Animal Feed Science and Technology 200 (2015) 107–111

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

ELSEVIER

Short communication

Individual mineral supplement intake by ewes swath grazing or confinement fed pea-barley forage

Devon L. Ragen[a], Erin E. Nix[a], Rachel L. Endecott[a], Patrick G. Hatfield[a], Mark K. Petersen[b], Janice G.P. Bowman[a,*]

[a] Department of Animal and Range Sciences, Montana State University, Bozeman, MT 59718, United States
[b] USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT 59301, United States

ARTICLE INFO

Article history:
Received 8 May 2014
Received in revised form 2 December 2014
Accepted 5 December 2014

Keywords:
Sheep
Mineral supplement
Swath grazing
Hay
Individual intake

ABSTRACT

Previous research has reported high variation in intake of self-fed protein and/or energy supplements by individual animals, however little is known about variation in consumption of mineral supplements. Sixty mature range ewes (non-pregnant, non-lactating) were used in a completely randomized design repeated 2 years to determine if feeding method of intercropped field pea (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L.) forage (swath grazed or fed as hay in confinement) affected individual ewe mineral consumption. Thirty ewes were allocated to 3 confinement pens (10 ewes/pen) and 30 ewes were allocated to 3 grazing plots (10 ewes/plot). Ewes had ad libitum access to feed, water, and a mineral supplement containing 1% titanium dioxide as an external marker. Forage dry matter intake (DMI) was calculated using estimates of fecal output, and in vitro 48-h forage DM digestibility. Ewe supplement intake was determined from fecal and supplement Ti concentrations, and fecal output. Forage and mineral intakes were analyzed using ewe as the experimental unit, and plot or pen as the experimental unit for intake variation. A year × treatment interaction ($P<0.01$) existed for DM forage and mineral intake. Ewes in confinement consumed more forage DM than grazing ewes in 2010, but less than grazing ewes in 2011. Mean mineral intake was highest ($P<0.01$) by grazing ewes in 2011 and 2010 (average 69 g/day), intermediate by confinement ewes in 2010 (57 g/day), and lowest by confinement ewes in 2011 (31 g/day). A year × treatment interaction ($P=0.05$) existed for mineral intake CV which was higher ($P=0.04$) for confinement ewes in 2011 (67 *vs.* 34%), but was not different ($P>0.05$) between treatments in 2010. In this study, variation in individual ewe intake of mineral supplement was large in both grazing ewes and ewes fed hay in confinement.

Published by Elsevier B.V.

1. Introduction

A major limitation to providing appropriate mineral nutrients to sheep is a lack of understanding factors affecting individual animal supplement consumption. Bowman and Sowell (1997) reported that some animals refuse supplements altogether,

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; BW, body weight; CP, crude protein; CV, coefficient of variation; DM, dry matter; DMI, dry matter intake; DMD, dry matter digestibility; FO, daily fecal output; NDF, neutral detergent fiber.

* Corresponding author. Tel.: +1 406 994 5563; fax: +1 406 994 5589.
E-mail address: jbowman@montana.edu (J.G.P. Bowman).

http://dx.doi.org/10.1016/j.anifeedsci.2014.12.003
0377-8401/Published by Elsevier B.V.

while others consume excessive amounts. Deviation from the targeted supplement intake can negatively impact animal production. Interpretation of data from grazing trials with supplementary feeding is difficult due to the lack of information concerning the quantity of supplement consumed by each animal in a group-feeding situation (Nolan et al., 1975). Researchers have looked at individual intake of protein and energy supplements (Curtis et al., 1994), but few studies have evaluated variation in individual consumption of mineral. Lobato and Pearce (1980) reported that confinement of sheep that had not licked molasses-urea blocks under grazing conditions increased the proportion of animals licking the blocks. In a study with cows, Stiles et al. (1967) obtained higher consumption of molasses-salt blocks when the animals were confined compared with free grazing. The objective of this study was to determine if feeding method of pea–barley forage (swath grazing or hay fed in confinement) affected individual ewe mineral consumption.

2. Materials and methods

2.1. Experimental design

All animal procedures were approved by the Montana State University Agricultural Animal Care and Use Committee (Protocol #2009-AA04). The study was conducted at the Montana State University's Fort Ellis Research Station in Bozeman, MT during fall 2010 and fall 2011. The experiment was a completely randomized design testing the effects of treatment (swath grazing pea-barley forage *vs.* pea–barley hay fed in confinement), year (2010 *vs.* 2011), and the treatment × year interaction.

