Growth Performance, Serum Hormones, and Metabolite Responses Before and After Weaning in Lambs Weaned at 42 Days of Age: Effect of Preweaning Milk and Postweaning Alfalfa or Grass Hay Diets

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ABSTRACT: Fourteen fall-born lambs were used to determine the effects of diet before and after weaning on intake, growth, serum hormones, and metabolite profiles. Before weaning, lambs were intensively sampled for 6 h at 35 and 42 d of age. Before sample collection, lambs were allowed to suckle, and milk intake was recorded. At 42 d of age, lambs were weaned and randomly allotted to ad libitum access to either alfalfa or grass hay. Blood samples were collected at 49 and 56 d of age for 6 h. Milk intake did not differ (P > .05) between groups. After weaning, lambs fed alfalfa hay consumed more (P < .05) hay and had greater (P < .05) ADG than lambs fed grass hay. Postweaning diet had no effect (P > .05) on serum insulin, growth hormone (GH), insulin:GH ratio, prolactin, cortisol, glucose, or nonesterified fatty acids (NEFA) concentrations. Lambs consuming alfalfa had higher (P < .05) serum urea nitrogen (SUN) at 49 and 56 d of age than lambs consuming grass. At 35 and 42 d of age, (P < .05) serum insulin and insulin:GH ratio were higher (P < .05) after milk intake than at 49 and 56 d of age after hay intake. Serum GH was higher (P < .05) in lambs at 35 and 42 d of age for 2 h postfeeding, but by h 3 through 5, lambs consuming milk had lower (P < .05) values than lambs consuming hay. Serum cortisol was lower (P < .05) in lambs at 35 d than at 42, 49, and 56 d of age through h 4. At 35 d of age, lambs had higher (P < .05) serum glucose than older lambs. These data suggest that during the first 2 wk postweaning, diet had little effect on serum constituents in lambs, although a significant change in growth response was observed. However, distinct differences were observed in serum hormone and metabolite profiles between the pre- and postweaned lamb.

Key Words: Lambs, Growth, Hormones, Weaning, Metabolites

Introduction

In young ruminants, weaning is associated with a dietary change from nonruminant to ruminant digestion (Breier et al., 1988). During this dietary change in lambs, marked changes in plasma metabolites (Poe et al., 1969; Lane and Albrecht, 1991) along with a lag in body growth have been observed for up to 2 wk after weaning (Fennessy et al., 1972; Lane and Albrecht, 1991). Although significant metabolite and growth changes have been observed during the weaning process, research examining the endocrine changes associated with this transitional period is limited. However, Breier et al. (1988) reported a significant decrease in serum insulin and insulin-like growth factor I (IGF-I) after weaning and suggested that these results may in part be due to inadequate nutrient absorption rather than to a change in the nature of nutrients absorbed. Therefore, it is likely that the weaning process affects both circulating
hormones that regulate body growth and dietary composition and intake. These latter two factors may also alter hormonal responses observed during this transitional period. Characterizing these hormonal changes associated with weaning and evaluating various postweaning diets may provide insights into physiological changes that occur during the weaning period.

The objective of this study was to evaluate the effect of the dietary change from a preweaning milk to postweaning hay diet on feed intake, growth, serum insulin, growth hormone (GH), prolactin (PRL), and metabolite profiles of lambs weaned at 42 d of age. Serum cortisol profiles were also examined to evaluate the stress associated with weaning.

Materials and Methods

Preweaning Animal Management. Fourteen Poly- pay × Suffolk, singled-sired, September-born, 35-d-old lambs (eight females, six castrated males) with an average BW of 15.5 ± .4 kg (mean ± SE) were used in the study. All lambs and their dams were maintained in one pen until weaning (42 d of age) and allowed free access to water, salt, and minerals (Leslie Salt). All animal care followed procedures outlined in the Consor- tium (1988) publication. Lambs were weaned at 42 d of age because previous data suggested that the rumen is functional by this time (Wardrop and Coombe, 1961). During the preweaning period lambs were allowed ad libitum access to a mixed alfalfa-grass hay diet that contained 92% DM and 14.7% CP, 29.5% ADF, and 45.6% NDF on a DM basis. Preweaning lambs weights were obtained at 35 and 42 d of age.

