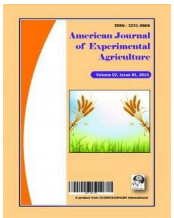

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Effects of Pasture vs. Drylot Flushing on Ewe Body Weight Change and Number of Lambs Born

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Authors' contributions

This work was carried out in collaboration between all authors. Authors PGH and DLR designed the experiment and performed statistical analysis. Authors DLR, EEN, WAW, TML, RBS, ESR, BSH and CGH performed the feeding trial, lab analysis, statistical analysis and wrote the manuscript. Author LBM performed statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

Flushing is the practice of increasing nutrient intake before and during breeding in order to increase ovulation and ultimately the number of lambs born (NLB). Although extensive research has investigated the impact of different feeds and feeding strategies on the flushing response, literature addressing the impacts of environment on flushing is limited. Generalized linear mixed models (GLMM) were used to evaluate the responses of ewes to flushing treatments. A two-year study using two breeds of white-faced ewes was conducted at Montana State University's Fort Ellis Experiment Station near Bozeman, MT. Two flushing trials were conducted to evaluate NLB per ewe, and BW (body weight) gain of ewes receiving 1 of 3 treatments: 1) control treatment; ad libitum access to pea-barley hay in drylot (CON), 2) ad libitum access to swathed pea-barley forage in paddocks (PAD), and 3) ad libitum access to swathed spring wheat straw in paddocks with 0.45 kg of supplement·ewe^{-1}·d^{-1} (WHT). Trial 1 (28 d) evaluated yearling Targhee ewes and Trial 2 (14 d) evaluated mature Rambouillet ewes. For Trials 1 and 2, ADG (average daily gain), BW gain, lambing date, and NLB did not differ among treatments (P > 0.10). However, BW gain of ewes in

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PAD treatments was more variable than ewes in CON and WHT treatments for both Trials. Similar responses by ewes to feeding treatments suggest swath grazing as a viable flushing strategy to reduce inputs while maintaining high productivity.

Keywords: Drylot; ewes; flushing; pasture; swath grazing.

1. INTRODUCTION

Reproductive performance is important in determining potential profitability in sheep production [1-3]. It is well known that good nutrition improves both reproductive performance and general health of sheep. However, the cost of feed can limit profitability despite the reproductive benefits of high forage diets. An efficient method to reduce the cost of feed and increase profits is to restrict the use of higher quality feeding regimes to times during a ewe's life cycle that will most influence reproductive performance. Flushing, the practice of increasing nutrient intake before and during breeding to increase ovulation and the number of lambs born, is commonly used to increase reproductive performance of ewes [4]. Flushing has been shown to increase ovulation rates [5], fecundity, and prolificacy [6] of ewes depending on diet [6-11], age, breed [12], live-weight [13], stage of breeding season [14], timing of flushing, and body condition (BC) [4,15-22].

Despite reported benefits of flushing on ewe productivity, little information exists on how feeding conditions and environment influence its efficacy. Flushing ewes with forage in a confinement system are time and labor intensive requiring the baling and hauling of hay. An alternative approach that may reduce feeding costs is flushing ewes on cut forage left in swaths in the field which eliminates costs associated with baling and moving forage. In a companion study that evaluated ewe intake, forage wastage, and nutrient composition of a pea/barley forage in a swath grazing verses baled feeding system, forage wastage did not differ between treatments [23]. Nevertheless, reproductive benefits accrued from flushing may be reduced if swath-grazing results in reduced gains in body weight and lower fecundity compared to confinement flushing. The objective of this study was to evaluate whether weight gain and reproductive performance of ewes was affected by flushing environment (i.e., confinement feeding vs. swath grazing).

2. MATERIALS AND METHODS

This study and all animal procedures were approved by the Montana State University Agricultural Animal Care and Use Committee (Protocol #2009-AA04). All animals were transported using generally accepted procedures [24]. This study was conducted at the Fort Ellis Agricultural Research and Teaching Farm, owned by Montana State University, near Bozeman, MT. All permissions for site access were granted and no permits were required. This study did not involve any endangered or protected species.