2.2. Experimental protocol

Sixty mature western whiteface range ewes were selected from the Bair Ranch in Martinsdale, MT to be used in 2010. The ewes (65.4 ± 5.84 kg body weight; BW) were non-pregnant, and non-lactating. For the second year, 60 mature western whiteface range ewes (61.9 ± 6.28 kg BW, non-pregnant, non-lactating) were selected from the Red Bluff Research Ranch near Norris, MT. Previously, ewes from the Bair Ranch only had access to a mineral supplement 2 weeks prior to breeding and during the lambing season. Ewes from Red Bluff Research Ranch had ad libitum access to a salt/mineral mixture prior to the study.

The same feeding and sampling protocol was used in 2010 and 2011. Each year upon arrival, 30 ewes were assigned to the swath grazing treatment and 30 ewes were assigned to the confinement feeding treatment. The swath grazing treatment consisted of 3 pastures (10 ewes/pasture) where pea–barley forage had been mechanically swathed and left in the field. Each pasture was 91 m × 15 m, and was divided into 2 equal sections each measuring 0.07 ha. The confinement feeding treatment consisted of 3 pens (10 ewes/pen) where pea-barley hay (harvested from the same field where the swath grazing pastures were located) was fed. Each pen measured 465 m^2. The experiment consisted of 7 days for diet adaptation, followed by 7 days of data collection. Ewes were restricted to grazing one half of the swathed pastures during the adaptation period, and the other half was grazed during the collection period. Ewes in the confinement feeding treatment were fed their respective hay during both the adaptation and collection periods.

Throughout the experiment, ewes had ad libitum access to forage, water, and a commercial mineral supplement (Payback – Sheep Range Mineral 16-8, Cenex Harvest States, Inc., Great Falls, MT; Content: min. 120 g/kg Ca from $CaCO_3$, max. 140 g/kg Ca, 120 g/kg P from $CaHPO_4$, min 110 g/kg salt, max. 125 g/kg salt, 30 g/kg Mg from MgO, 4 mg/kg Co from $CoCO_3$, 7 mg/kg Cu from $CuSO_4$, 100 mg/kg I from $C_2H_{10}I_2N_2$, 1.8 g/kg Mn from $MnSO_4$, 19 mg/kg Se from Na_2SeO_3, 2.0 g/kg Zn from $ZnSO_4$, 550,000 IU/kg vit. A, 55,000 IU/kg vit. D, 1100 IU/kg vit.E, remainder of supplement consisted of distillers dried grains with solubles, molasses products, and soybean oil) with 10 g/kg TiO_2 mechanically mixed into the supplement as an external marker to estimate supplement intake. A Hobart mixer was used to combine 22,473 g of commercial mineral with 227 g TiO_2. A new batch of mineral and TiO_2 was mixed and used the second year.

One mineral feeder was placed in each confinement pen and grazing pasture. Only 1 ewe could consume mineral at a time. Mineral feeders were checked daily and kept full of mineral. Throughout the entire experiment, ewes on both treatments were moved into handling facilities daily and dosed with gelatin capsules filled with 2 g Cr_2O_3 as an external marker to estimate fecal output (FO). Following the adaptation period, swath grazing ewes were moved into the remaining 0.07 ha of their pasture with fresh forage for data collection. Mineral feeders were also moved and placed in the middle of the grazing area. During the data collection, all ewes were gathered daily, and fecal grab samples were collected via rectum. Just prior to the collection period, hay and swath forage samples were taken for forage composition analysis (Table 1). Hay forage samples were taken by core sampling random bales, and compositing the cores. Swath forage samples were collected by randomly taking three 10-cm profile sections of an un-grazed swath per pasture, and compositing.