Preweaning Blood Sampling. To determine effects of preweaning milk consumption on serum constituents, lambs were subjected to blood sampling at 35 and 42 d of age. Lambs were fitted with indwelling cannulas (18 gauge × 5.1 cm) (Abbocath- T, Abbott Hospitals, Chicago, IL) at 1300 on the day before intensive sampling was initiated. The catheterization procedure was approved by the university animal care committee. Milk consumption was determined by a weigh-suckle-weigh technique (Loerch et al., 1985). Lambs were separated from their dams at 2200 on the day of cannulation and remained separated for 8 h. After the 8-h period, lambs were weighed (0600), allowed to suckle until satisfied, and reweighed (0630). A jugular blood sample (3 mL) was obtained just before nursing (0600) and at 30-min intervals after nursing, beginning at 0700, for the ensuing 6 h.

Postweaning Management. After intensive sampling (1300) at 42 d of age, lambs were weaned and placed in individual pens (1.5 m × 1.5 m). At this time lambs were randomly allotted to ad libitum access to either a chopped (2.54-cm screen) alfalfa or grass hay diet (four females and three males per diet). The alfalfa hay contained 93% DM and 17% CP, 32% ADF, and 41% NDF on a DM basis and the grass hay contained 92% DM and 12% CP, 34% ADF, and 56% NDF on a DM basis. Fresh feed was provided at 0700 daily and feed refusals from the previous day were recorded for 14 d. During the 14-d period lambs were allowed free access to water, salt, and minerals (Leslie Salt). Lambs were weighed at 49 and 56 d of age (1 and 2 wk postweaning, respectively).

Postweaning Blood Sampling. To determine effects of weaning on serum constituents, jugular blood samples were collected daily (0630) for 1 wk after weaning. In addition, to examine effects of grass or alfalfa hay diet fed postweaning on serum hormone and metabolite profiles, lambs were sampled via indwelling cannula at 49 and 56 d of age. Before sampling, animals were fasted for 12 h, after which a prefeeding sample (3 mL) was obtained (0600). After the prefeeding sample had been collected, lambs were allowed access to their designated diet for 1 h. After feed removal, samples were collected at 0700 and continued at 30-min intervals for 6 h. Blood samples were treated in the same fashion as described earlier and stored at -20°C until they were analyzed.

Laboratory Analysis. Samples collected daily for 1 wk postweaning were analyzed for glucose, nonesterified fatty acids (NEFA), and urea N (SUN). Serum glucose and SUN were determined colorimetrically using the o-toluidine (Stanbio Laboratory, San Antonio, TX) and diacetyl-monoxime (Stanbio Laboratory) assay procedures, respectively. Nonesterified fatty acid (NEFA-C Kit, Wako Chemicals, Richmond, VA) concentrations were determined using a modified colorimetric method described by McCutcheon and Bauman (1986). Because of limited serum volume obtained from samples obtained at 35, 42, 49, and 56 d of age, serum glucose, SUN, insulin, and GH were determined in hourly samples. Serum insulin and GH were quantified by RIA as described by Sanson and Halford (1984) and Hoefer and Halford (1987), respectively. Samples collected at 0700 and on the half-hour were analyzed for NEFA, PRL, and cortisol. Prolactin was determined by RIA (Spoon and Halford, 1989). Serum cortisol levels

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4Contained more than 98% NaCl, 3% Zn, 2% Mn, 2% Fe, .04% Cu, .002% Co, and .002% I.
were quantified using an ELISA reported by Munro and Stabenfeldt (1985).

Statistical Analysis. Body weights were analyzed by analysis of variance as a completely randomized design (Snedecor and Cochran, 1967). Milk and feed intake, efficiency of gain, and serum samples collected daily for 1 wk after weaning were evaluated by split-plot analyses of variance for repeated measurements as described by Gill and Hafs (1971). Effect of postweaning diet was tested using animal within postweaning diet as a split-split-plot design with sampling time and day of age effect and the interaction of day of age × postweaning diet were tested against residual error using the GLM procedure of SAS (1985). Metabolic hormone and metabolite profiles obtained from samples obtained at 35, 42, 49, and 56 d of age were analyzed as a split-split-plot design with sampling time and the interactions of sampling time × postweaning diet and sampling time × day of age added to the model. When a significant F-test (P < .05) was observed, differences in days of age were separated using the LSD procedure.