2.1 Sheep Selection and Management

A two-year study using two breeds of white-faced ewes was conducted. Most ewes begin their estrous cycle by early October in Montana [25]. Therefore ewes were moved into the experiment in mid to late September of both years. Prior to both trials ewes were grazing native range. In 2010 (hereafter Trial 1), 90 yearling Targhee ewes (average BW = 65.4±5.8 kg, non-pregnant, non-lactating, 18 mo of age) were randomly chosen from a group of approximately 1,400 yearling ewes. Ewes were transported approximately 90 miles from the Bair Ranch in Martinsdale, MT on September 25 (d 0) to Montana State University's Fort Ellis Experiment Station near Bozeman, MT. In 2011 (Trial 2), 60 mature Rambouillet ewes (BW = 61.9±6.3 kg BW, non-pregnant, non-lactating (3.3±0.48 yr of age) were selected at random from a group of approximately 125 ewes. Ewes were transported approximately 40 miles from the Red Bluff Research Ranch near Norris, MT on September 6, 2011 (d 0) to the Fort Ellis Experiment Station. Average September-October temperature was 12℃ and 16℃, and total September precipitation was 39 mm and 16 mm in 2010 and 2011, respectively. Ewes in both trials were fasted for 24 to 48 h before arrival to reduce effects of gut fill on initial body weight (BW). Ewes were paint-branded or ear-tagged for identification purposes and fasted weights were recorded. In both trials, 10 ewes were randomly assigned to one of 3 replicates of each feeding treatment. Ewes had ad libitum access to treatment forage, water, and a salt and mineral supplement. Mineral composition is shown in Table 3. All treatments were formulated to meet or exceed NRC [4] recommendations for mature ewes at flushing and gaining 0.10 kg/d. Composition and nutrient analysis of diets are shown in Tables 1 and 2, respectively.

2.2 Trial 1

Upon arrival at Fort Ellis on d 0, groups of 10 yearling ewes were randomly allocated to 1 of 3 treatments: 1) control treatment; ad libitum access to pea-barley hay in drylot (CON), 2) ad libitum access to swathed and standing pea-barley forage in paddocks (PAD), and 3) ad libitum access to swathed and standing spring wheat straw stubble in paddocks plus 0.45 kg of an 18.9% CP (crude protein) supplement$\cdot$ewe$^{-1}\cdot$d^{-1} (WHT; Table 1). Drylot pens measured 40 m × 12 m and swath grazing paddocks measured 91 m × 15 m for PAD and 91 m × 50 m for WHT. Intense grazing of spring wheat stubble by ewes caused forage to become scarce. Therefore ewes were supplemented with wheat straw in the WHT treatment on d 21 through 27. In an effort to match diet quality, supplemental alfalfa hay was added to both CON and PAD treatments on d 21 through 27 of the trial. Ewes in the WHT treatment received their daily ration of supplement in feed buckets; 5 feed tubs each measuring 46 cm diameter by 20 cm deep with evenly divided rations of supplement split between 10 ewes. The daily allocation of supplement was consumed by ewes in approximately 5 min. The trial ended on October 22, 2010 (d 27). Body weights were recorded on d 28 after a 16 h fast and ewes were returned to the Bair Ranch and were placed on alfalfa stubble until breeding (November 1, 2010). Lambing began April 2, 2011 and the number of lambs born (NLB) for each ewe was recorded at parturition.

2.3 Trial 2

On September 6, 2011 (d 0), 60 ewes (3.4±1.4 yr old) were randomly assigned to either CON or PAD (Table 1). The trial ended on September 19, 2011 (d 13) and ewes were weighed on d 14 after 24 h of fasting. Ewes were returned to the Red Bluff Research Ranch and placed on alfalfa stubble until breeding (November 10, 2011). Lambing began April 13, 2012 and the NLB for each ewe was recorded at parturition.

2.4 Forage Analysis

The nutritional composition and nutrient analysis of the treatment forages and supplement are presented in Tables 1 and 2, respectively. Hand-clipped samples of standing pea-barley forage and standing spring wheat straw stubble were collected from each paddock prior to sheep grazing. Samples were collected with ten 0.1-m^2 rings selected randomly throughout each paddock. Three 10-cm profile sections of the pea-barley swath were collected and three, 1-m sections of swath were weighed. Pea-barley hay samples were collected from bales using a bale corer. A Daisy II Incubator (ANKOM Technology Corp., Macedon, NY) was used to measure true IVDMD (In vitro dry matter digestibility; according to ANKOM procedures) of the forages and supplement using rumen fluid collected from two cannulated cows consuming pea-barley hay forage. Bags containing pea-barley hay, pea-barley swath, pea-barley regrowth, wheat forage, CP supplement (4 replications/feed type) and 2 blanks were assigned to one of 4 digestion jars; samples were analyzed within one run.