Forage samples were dried at 60 °C and ground in a Wiley mill through a 1-mm screen. Forage samples were analyzed for DM (930.15) and OM (9442.05) via AOAC (2000); NDF (inclusive of residual ash without amylase; Mertens, 2002) and ADF (973.18 via AOAC (2000), ANKOM[200] Fiber Analyzer, ANKOM Technology Corp., Macedon, NY; and crude protein using Leco, total combustion method, 968.06 (AOAC, 2000). Individual fecal samples were composited by ewe within year, dried at 60 °C, ground through a 1-mm screen in a Wiley mill, and analyzed for DM (930.15; AOAC, 2000); Ti (Myers et al., 2004); and Cr by atomic absorption spectrometry (Ellis et al., 1982). Forage in vitro digestibility (Table 1) was measured each year on the composited sample of hay and swathed forage used for composition analysis. Triplicate samples of each forage were used in

Table 1
Composition of pea-barley forage consumed by ewes fed hay in confinement or swath grazing.

Composition	2010		2011	
	Hay	Swaths	Hay	Swaths
DM, g/kg	932	936	934	913
OM, g/kg[a]	927	919	921	921
CP, g/kg[a]	105	113	71	73
NDF, g/kg[a]	508	550	487	506
ADF, g/kg[a]	287	295	266	271
In vitro DMD, g/kg	574	341	482	373

[a] Expressed on a DM basis.

a modified Tilley and Terry (1963) method. Ruminal fluid was collected from 2 ruminally cannulated cows, combined, and strained through 16 layers of cheese cloth. A pre-heated buffer solution (20 mL) was added to the samples and incubated at 39 °C for 20 min before ruminal fluid was added, and the incubation was carried out for 48 h.

Fecal output (FO) was estimated for each ewe using the following equation:

$$\mathrm{FO(g\ \ DM/day)} = \frac{\mathrm{Cr\ \ daily\ \ dose(g/day)}}{\mathrm{fecal\ \ Cr\ \ concentration\ \ (g/g\ \ DM)}}$$

Forage DM intake (DMI) was estimated for each ewe using the following equation:Forage DMI $(\mathrm{kg/day}) = \frac{\mathrm{FO\ \ (kg\ \ DM/day)}}{\mathrm{forage\ \ indigestebility}}$

Individual ewe mineral supplement intake was estimated using the following equation:Supplement DMI $(\mathrm{g/day}) = \frac{\mathrm{fecal\ \ Ti(g/g\ \ DM)} \times \mathrm{FO(g\ \ DM/day)}}{\mathrm{supplement\ \ Ti\ \ concentration(g/g\ \ DM)}}$

Distribution of supplement intake was evaluated by grouping ewes into four mineral supplement intake categories: none (≤10 g/day), low (11–28 g/day), average (29–84 g/day) and high consumers (≥85 g/day).

2.3. Statistical analysis

Data were analyzed using the GLM procedure of SAS (9.1 version, 2003) for a completely randomized design with least square means and P-values reported. Ewe was the experimental unit for mineral supplement, and forage intake. Pasture or pen (a group of 10 ewes) within year was the experimental unit for the coefficient of variation (CV) of supplement intake, and supplement intake distribution. The model included effects due to year, treatment, and year × treatment. Means were separated using the LSD procedure when a significant *F* value was found (P≤0.05).

3. Results

No year by treatment interactions (P≥0.44; Table 2) or treatment effects (P≥0.07) were detected for ewe initial weight or average daily gain (ADG). However, ewes in 2010 had greater initial weights (P=0.02), and ADG (P<0.01) than ewes in 2011.

Year by treatment interactions were seen for forage DMI (P<0.01), expressed both as kg/day and as kg/100 kg BW (Table 2). Ewes swath grazing in 2010 and ewes consuming hay in 2011, ate similar amounts of forage, but consumed less forage than ewes in confinement in 2010, and ewes swath grazing in 2011. A year by treatment interaction was detected for mineral supplement intake by individual ewes (P<0.01; Table 2). Ewes in confinement in 2011 consumed the least amount of mineral supplement. Ewes grazing in 2010 consumed a similar and intermediate amount of supplement to those in confinement in 2010, and to those grazing in 2011.

No year by treatment interaction (P≥0.07) was detected for minimum or maximum mineral supplement intake (Table 2). However, ewes in confinement had a lower (P=0.05) minimum supplement intake (average 10 g/d) compared with ewes grazing (average 33 g/d). Maximum supplement intake did not differ due to year or treatment (P≥0.21) and averaged 110 g/d. Mineral supplement intake CV demonstrated a year by treatment interaction (P=0.05). In 2010, ewes in confinement and grazing had similar supplement intake CV (55.4 *vs.* 46.5%, respectively). In 2011, ewes in confinement had a greater supplement intake CV compared with ewes grazing (67.2 *vs.* 33.7%, respectively).