Results and Discussion

Intake and Growth Responses. Because no postweaning diet × day of age interactions were detected for preweaning milk or postweaning hay intake, ADG, or feed conversion, overall means were tested. Milk consumption was similar across day of age between groups before weaning (26.2 and 25.8 ± 2.0 g·kg of BW⁻¹·d⁻¹ for lambs fed alfalfa and grass hay postweaning, respectively). However, when the effect of day of age was examined across postweaning diets, lambs consumed more (P < .05) milk at 35 d of age (30.1 ± 1.5 g·kg of BW⁻¹·d⁻¹) than at 42 d of age (21.6 ± 1.5 g·kg of BW⁻¹·d⁻¹). Preweaning weights were comparable between groups at 35 and 42 d of age (13.4 and 13.5 ± .4 and 14.8 and 15.5 ± .5 kg for lambs receiving alfalfa and grass hay postweaning, respectively).

After weaning, lambs receiving alfalfa consumed more (P < .05) hay the first 2 wk postweaning than lambs receiving grass hay (28 and 20 ± 2 g·kg of BW⁻¹·d⁻¹, respectively). Likewise, ADG was higher (P < .05) for alfalfa-fed lambs (173 ± 30 g/d) than for grass-fed lambs (65 ± 30 g/d) for the 2-wk period after weaning. Although intake and ADG were higher for alfalfa-fed lambs, BW were similar between groups (P > .10) at both 49 d (16.2 and 15.8 ± .5 kg for alfalfa- and grass-fed lambs, respectively) and 56 d of age (17.3 and 16.4 ± .6 kg for alfalfa- and grass-fed lambs, respectively). However, net weight gain for the 2 wk after weaning was greater (P < .01) in the alfalfa-fed lambs (2.5 ± .3 kg) than in the grass-fed lambs (.9 ± .3 kg). When the effect of day of age across postweaning diets was evaluated, lambs consumed less hay DM (P < .05) at 1 wk postweaning (22 ± 1 g·kg of BW⁻¹·d⁻¹) than at 2 wk postweaning (26 ± 1 g·kg of BW⁻¹·d⁻¹); however, no difference was observed in ADG (132.0 and 105.8 ± 26.7 g/d at 1 and 2 wk postweaning, respectively).

Serum Hormones and Metabolites. Serum insulin values exhibited no postweaning diet × day of age interaction; however, a postweaning diet × sampling interaction was detected (P < .05; Table 1). No difference was detected in serum insulin concentrations between postweaning diet groups at any sampling time. In contrast, serum insulin was lower in lambs receiving a low-protein (7% CP) diet than in lambs receiving a high-protein (15%) diet when fed from 60 to 120 d of age (Johns and Bergen, 1978). Because no postweaning diet × day of age interaction was detected, the treatment

<table>
<thead>
<tr>
<th>Time after feeding, h</th>
<th>Insulin, ng/mL</th>
<th>Growth hormone, ng/mL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Alfalfa</td>
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</tr>
<tr>
<td>0</td>
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<td>.29</td>
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<tr>
<td>7</td>
<td>.22</td>
<td>.30</td>
</tr>
</tbody>
</table>

<sup>a</sup> Seven lambs per diet. Lambs were weaned at 42 d of age and received alfalfa or grass hay postweaning.

<sup>b</sup> Split-split-plot revealed a postweaning diet × time interaction (P < .05) but no postweaning diet × day interaction. Therefore, postweaning diet effects were examined within time across days of age.

<sup>c</sup> Row means within hormone without common superscripts differ (P < .05).