Table 1. Composition (% DM basis) of treatment forages and supplement

Ingredient	Treatment[a]		
	CON	**PAD**	**WHT**
Trial 1		**Diet DM, %**	
Hay	100.0	—	—
Standing forage	—	66.81	—
Swathed forage	—	33.19	—
Wheat straw	—	—	96.1
Supplement[b]	—	—	3.9
Trial 2			
Hay	100.0	—	—
Standing forage	—	38.15	—
Swathed forage	—	61.85	—

[a] CON = ad libitum access to pea-barley hay in drylot; PAD = ad libitum access to swathed and standing pea-barley forage in paddocks; WHT = ad libitum access to swathed and standing spring wheat straw stubble with 0.45 kg 18.9% CP supplement$\cdot$ewe$^{-1}\cdot$d^{-1}; [b] Crude protein, minimum 20.0%; crude fat, minimum 2.0%; crude fiber, maximum 12.0%, Ca, 1.5% to 2.0%; P, minimum 0.75%; salt, 1.5% to 2.0%; Se, minimum 1.5 ppm; Vitamin A, minimum 52,911 IU/kg; Vitamin D, minimum 5,291 IU/kg; Vitamin E, minimum 132 IU/kg

Table 2. Nutrient analysis of treatment forages and supplement

	Treatment[a]				
	CON	PAD		WHT	
		Standing	Swath	Wheat	Supplement[b]
Item					
Trial 1					
CP	11.7	8.3	12.4	4.7	18.9
ADF	21.7	25.8	30.0	58.2	14.9
NDF	43.2	48.8	54.5	74.6	29.3
DM digestibility	67.7	65.3	74.6	56.6	81.7
OM	92.1	91.7	84.5	91.1	87.0
Trial 2					
CP	6.6	5.0	5.3	--	--
ADF	28.7	39.9	34.4	--	--
NDF	50.6	60.0	60.6	--	--
DM digestibility	56.2	55.0	49.1	--	--
OM	91.7	82.4	92.0	--	--

[a] CON = ad libitum access to pea-barley hay in drylot; PAD = ad libitum access to swathed and standing pea-barley forage in paddocks; WHT = ad libitum access to swathed and standing spring wheat straw stubble with 0.45 kg 18.9% CP supplement·ewe^{-1}·d^{-1}.

[b] Crude protein, minimum 20.0%; crude fat, minimum 2.0%; crude fiber, maximum 12.0%, Ca, 1.5%to 2.0%; P, minimum 0.75%; salt, 1.5% to 2.0%; Se, minimum 1.5 ppm; Vitamin A, minimum 52,911 IU/kg; Vitamin D, minimum 5,291 IU/kg; Vitamin E, minimum 132 IU/kg

Table 3. Composition of mineral supplement (values provided by manufacturer)

Item	Amount
Calcium, min.	12.0%
Calcium, max.	14.0%
Phosphorus, min.	12.0%
Salt, min.	11.0%
Salt, max.	12.5%
Magnesium, min.	3.0%
Cobalt, min.	4 ppm
Copper, min.	7 ppm
Iodine, min.	100 ppm
Manganese, min.	1,800 ppm
Selenium, min.	19.0 ppm
Zinc, min.	2,000 ppm
Vit. A, min.	250, 000 IU/lb
Vit. D, min.	25,000 IU/lb
Vit. E, min.	500 IU/lb

Forage samples were analyzed for NDF (neutral detergent fiber) and ADF (acid detergent fiber) using the ANKOM^{200} Fiber Analyzer and Ankom methods (ANKOM Technology Corp., Macedon, NY; Table 1); Na sulfite and *alpha* amylase were used. All forage samples were analyzed for N content using a Leco FP-528 Nitrogen Analyzer (Leco Corp., St. Joseph, MI) and multiplied by 6.25 for adjustment to CP [26].