The proportion of ewes consuming ≤10 g/day of mineral was not affected by year, treatment, or the interaction (P≥0.08; Table 2), and averaged 0.03. A year by treatment interaction (P=0.01) was seen for the proportion of ewes consuming low levels of supplement. Ewes in confinement in 2011 demonstrated the largest proportion consuming low levels of supplement (average 0.50). Ewes in confinement in 2010, and those grazing in 2010 and 2011 resulted in a smaller proportion consuming low levels of supplement (average 0.07). The proportion of ewes consuming an average amount of supplement was greater (P=0.04) for grazing ewes compared with ewes in confinement (0.71 *vs.* 0.50, respectively). In addition, the proportion of ewes consuming a high level of supplement was greater (P=0.04) for ewes swath grazing than for those in confinement (0.26 *vs.* 0.12, respectively).

Table 2
Individual performance, forage DMI, mineral supplement DMI, and mineral supplement DMI distribution by ewes consuming pea-barley forage in confinement or swath grazing.

Item	Treatment				SEM	P value[2]		
	2010		2011			Year	Trt	Year × Trt
	Confinement	Grazing	Confinement	Grazing				
Initial weight, kg[1]	64.7	66.2	60.8	63.2	1.09	0.02	0.07	0.66
ADG, kg[1]	0.24	0.21	0.12	0.11	0.023	<0.01	0.26	0.70
Forage DMI, kg[1]	2.6[b]	1.9[a]	2.0[a]	2.5[b]	0.14	0.96	0.40	<0.01
Forage DMI, kg/100 kg BW[1]	3.9[b]	2.7[a]	3.3[a]	3.9[b]	0.23	0.21	0.30	<0.01
Mineral supplement DMI, g/d[1]	57[b]	64[bc]	31[a]	73[c]	5.2	0.10	<0.01	<0.01
Supplement DMI, g[3]								
Minimum[3]	10	25	10	41	4.0	0.08	0.05	0.07
Maximum[3]	118	118	83	122	14.4	0.31	0.21	0.22
Supplement DMI CV, %[3]	55.4[bc]	46.5[ab]	67.2[c]	33.7[a]	5.33	0.92	0.04	0.05
Supplement DMI, proportion of ewes[3]								
None, ≤10 g[3]	0.03	0	0.10	0	0.019	0.35	0.08	0.34
Low, 11–28 g[3]	0.14[a]	0.07[a]	0.50[b]	0[a]	0.065	0.07	<0.01	0.01
Average, 29–84 g[3]	0.66	0.69	0.33	0.72	0.059	0.14	0.04	0.07
High, ≥85 g[3]	0.17	0.24	0.06	0.28	0.035	0.59	0.04	0.27

[1] Experimental unit was individual ewe; number of ewes per treatment was 28 in 2010; in 2011 it was 29 in confinement, and 28 in grazing.
[2] P value for the ANOVA *F* test of year, treatment, and the interaction.
[3] Experimental unit was confinement pen or grazing pasture; *N* equals 3 per treatment per year.
Means within a row with different superscripts (a, b, c) differ (P<0.05).

4. Discussion

Both the hay and swath CP content was higher in 2010 than in 2011, which would have resulted in a greater CP intake by ewes in 2010. Based on estimated DMI values, all ewes met or exceeded their CP requirements (NRC, 2007), however, 7 g of CP/kg DM might not allow optimal rumen microbial function. In addition, the in vitro DMD for hay in 2010 was approximately 10 g/kg higher than for hay in 2011, which could have provided a higher energy level to ewes in 2010, and resulted in the observed greater ADG by ewes during that year.

During 2010, the forage in swaths had a higher NDF content, and a lower DMD than did the hay, which could have resulted in reduced intake of swaths by ewes. However, in 2011 the NDF content of swaths and hay did not differ substantially. Maintenance energy requirements for grazing sheep have been estimated to be 60–70% higher than for confinement-fed sheep (Young and Corbett, 1972), which could have influenced forage intake.

