report

Patient Name: Tag 202 Chart ID: 202 Wound No: 202-1 Location: Breech

Original Image	**Current Image**	**PictZar Measured Image**
Initial Measurement Date: 07-16-2015	Date Of This Assessment: 08/12/15	Measurement No: 2 of 2

CORE MEASUREMENTS

Initial Area (CmSq)	Current Area (CmSq)	Percent Area Change	Length	Width	Depth	Volume
153.798	45.633	-70.33%	15.72cm	15.25cm	0cm	0cc

DETAIL MEASUREMENT ANALYSIS

Area cmSq.	Color	Percent	Tissue Type by Color	Depth in cm	Color	Volume in cc		Linear Measurements
45.633	Blue	100.0	Not Entered	0	Blue	0		
0.00	Red	0	Not Entered	0	Red	0		Length: 15.72cm
0.00	Green	0	Not Entered	0	Green	0		Width: 15.25cm
0.00	Yellow	0	Not Entered	0	Yellow	0		Circumference: 0cm
45.633	Total Area			0	Aver. Depth	0	Total Volume	

Comments:

Figure 6. Output from the digital planimetric wound analysis software, PictZar (PictZar® CDM, BioVisual Technologies L.L.C. New Jersey, USA). Wound surface area is provided for Day 0 and Day 28. The rate of contraction is provided as the Percent Area Changed.

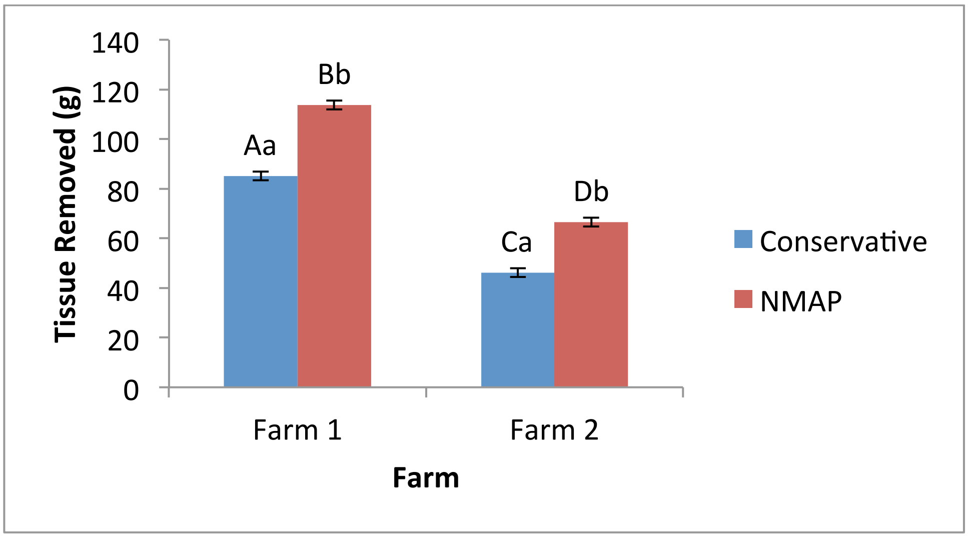

Figure 7. The mean amount of tissue removed with the conservative and NMAP treatments at Farm 1 and Farm2. Means without common superscripts differ significantly ($P = 0.018$); lower case (a,b) indicate differences within a Farm; capitals (A,B) indicates differences across Farms.