2.5 Statistical Analysis

Individual ewes grouped in each of 3 replicate pens per feeding treatment were not independent. Therefore, generalized linear mixed models (GLMM) were used to evaluate the responses of ewes to flushing treatments, and spatial psuedoreplication was accounted for by including pen as a random effect in all analyses [27,28]. ADG and final BW were analyzed with a normal linear mixed effects model, whereas NLB was sampled from a non-normal distribution (i.e., discrete count data) and thus analyzed with a Poisson mixed effects model [29]. Multiple model selection and inference based on minimization of Akaike's Information Criterion adjusted for small sample size (AIC_c) was used to evaluate competing hypotheses regarding the effects of feeding treatment (CON, PAD, and WHT) and a covariate of initial BW [30] (Appendix, Table 5). Models with ΔAIC_c values ≤ 2 were considered equally parsimonious and Akaike weights (w_i) were evaluated to assess relative support for candidate models, including a null model. All statistical analyses were performed in R statistical software (ver. 2.4; R Development Core Team 2011, Vienna, Austria), where GLMM models were fit with the lme4 package [31].

3. RESULTS AND DISCUSSION

3.1 ADG

The null model was the most parsimonious model (Appendix, Table 5) and effects of flushing treatment and initial BW on ADG were not supported in either Trial (Table 4). Overall, ADG did not differ between CON, WHT and PAD treatments regardless of trial (P > 0.10; Table 4), suggesting similar net nutritional benefits between swathed and bale-fed pea-barley hay treatments and wheat stubble with supplementation treatments. Our results appear to conflict with previous research reporting differences in body weight gains between ewes flushed on drylots and those supplemented on rangeland [7].

3.2 Final BW

Models with the effect of initial BW had virtually all the relative support of the data (Σwi > 0.99). Although models with treatment effects had $\Delta AIC_c \leq 2$ (Appendix, Table 5), measures of treatment effects overlapped 0, indicating differences in final BW among treatments were not significant ($P > 0.10$; Appendix, Table 5). Our results are consistent with Dahmen et al. [6] who reported that BW among four groups of mature ewes (flushed in drylot or pasture) were similar. Torell et al. [8] found that for every kg increase in ewe BW gain during flushing, lambing percent increased approximately 8%. In our study, final BW was driven by initial BW, not by feeding treatments, and as a result NLB did not differ among treatments. Our results agree with Hulet et al. [16] who suggested that relative BW gain is not the defining factor impacting ewe productivity and the efficacy of flushing. Tribe and Seebeck [32] also found little support that BW and gains during flushing were the determining factor influencing ewe productivity. Their results showed greater lamb production compared to non-flushed ewes despite the fact that both flushed and non-flushed ewes lost weight. Live-weights of the ewes at breeding, and, to a lesser extent, before flushing, are probably most influential to subsequent lambing performance [32-34].

3.3 NLB

The null model was the most parsimonious model and effects of feeding treatment on NLB were not supported for either Trial (Appendix, Table 5). Torell et al. [8] reported that supplementation of range ewes twice per week with 2.25 kg alfalfa pellets·ewe^{-1}·wk^{-1}, did not improve lambing performance compared to drylot feeding (1.82 kg alfalfa hay·ewe^{-1}·d^{-1}). In the second year of their study, the ewes fed alfalfa hay in drylot and ewes with access to improved pasture (mown prior to maturity and left in swath) for a 34-d flushing trial had a 29.1% and 28.4% increase in NLB respectively. The improvement in reproductive performance was due mainly to the increase in the incidence of multiple births when the ewes were fed in drylot or grazed on improved pasture; there was no significant effect due to a reduction in the number of dry ewes [8].

Table 4. Average initial and final BW, ADG, number of lambs born (NLB) and Julian lambing date to yearling ewes (Trial 1) and mature ewes (Trial 2) on 1 of 3 flushing treatments

	Treatment[a]			
Item	**CON**	**PAD**	**WHT**	**P-value[b]**
Trial 1				
Initial BW, kg	65.0 (1.1)	66.3 (1.6)	65.4 (1.6)	0.73
Final BW, kg	71.8 (1.1)	71.6 (1.6)	70.1 (1.6)	0.21
ADG, kg	0.25 (0.03)	0.22 (0.04)	0.17 (0.04)	0.14
NLB•ewe	1.45 (0.15)	1.53 (0.21)	1.64 (0.21)	0.35
Lambing date	101 (1.4)	103 (2.0)	104 (2.0)	0.16
Trial 2				
Initial BW, kg	60.8 (1.2)	63.2 (1.6)	--	0.21
Final BW, kg	62.5 (1.1)	64.7 (1.6)	--	0.95
ADG, kg	0.12 (0.03)	0.11 (0.04)	--	0.74
NLB•ewe	1.42 (0.16)	1.58 (0.23)	--	0.65
Lambing date	112 (1.2)	114 (1.6)	--	0.26