Intake of mineral supplement was similar for grazing and confinement-fed ewes during the first year, but higher for grazing ewes the second year (Table 2). The effects of forage stage of maturity (Vona et al., 1984), forage cutting, and forage species combination (Reid et al., 1987) on mineral utilization (apparent absorption, retention) in crossbred wether lambs and mature wethers has been documented.

Doreau et al. (2004) suggested that salt block intake was higher when cows were fed at low intake, probably due to boredom. However, in our study, ewes had ad libitum access to forage, and a greater proportion of grazing ewes consumed an average and a high level of supplement compared to ewes in confinement. Ducker et al. (1981) found that as the grazing area per ewe increased so did the proportion of ewes not consuming feed-block. Therefore, increased consumption of mineral by grazing ewes could be due to the small area of the grazing plots. During the data collection period, ewes swath-grazing on 0.07 ha may have traveled past the mineral feeders more often while grazing, therefore consuming more mineral than ewes in confinement. Confinement pens measured 0.05 ha, but hay was fed in the same designated areas every day reducing the amount of travel past mineral feeders by ewes.

The previous experience with supplements, social interactions, and forage quality and availability have been shown to influence the amount of supplement consumed by individual animals (Bowman and Sowell, 1997) and may have affected the distribution of mineral supplement intake in our study. The variation in mineral supplement intake seen in this study was similar to the variation in individual animal intake of protein and energy supplements reported by Bowman and Sowell (1997).

In conclusion, mineral intake was highest (P<0.01) by grazing ewes in 2011 and 2010, intermediate by ewes in confinement in 2010, and lowest by ewes in confinement in 2011. This study found a large variation in mineral supplement intake by individual ewes (CV of 34–67%), and indicated there may be up to 0.10 of ewes in a flock which consume only trace amounts. A better understanding of the factors that regulate mineral supplement intake could possibly improve the effectiveness of mineral supplement programs.

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

This work was supported in part by the Bair Ranch Foundation, Billings, MT.

References

AOAC, Official methods of analysis, 17th ed., *J. AOAC Int., Arlington, VA*, ISSN:1060-3271, 2000.
Bowman, J.G.P., Sowell, B.F., 1997. Delivery method and supplement consumption by grazing ruminants: a review. J. Anim. Sci. 75, 543–550.
Curtis, K.M.S., Holst, P.J., Murray, P.J., 1994. Measuring supplement intake in the field using Ytterbium. Aust. J. Exp. Agric. 34, 339–343.
Doreau, M., Michalet-Doreau, B., Bechet, G., 2004. Effect of underfeeding on digestion in cows. Interaction with rumen degradable N supply. Livest. Prod. Sci. 88, 33–41.
Ducker, M.J., Kendall, P.T., Hemingway, R.G., McClelland, T.H., 1981. An evaluation of feedblocks as a means of providing supplementary nutrients to ewes grazing upland/hill pastures. Anim. Prod. 33, 51–57.
Ellis, W.C., Lascano, C., Teeter, R., Owens, F.N., 1982. Solute and particulate flow markers. In: Owens, F.N. (Ed.), Protein Requirements for Cattle: Symposium. OK St. Univ. MP-109, pp. 37–56.
Lobato, J.F.P., Pearce, G.R., 1980. Responses to molasses-urea blocks of grazing sheep and sheep in yards. Aust. J. Exp. Agric. Anim. Husb. 20, 417–421.
Mertens, D.R., 2002. Gravimetric determination of amylase-treated neutral detergent fibre in feeds with refluxing beakers or crucibles: collaborative study. J. Assoc. Off. Assoc. Chem. Int. 85, 1217–1240.
Myers, W.D., Ludden, P.A., Nayigihugu, V., Hess, B.W., 2004. Technical note: a procedure for the preparation and quantitative analysis of samples for titanium dioxide. J. Anim. Sci. 82, 179–183.
Nolan, J.V., Norton, B.W., Murray, R.M., Ball, F.M., Roseby, F.B., Rohan-Jones, W., Hill, M.K., Leng, R.A., 1975. Body weight and wool production in grazing sheep given access to a supplement of urea and molasses: intake of supplement/response relationships. J. Agric. Sci. 84, 39–48.
NRC, 2007. Nutrient Requirements of Small Ruminants. National Academy Press, Washington, DC.
Reid, R.L., Templeton, W.C.J., Ranney, T.S., Thayne, W.V., 1987. Digestibility, intake and mineral utilization of combinations of grasses and legumes by lambs. J. Anim. Sci. 64, 1725–1734.
SAS Inc., 2003. SAS® User's Guide: Statistics, Version 9.1 ed. SAS Inc., Cary, NC.
Stiles, D.A., Bartley, E.E., Erhart, A.B., Meyer, R.M., Boren, F.W., 1967. Bloat in cattle. 13. Efficacy of molasses-salt blocks containing poloxalene in control of alfalfa bloat. J. Dairy Sci. 50, 1437–1443.
Tilley, J.M.A., Terry, R.A., 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassland Soc. 18, 104–111.
Vona, L.C., Jung, G.A., Reid, R.L., Sharp, W.C., 1984. Nutritive value of warm-season grass hays for beef cattle and sheep; digestibility, intake and mineral utilization. J. Anim. Sci. 59, 1582–1593.
Young, B.A., Corbett, J.L., 1972. Maintenance energy requirements of grazing sheep in relation to herbage availability. Aust. J. Agric. Res. 23, 57–76.