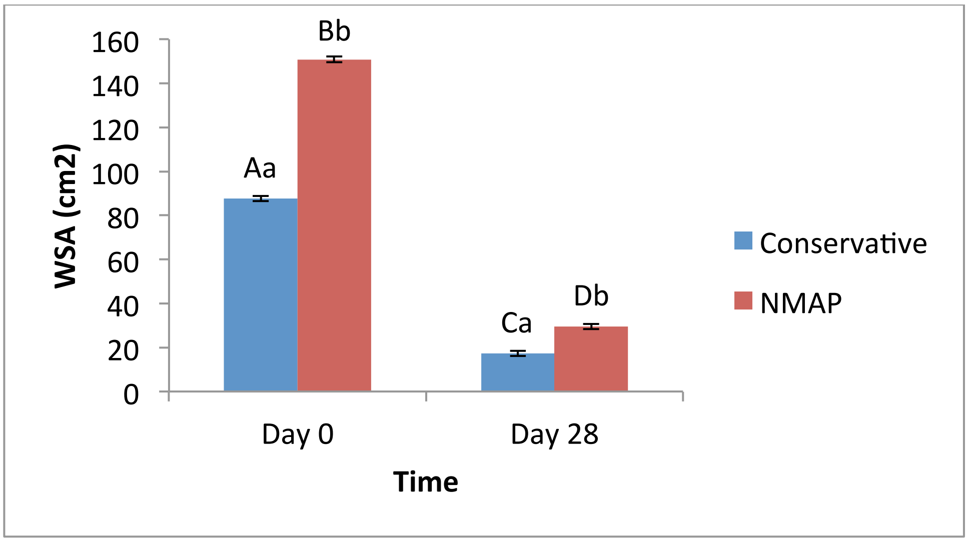

Figure 8. The mean wound surface area (cm^2) of the conservative and NMAP treatments at Day 0 and Day 28 in Merino ewe weaners. Means without common superscripts differ significantly ($P < 0.001$); lower case (a,b) indicate differences within a time point; capitals (A,B) indicates differences across time points.

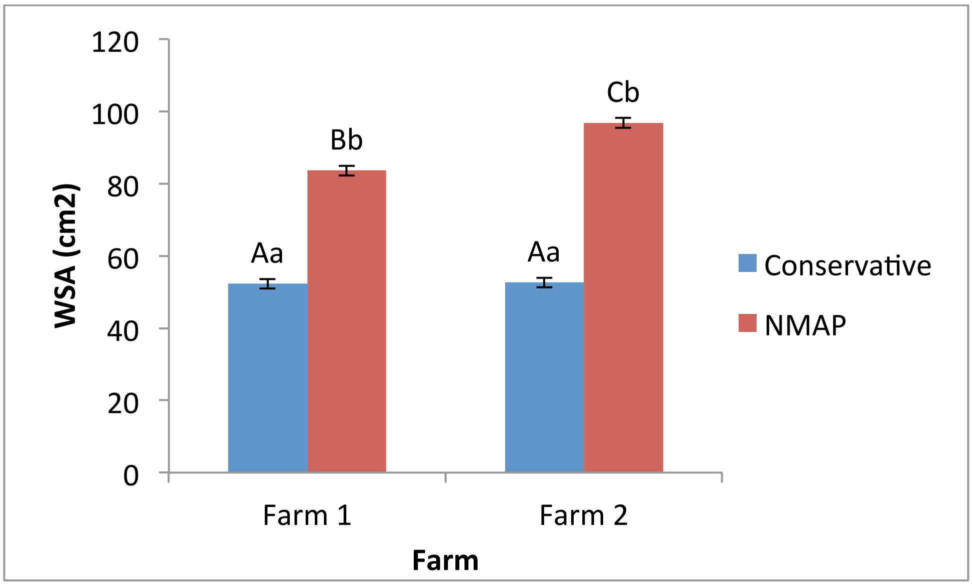

Figure 9. The mean wound surface area (cm^2) of the conservative and NMAP treatments at Farm 1 and Farm 2 in Merino ewe weaners. Means without common superscripts differ significantly ($P < 0.001$); lower case (a,b) indicate differences within a Farm; capitals (A,B) indicates differences across Farms.