[a]CON = ad libitum access to pea-barley hay in drylot;
PAD = ad libitum access to swathed and standing pea-barley forage in paddocks;
WHT = ad libitum access to swathed and standing spring wheat straw stubble with 0.45 kg of an 18.9% CP supplement·ewe^{-1}·d^{-1}.
[b]P-values for treatment effects evaluated from linear mixed effects models where Pen was included as random effect

In contrast to Torell et al. [7-8], Dahmen et al. [6] reported that NLB per ewe bred under pasture management exceeded the drylot managed ewes and was related to increased ovulation rate. They compared confined ewes flushed for 14 d prior to breeding with 0.45 kg barley and 1.8 kg alfalfa hay·ewe^{-1}·d^{-1} to pasture ewes flushed on fresh lush pasture. Although Trials 1 and 2 differed in duration, NLB was similar for all treatments.

Flushing a few weeks immediately prior to breeding is an accepted practice among producers. However, Hulet et al. [16] reported that termination of flushing treatment prior to mating did not seem to lower the ovulation and/or embryo survival rates relative to the controls as measured by NLB. It appeared that a greater flushing effect was obtained in those ewes that were mated approximately 13 to 18 d following the termination of the feed treatment than those that presumably mated the first 6 d following the termination of the feed treatment [16]. While Hulet et al. [16] did not increase the gap between flushing and mating beyond 18 d, they did report a greater flushing effect with increased time between flushing and mating.

In the ewe, it takes approximately 6 mo from when follicles first commence growing to when one or more of these undergo final maturation and ovulate [14,35]. Nottle et al. [13] reported that imposing nutritional handicaps at different stages of folliculogenesis have been shown to influence ovulation rate in the ewe. Also, ovulation rate responses to increased allowance of pasture were not observed for at least 3 wk in a study conducted by Smith et al. [36]. Fletcher [5] showed that restricting feed intake 6 mo prior to ovulation when those follicles destined to ovulate first commence growing, reduced ovulation rate. In our study, ewes were mated approximately 8 d after flushing commenced in Trial 1 and 52 d after flushing commenced in Trial 2. Irrespective of the length of time between flushing and breeding, NLB was similar for all treatments. Coop [37] suggested that the flushing response was the resultant of a static effect due to increased live weight irrespective of how and when the ewe obtained that live weight and therefore not necessarily related in time sequence to mating.

4. CONCLUSION

Feeding treatments did not influence ADG, final BW, or NLB in our study, suggesting cost-saving benefits for sheep producers using swath grazing flushing practices. In non-extreme weather conditions, it may be more economical for livestock producers to flush ewes on pasture alone, or on a poor quality pasture with supplementation vs. confining ewes and providing full feed. As an alternative to flushing ewes immediately prior to breeding, it may be possible for producers to flush ewes on pasture earlier in the season, when forage nutrient quality is higher, and still experience a flushing effect. However, long-term studies are needed to assess the relationship between flushing and the length of time between nutritional influence and breeding.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Brash LD, Fogarty NM, Gilmour AR. Genetic parameters for Australian maternal and dual-purpose meat sheep breeds. II. Live weight, wool and reproduction in Corriedale sheep. Aust. J. Agric. Res. 1994;45:469−480.
2. Tosh JJ, Kemp RA. Estimation of variance components for lamb weights in three sheep populations. J. Anim. Sci. 1994;72: 1184–1190.
3. Matos CAP, Thomas DL, Gianola D, Tempelman RJ, Young LD. Genetic analysis of discrete reproductive traits in sheep using linear and nonlinear models. I. Estimation of genetic parameters. J. Anim. Sci. 1997;75:76–87.
4. NRC. Nutrient Requirements of Small Ruminants. Natl. Acad. Press, Washington, D. C; 2007.
5. Fletcher IC. An effect of previous nutritional treatment on the ovulation rate of Merino ewes. Proc. Aust. Soc. Anim. Prod. 1974;10:261-264.
6. Dahmen JJ, Hulet CV, Price DA, Everson DO. Effects of drylot and pasture management on ovulation rate and lamb