Animal Feed Science and Technology 200 (2015) 107–111

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Short communication

Individual mineral supplement intake by ewes swath grazing or confinement fed pea-barley forage

Devon L. Ragen[a], Erin E. Nix[a], Rachel L. Endecott[a], Patrick G. Hatfield[a], Mark K. Petersen[b], Janice G.P. Bowman[a,*]

[a] Department of Animal and Range Sciences, Montana State University, Bozeman, MT 59718, United States
[b] USDA-ARS Fort Keogh Livestock and Range Research Laboratory, Miles City, MT 59301, United States

ARTICLE INFO

Article history:
Received 8 May 2014
Received in revised form 2 December 2014
Accepted 5 December 2014

Keywords:
Sheep
Mineral supplement
Swath grazing
Hay
Individual intake

ABSTRACT

Previous research has reported high variation in intake of self-fed protein and/or energy supplements by individual animals, however little is known about variation in consumption of mineral supplements. Sixty mature range ewes (non-pregnant, non-lactating) were used in a completely randomized design repeated 2 years to determine if feeding method of intercropped field pea (*Pisum sativum* L.) and spring barley (*Hordeum vulgare* L.) forage (swath grazed or fed as hay in confinement) affected individual ewe mineral consumption. Thirty ewes were allocated to 3 confinement pens (10 ewes/pen) and 30 ewes were allocated to 3 grazing plots (10 ewes/plot). Ewes had ad libitum access to feed, water, and a mineral supplement containing 1% titanium dioxide as an external marker. Forage dry matter intake (DMI) was calculated using estimates of fecal output, and in vitro 48-h forage DM digestibility. Ewe supplement intake was determined from fecal and supplement Ti concentrations, and fecal output. Forage and mineral intakes were analyzed using ewe as the experimental unit, and plot or pen as the experimental unit for intake variation. A year × treatment interaction ($P<0.01$) existed for DM forage and mineral intake. Ewes in confinement consumed more forage DM than grazing ewes in 2010, but less than grazing ewes in 2011. Mean mineral intake was highest ($P<0.01$) by grazing ewes in 2011 and 2010 (average 69 g/day), intermediate by confinement ewes in 2010 (57 g/day), and lowest by confinement ewes in 2011 (31 g/day). A year × treatment interaction ($P=0.05$) existed for mineral intake CV which was higher ($P=0.04$) for confinement ewes in 2011 (67 *vs.* 34%), but was not different ($P>0.05$) between treatments in 2010. In this study, variation in individual ewe intake of mineral supplement was large in both grazing ewes and ewes fed hay in confinement.

Published by Elsevier B.V.

1. Introduction

A major limitation to providing appropriate mineral nutrients to sheep is a lack of understanding factors affecting individual animal supplement consumption. Bowman and Sowell (1997) reported that some animals refuse supplements altogether,

Abbreviations: ADF, acid detergent fiber; ADG, average daily gain; BW, body weight; CP, crude protein; CV, coefficient of variation; DM, dry matter; DMI, dry matter intake; DMD, dry matter digestibility; FO, daily fecal output; NDF, neutral detergent fiber.