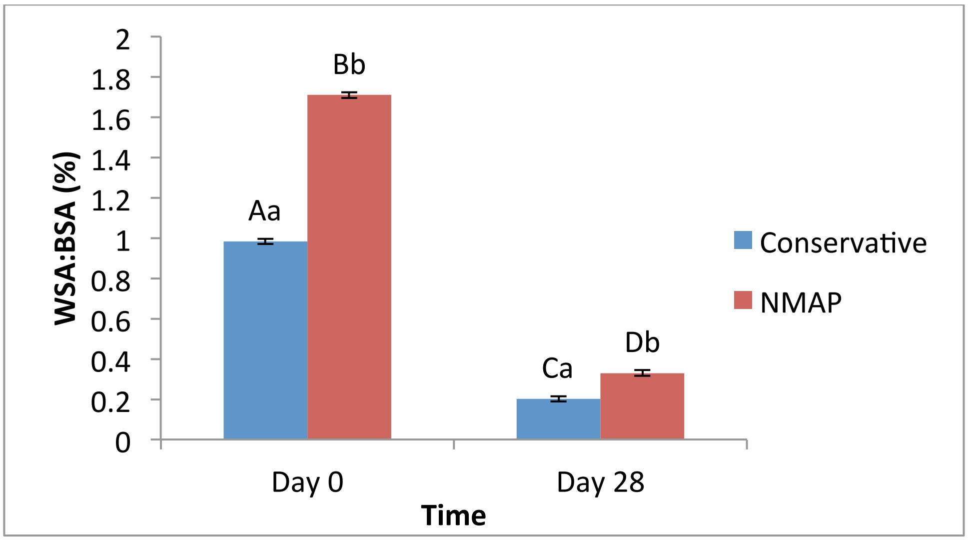

Figure 10. The mean wound surface area to body surface area percentage (WSA:BSA) of the conservative and NMAP treatments at Day 0 and Day 28. Means without common superscripts differ significantly ($P < 0.001$); lower case (a,b) indicate differences within a time point; capitals (A,B) indicates differences across time points.

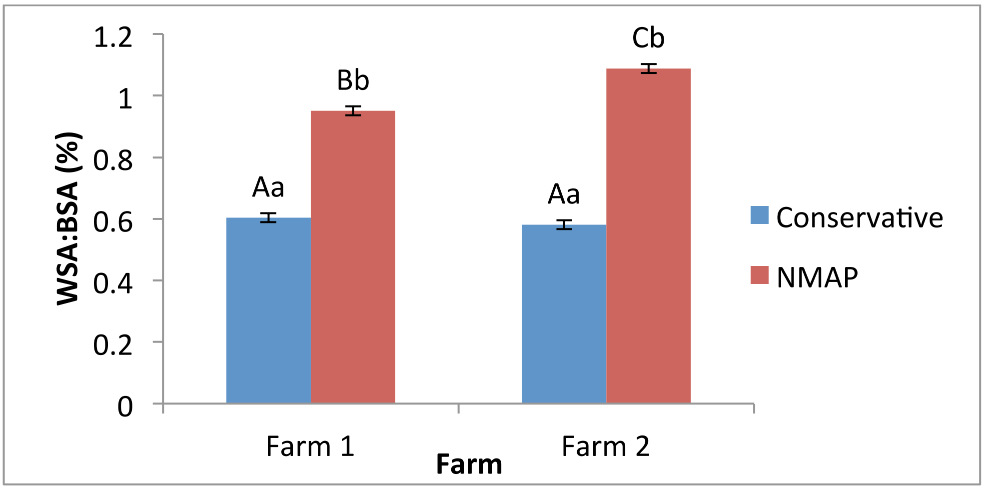

Figure 11. The mean wound surface area to body surface area percentage (WSA:BSA) of the conservative and NMAP treatments at Farm 1 and Farm 2. Means without common superscripts differ significantly (P < 0.001); lower case (a,b) indicate differences within a Farm; capitals (A,B) indicates differences across Farms.