production in Panama ewes. J. Anim. Sci. 1976;42:427−433.
7. Torell DT, Hume ID, Weir WC. Biuret as a nitrogen supplement for flushing range ewes. J. Anim. Sci. 1972;35:606−610.
8. Torell DT, Hume ID, Weir WC. Flushing of range ewes by supplementation, drylot feeding, or grazing of improved pasture. J. Range Manage. 1972;25:357−360.
9. Dally MR, Milton BJ, Depeters EJ. Supplemented native range and sub-clover pastures improved lambing rates. Can. Agric. 1994;48:14−17.
10. Molle G, Landau S, Branca A, Sitzia M, Fois N, Liqios S, et al. Flushing with soybean meal can improve reproductive performances in lactating Sarda ewes on a mature pasture. J. Intern. Goat Assoc.-Small Rum. Res. 1997;24:157−165.
11. Ocak N, Cam MA, Kuran M. The influence of pre- and post-mating protein supplementation on reproductive performance in ewes maintained on rangeland. Small Rum. Res. 2006;64: 16−21.
12. Foote WC, Pope AL, Chapman AB, Casida LE. Reproduction in the yearling ewe as affected by breed and sequence of feeding levels. I. Effects on ovulation rate and embryo survival. J. Anim. Sci. 1959;18: 453−462.
13. Nottle MB, Kleemann DO, Seamark RF. Effect of previous undernutrition on the ovulation rate of Merino ewes supplemented with lupin grain. Anim. Reprod. Sci. 1997;49:29–36.
14. Cahill LP, Mauleon P. Influences of season, cycle and breed on follicular growth rates in sheep. J. Reprod. Fertil. 1980;58:321-328.
15. El-Sheikh AS, Hulet CV, Pope AL, Casida LE. Effect of level of feeding on the reproductive capacity of the ewe. J. Anim. Sci. 1955;14:919−929.
16. Hulet CV, Blackwell RL, Ercanbrack SK, Price DA, Humphrey RD. Effects of feed and length of flushing period on lamb production in range ewes. J. Anim. Sci. 1962;21:505−510.
17. Laster DB, Glimp HA, Dickerson GE. Factors affecting reproduction in ewe lambs. J. Anim. Sci. 1972;35:79.
18. Bush LF, Lind RA. Performance of ewes and lambs in confinement. J. Anim. Sci. 1973;36:407.
19. Meyer HH, Bradford GE. Reproduction in Targhee and finnish landrace × Targhee ewes. J. Anim. Sci. 1973;36:847−853.
20. Stewart R, Oldham C. Feeding lupins to ewes for four days during the luteal phase can increase ovulation rate. Proc. Aust. Soc. of Anim. Prod. 1986;16:367–370.
21. Molle G, Branca A, Ligios S, Sitzia M, Casu S, Landau S, et al. Effect of grazing background and flushing supplementation on reproductive performance in Sarda ewes. Small Rum. Res. 1995;17:245−254.
22. Viñoles C, Paganoni B, Glover KM, Milton JT, Blache D, Blackberry MA, et al. The use of a 'first-wave' model to study the effect of nutrition on ovarian follicular dynamics and ovulation rate in the sheep. Reproduction. 2010;140:865–874.
23. Nix EE, Ragen DL, Bowman JGP, Kott RW, Hatfield PG. Effect of swath grazing on forage intake and wastage by ewes. Proc. West. Sec. Amer. Soc. Anim. Sci. 2012;63:58-61.
24. Fisher AD, Niemeyer DO, Lea JM, Lee C, Paull DR, Reed MT, et al. The effects of 12, 30, or 48 hours of road transport on the physiological and behavioral responses of sheep. J. Anim. Sci. 2010;88:2144-2152.
25. Kott R. Reproduction - MT Sheep Production Handbook. Extension Service — Animal & Range Sciences; 2005.
Available:http://animalrangeextension.montana.edu/sheep/reproduction.html (Accessed 2 November 2015)
26. AOAC. Official methods of analysis (17th Ed.). Assoc. Off. Anal. Chem. Gaithersburg, MD; 2000.
27. Millar RB, Anderson MJ. Remedies for pseudoreplication. Fisheries Research. 2011;70:397–407.
28. Crawley M. The R Book, second edition. John Wiley & Sons, Ltd. Chichester, UK; 2012.
29. McCullagh P, Nelder JA. Generalized linear models, 2nd Edition. Chapman and Hall, London, UK; 1989.
30. Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information theoretic approach. Second edition. Springer-Verlag, New York; 2002.
31. Bates D, Maechler M, Bolker B. lme4: linear mixed-effects models using S4 classes. R package version 0.999999-0; 2012.