* Corresponding author. Tel.: +1 406 994 5563; fax: +1 406 994 5589.
E-mail address: jbowman@montana.edu (J.G.P. Bowman).

http://dx.doi.org/10.1016/j.anifeedsci.2014.12.003
0377-8401/Published by Elsevier B.V.

Table 1
Composition of pea-barley forage consumed by ewes fed hay in confinement or swath grazing.

Composition	2010		2011	
	Hay	Swaths	Hay	Swaths
DM, g/kg	932	936	934	913
OM, g/kg[a]	927	919	921	921
CP, g/kg[a]	105	113	71	73
NDF, g/kg[a]	508	550	487	506
ADF, g/kg[a]	287	295	266	271
In vitro DMD, g/kg	574	341	482	373

[a] Expressed on a DM basis.

a modified Tilley and Terry (1963) method. Ruminal fluid was collected from 2 ruminally cannulated cows, combined, and strained through 16 layers of cheese cloth. A pre-heated buffer solution (20 mL) was added to the samples and incubated at 39 °C for 20 min before ruminal fluid was added, and the incubation was carried out for 48 h.

Fecal output (FO) was estimated for each ewe using the following equation:

$$\mathrm{FO(g\ \ DM/day)} = \frac{\mathrm{Cr\ \ daily\ \ dose(g/day)}}{\mathrm{fecal\ \ Cr\ \ concentration\ \ (g/g\ \ DM)}}$$

Forage DM intake (DMI) was estimated for each ewe using the following equation:Forage DMI (kg/day) = $\frac{\mathrm{FO\ \ (kg\ \ DM/day)}}{\mathrm{forage\ \ indigestebility}}$

Individual ewe mineral supplement intake was estimated using the following equation:Supplement DMI (g/day) = $\frac{\mathrm{fecal\ \ Ti(g/g\ \ DM)\times FO(g\ \ DM/day)}}{\mathrm{supplement\ \ Ti\ \ concentration(g/g\ \ DM)}}$

Distribution of supplement intake was evaluated by grouping ewes into four mineral supplement intake categories; none (≤10 g/day), low (11–28 g/day), average (29–84 g/day) and high consumers (≥85 g/day).

2.3. Statistical analysis

Data were analyzed using the GLM procedure of SAS (9.1 version, 2003) for a completely randomized design with least square means and P-values reported. Ewe was the experimental unit for mineral supplement, and forage intake. Pasture or pen (a group of 10 ewes) within year was the experimental unit for the coefficient of variation (CV) of supplement intake, and supplement intake distribution. The model included effects due to year, treatment, and year × treatment. Means were separated using the LSD procedure when a significant *F* value was found (P≤0.05).

3. Results

No year by treatment interactions (P≥0.44; Table 2) or treatment effects (P≥0.07) were detected for ewe initial weight or average daily gain (ADG). However, ewes in 2010 had greater initial weights (P=0.02), and ADG (P<0.01) than ewes in 2011.

Year by treatment interactions were seen for forage DMI (P<0.01), expressed both as kg/day and as kg/100 kg BW (Table 2). Ewes swath grazing in 2010 and ewes consuming hay in 2011, ate similar amounts of forage, but consumed less forage than ewes in confinement in 2010, and ewes swath grazing in 2011. A year by treatment interaction was detected for mineral supplement intake by individual ewes (P<0.01; Table 2). Ewes in confinement in 2011 consumed the least amount of mineral supplement. Ewes grazing in 2010 consumed a similar and intermediate amount of supplement to those in confinement in 2010, and to those grazing in 2011.

No year by treatment interaction (P≥0.07) was detected for minimum or maximum mineral supplement intake (Table 2). However, ewes in confinement had a lower (P=0.05) minimum supplement intake (average 10 g/d) compared with ewes grazing (average 33 g/d). Maximum supplement intake did not differ due to year or treatment (P≥0.21) and averaged 110 g/d. Mineral supplement intake CV demonstrated a year by treatment interaction (P=0.05). In 2010, ewes in confinement and grazing had similar supplement intake CV (55.4 *vs.* 46.5%, respectively). In 2011, ewes in confinement had a greater supplement intake CV compared with ewes grazing (67.2 *vs.* 33.7%, respectively).