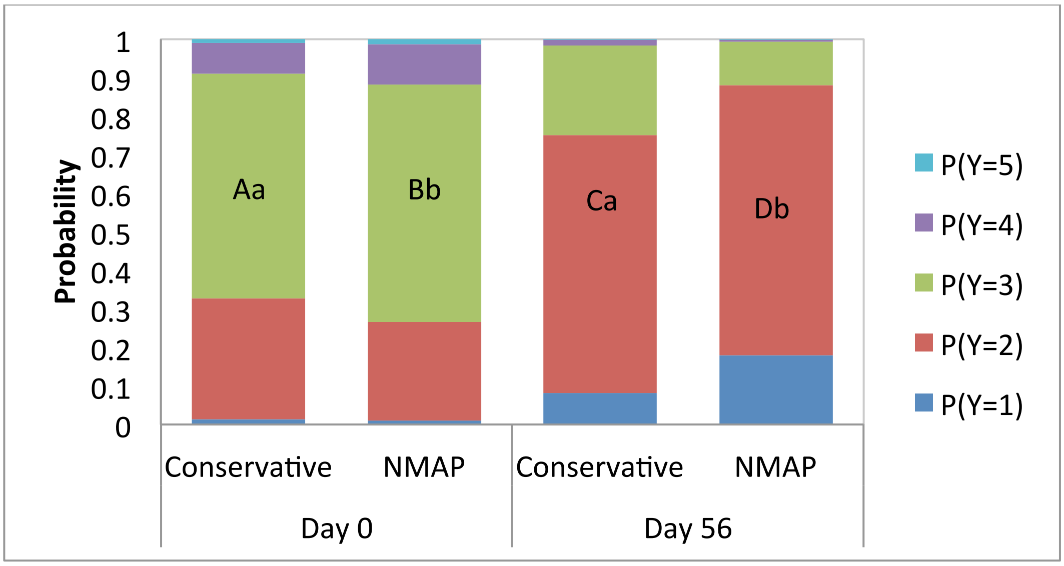

Figure 12. The probability of breech wrinkle (BRWR) scores (Y) in each treatment over time. On Day 56 there was a significant effect of treatment on BRWR with the mean NMAP scores being lower than the conservative treatment. Probabilities without common superscripts differ significantly (P < 0.001); lower case (a,b) indicate differences within a time point; capitals (A,B) indicates differences across time points.

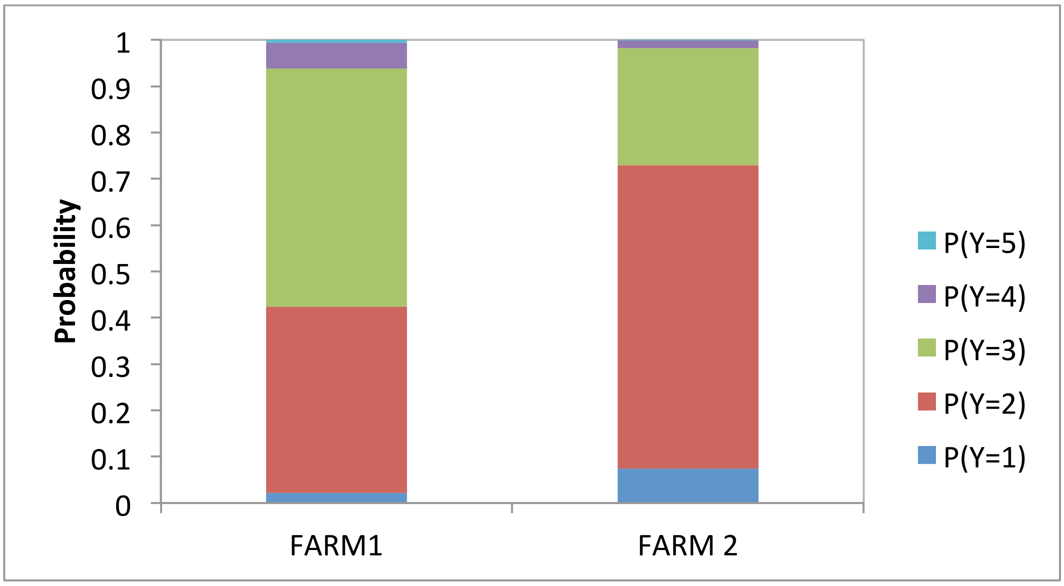

Figure 13. The probability of breech wrinkle (BRWR) scores (Y) at each farm. Farm 2 had significantly lower BRWR scores than Farm 1 (P < 0.001).