Available:http://CRAN.R-project.org/package=lme4

32. Tribe DE, Seebeck RM. Effect of live-weight and live-weight change on the lambing performance of ewes. J. Agric. Sci. 1962;59:105−110.
33. Wallace LR. Proc. Ruakura Fmrs' Conf. Week. 1961;14.
34. Coop IE. Effect of flushing on reproductive performance of ewes. J. agric. Sci. 1966;67:305-323.
35. Driancourt MA, Cahill LP. Preovulatory follicular events in sheep. J. Reprod. Fertil. 1984;71:205-211.
36. Smith J, Jagusch K, Farquhar P. The effect of the duration and timing of flushing on the ovulation rate of ewes. Proc. N.Z. Soc. Anim. Prod. 1983;43:13–16.
37. Coop IE. Liveweight-productivity relationships in sheep. 1. Live weight and reproduction. N. Z. J. Agr. Res. 1962;5: 249-264.

APPENDIX

Table 5. Model selection results for average daily gain (ADG), final body weight (BW), number of lambs born (NLB), and Julian lambing date for ewes at Fort Ellis research Station, Montana, During 2010 (Trial 1) AND 2011 (Trial 2). All GLMM models included a random effect of pen. Models ranked by the difference (∆AICC) between it and the model with the lowest AIC_C value

Model factors	K[a]	AIC_c	ΔAIC_c	w_i[b]	-2 logL
ADG					
Trial 1					
Null model	3	-116.3	0.0	0.97	-122.6
Initial BW	4	-108.7	7.6	0.02	-117.2
Treatment	5	-106.4	9.9	0.01	-117.2
Treatment + initial BW	6	-98.8	17.4	0.00	-111.8
Treatment × initial BW	8	-84.8	31.5	0.00	-102.6
Trial 2					
Null model	3	-54.3	0.0	0.92	-60.8
Initial BW	4	-48.5	5.8	0.05	-57.2
Treatment	4	-47.4	6.9	0.03	-56.2
Treatment + initial BW	5	-41.4	12.9	0.00	-52.6
Treatment × initial BW	6	-34.5	19.8	0.00	-48.0
Final BW					
Trial 1					
Treatment + initial BW	6	461.6	0.0	0.60	448.6
Treatment × initial BW	8	462.6	0.1	0.30	444.8
Initial BW	4	464.8	3.2	0.10	456.2
Treatment	5	585.0	123.5	0.00	574.4
Null model	3	587.2	125.6	0.00	580.8
Trial 2					
Initial BW	4	257.6	0.0	0.63	249.0
Treatment + initial BW	5	259.5	1.8	0.26	248.4
Treatment × initial BW	6	261.1	3.5	0.11	247.6
Treatment	4	390.4	132.7	0.00	381.6
Null model	3	392.7	135.0	0.00	386.2
NLB					
Trial 1					
Null model	2	227.0	0.0	0.60	222.8
Initial BW	3	229.0	1.9	0.20	223.8
Treatment	4	230.4	3.5	0.10	222.0
Treatment + initial BW	5	232.4	5.5	0.00	222.0
Treatment × initial BW	7	236.8	9.8	0.00	222.0
Trial 2					
Null model	1	130.9	0.0	0.49	128.8
Initial BW	2	132.4	1.6	0.23	128.2
Treatment	2	132.8	1.0	0.18	128.6
Treatment + initial BW	3	134.6	3.7	0.08	128.0
Treatment × initial BW	4	136.8	5.9	0.03	128.0

Lambing date					
Trial 1					
Null model	8	534.5	0.0	0.71	516.5
Initial BW	5	537.8	3.5	0.14	526.9
Treatment	6	538.1	3.6	0.12	524.9
Treatment + initial BW	3	542.0	7.5	0.02	535.7
Treatment × initial BW	4	542.2	7.7	0.02	533.6
Trial 2					
Null model	1	334.15	0.0	0.34	320.3
Initial BW	2	334.41	0.3	0.3	325.6
Treatment	2	335.42	1.3	0.18	324.1
Treatment + initial BW	3	336.56	2.4	0.1	330.1
Treatment × initial BW	4	337.41	3.3	0.07	328.6

a K = number of model parameters; b wi = Akaike weights measure relative support for each model

Peer-review history:
The peer review history for this paper can be accessed here:
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