The proportion of ewes consuming ≤10 g/day of mineral was not affected by year, treatment, or the interaction (P≥0.08; Table 2), and averaged 0.03. A year by treatment interaction (P=0.01) was seen for the proportion of ewes consuming low levels of supplement. Ewes in confinement in 2011 demonstrated the largest proportion consuming low levels of supplement (average 0.50). Ewes in confinement in 2010, and those grazing in 2010 and 2011 resulted in a smaller proportion consuming low levels of supplement (average 0.07). The proportion of ewes consuming an average amount of supplement was greater (P=0.04) for grazing ewes compared with ewes in confinement (0.71 *vs.* 0.50, respectively). In addition, the proportion of ewes consuming a high level of supplement was greater (P=0.04) for ewes swath grazing than for those in confinement (0.26 *vs.* 0.12, respectively).

Conflict of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

This work was supported in part by the Bair Ranch Foundation, Billings, MT.

References

AOAC, Official methods of analysis, 17th ed., *J. AOAC Int., Arlington, VA*, ISSN:1060-3271, 2000.

Bowman, J.G.P., Sowell, B.F., 1997. Delivery method and supplement consumption by grazing ruminants: a review. J. Anim. Sci. 75, 543–550.

Curtis, K.M.S., Holst, P.J., Murray, P.J., 1994. Measuring supplement intake in the field using Ytterbium. Aust. J. Exp. Agric. 34, 339–343.

Doreau, M., Michalet-Doreau, B., Bechet, G., 2004. Effect of underfeeding on digestion in cows. Interaction with rumen degradable N supply. Livest. Prod. Sci. 88, 33–41.

Ducker, M.J., Kendall, P.T., Hemingway, R.G., McClelland, T.H., 1981. An evaluation of feedblocks as a means of providing supplementary nutrients to ewes grazing upland/hill pastures. Anim. Prod. 33, 51–57.

Ellis, W.C., Lascano, C., Teeter, R., Owens, F.N., 1982. Solute and particulate flow markers. In: Owens, F.N. (Ed.), Protein Requirements for Cattle: Symposium. OK St. Univ. MP-109, pp. 37–56.

Lobato, J.F.P., Pearce, G.R., 1980. Responses to molasses-urea blocks of grazing sheep and sheep in yards. Aust. J. Exp. Agric. Anim. Husb. 20, 417–421.

Mertens, D.R., 2002. Gravimetric determination of amylase-treated neutral detergent fibre in feeds with refluxing beakers or crucibles: collaborative study. J. Assoc. Off. Assoc. Chem. Int. 85, 1217–1240.

Myers, W.D., Ludden, P.A., Nayigihugu, V., Hess, B.W., 2004. Technical note: a procedure for the preparation and quantitative analysis of samples for titanium dioxide. J. Anim. Sci. 82, 179–183.

Nolan, J.V., Norton, B.W., Murray, R.M., Ball, F.M., Roseby, F.B., Rohan-Jones, W., Hill, M.K., Leng, R.A., 1975. Body weight and wool production in grazing sheep given access to a supplement of urea and molasses: intake of supplement/response relationships. J. Agric. Sci. 84, 39–48.

NRC, 2007. Nutrient Requirements of Small Ruminants. National Academy Press, Washington, DC.

Reid, R.L., Templeton, W.C.J., Ranney, T.S., Thayne, W.V., 1987. Digestibility, intake and mineral utilization of combinations of grasses and legumes by lambs. J. Anim. Sci. 64, 1725–1734.

SAS Inc., 2003. SAS® User's Guide: Statistics, Version 9.1 ed. SAS Inc., Cary, NC.

Stiles, D.A., Bartley, E.E., Erhart, A.B., Meyer, R.M., Boren, F.W., 1967. Bloat in cattle. 13. Efficacy of molasses-salt blocks containing poloxalene in control of alfalfa bloat. J. Dairy Sci. 50, 1437–1443.

Tilley, J.M.A., Terry, R.A., 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassland Soc. 18, 104–111.

Vona, L.C., Jung, G.A., Reid, R.L., Sharp, W.C., 1984. Nutritive value of warm-season grass hays for beef cattle and sheep; digestibility, intake and mineral utilization. J. Anim. Sci. 59, 1582–1593.

Young, B.A., Corbett, J.L., 1972. Maintenance energy requirements of grazing sheep in relation to herbage availability. Aust. J. Agric. Res. 23, 57–76.