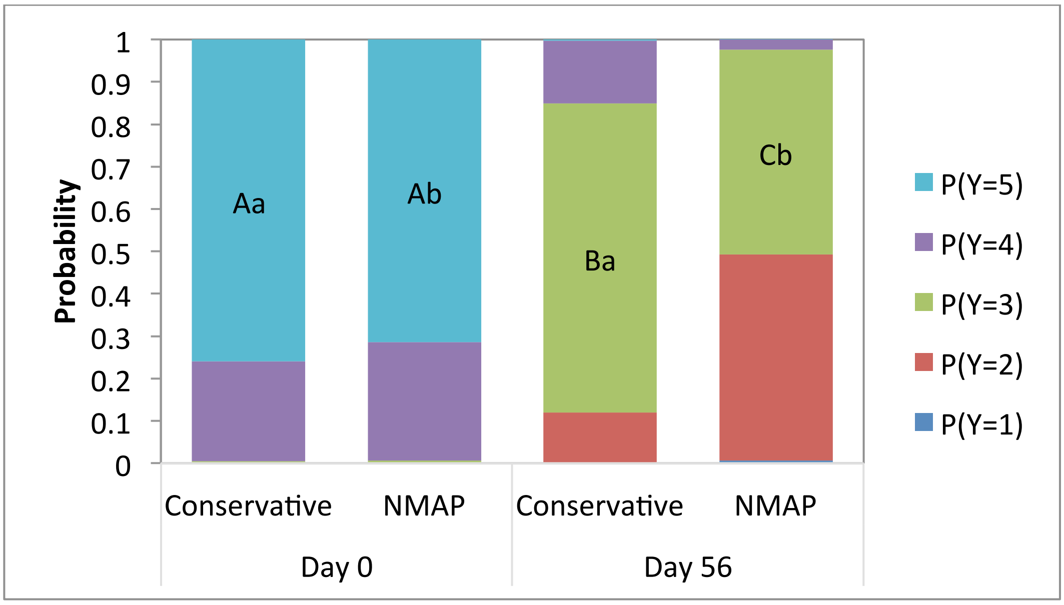

Figure 14. The probability of breech cover (BCOV) scores (Y) in each treatment over time. On Day 56 there was a significant effect of treatment on BCOV with the NMAP treatment having lower scores than the conservative treatment. Probabilities without common superscripts differ significantly (P < 0.001); lower case (a,b) indicate differences within a time point; capitals (A,B) indicate differences across time points.

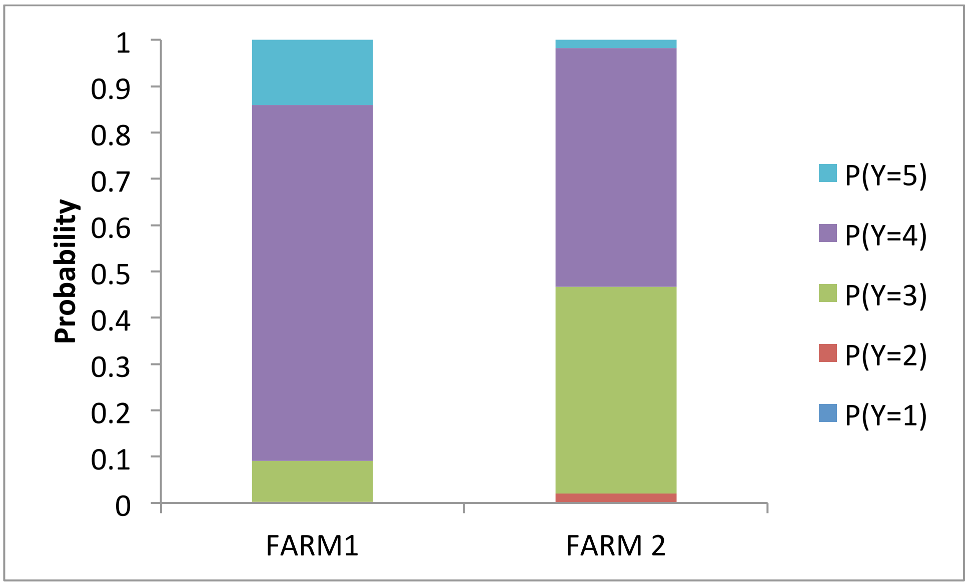

Figure 15. The probability of breech wrinkle (BRWR) scores (Y) at each farm. Farm 2 had significantly lower BRWR scores than Farm 1 ($P < 0.001$).

Appendix 2

Tables

Table 1. The effect of mulesing treament on breech wrinkle (BRWR) scores at Day 0 and Day 56.

		Day 0 Mean BRWR	Day 56 Mean BRWR	Change in BRWR
Conservative mules	Total	2.76	2.19	- 0.57
	Farm 1	2.88	2.52	- 0.36
	Farm 2	2.63	1.87	- 0.76
Standard 'V' modified mules (NMAP)	Total	2.86	1.94	- 0.92
	Farm 1	2.86	2.25	- 0.64
	Farm 2	2.82	1.62	- 1.20

Table 2. The effect of mulesing treatments on breech cover (BCOV) scores at Day 0 and Day 56.

		Day 0 Mean BCOV	Day 56 Mean BCOV	Change in BCOV
Conservative mules	Total	4.70	3.03	- 1.67
	Farm 1	4.98	3.24	- 1.74
	Farm 2	4.42	2.84	- 1.58
Standard 'V' modified mules (NMAP)	Total	4.66	2.55	- 2.11
	Farm 1	4.99	2.66	- 2.33
	Farm 2	4.31	2.43	- 1.88