Table 1. Serum insulin and growth hormone in samples collected hourly across days of age in lambs fed alfalfa or grass hay postweaning<sup>b</sup>
groups were pooled and effect of day of age on serum insulin concentration was examined. A sampling time × day of age interaction was observed (P < .05), so day of age effects were examined within sampling time (Figure 1). Day of age did not influence prefeeding serum insulin concentrations. However, lambs at 35 and 42 d of age had higher (P < .01) insulin levels 1 h postfeeding than lambs at 49 and 56 d of age, and this difference continued through h 5 of sampling. The rise in serum insulin 1 h after milk ingestion has also been reported in lambs at 1, 2, and 3 mo of age receiving 250 or 500 mL of milk (Bassett, 1974a; Porter and Bassett, 1979). After weaning, lambs at 49 and 56 d of age given the alfalfa or grass hay diets did not demonstrate this postprandial increase in insulin associated with feeding. This increase, however, has been associated with the amount of grain in the diet (Trenkle, 1972; Bassett, 1974a; Cole et al., 1988). Increased insulin has also been positively correlated with ruminal OM digested and intestinal CP digested by sheep (Bassett et al., 1971; Weston and Hogan, 1974). Because lambs were limited to a 1-h feeding period, the lack of response may be related to the amount of feed consumed during this period.

Serum GH levels demonstrated no postweaning diet × day of age interaction, although a postweaning diet × sampling time interaction was observed (P < .05). When effect of diet fed postweaning was examined within sampling time, serum GH was elevated (P < .05) at 2 h postfeeding in lambs receiving grass hay compared with alfalfa-fed lambs (Table 1). No difference, however, was detected for any other sampling time, suggesting that diet fed postweaning had little influence on GH concentrations (Table 1). Cole et al. (1988) reported that lambs fed low-energy diets had higher GH values than lambs fed high-energy diets. Bassett et al. (1971) also found a negative relationship between energy density and serum GH concentration. Although hay diets fed postweaning differed in CP content, if there were significant differences between hay DE content they were not reflected in serum GH levels.

Figure 1. Effect of day of age on serum insulin and growth hormone (GH) concentrations and on insulin:GH ratio in lambs weaned at 42 d of age. Samples were collected before (h = 0) and after (h = 1) milk (35 and 42 d of age) or hay (49 and 56 d of age) consumption. The SE for serum insulin, GH, and insulin:GH ratio were .05 to .15 ng/mL, .9 to 1.8 ng/mL, and .01 to .06, respectively.
in lambs 21, 33, and 46 d of age (Symonds et al., 1989). In addition, Symonds et al. (1989) found that this response increased with age and was not related to any other consistent stimulatory metabolic response after feeding and suggested that this effect may be related to the onset of development of the rumen and the influence of mechanical factors such as passage of digesta through the reticulorumen (Tindal et al., 1985). In contrast, some metabolic changes in this study were associated with milk and hay ingestion. Serum NEFA were lower after feeding (P < .05) in lambs fed milk. High concentrations of NEFA have been shown to suppress the release of GH (Blackard et al., 1969); therefore, ingested milk would be expected to decrease NEFA levels and might permit a rapid increase in GH secretion. Feeding has resulted in a marked decline in plasma NEFA levels in adult sheep, yet no rapid increase in plasma GH concentrations were noted (Bassett, 1974). However, consumption of dry feed is followed by a marked increase in plasma VFA concentrations, and acetate and propionate have been shown to influence plasma GH concentration (Hertelendy and Kipnis, 1973). Therefore, it is possible that different responses in GH after ingestion of milk or dry food are related to the differences in plasma VFA levels.

No postweaning diet × day of age or postweaning diet × sampling time interactions were observed for serum insulin:GH ratio. Serum insulin:GH ratios were similar between lambs fed alfalfa (.09 ± .02) and lambs fed grass (.06 ± .02). When effect of day of age across postweaning diets was examined (day of age × sampling time, P < .05), prefeeding serum insulin:GH ratios were similar among days before feeding (Figure 1). However, after consumption of milk or hay, lambs fed milk had an increased (P < .05) insulin:GH ratio through 6 h of sampling compared with lambs fed hay. Bassett (1974a) suggested that this increase in insulin:GH ratio (i.e., increase in serum insulin and decrease in serum GH) was the result of a reflex nervous mechanism followed by a response to carbohydrate absorption. A corresponding increase in serum glucose was observed at 35 d of age; however, only a slight rise in glucose was observed at 42 d of age, although both groups received milk.

Lack of postweaning diet × day of age and postweaning × sampling time interactions allowed evaluation of PRL response to postweaning diet across day of age and sampling time. Prolactin concentrations in alfalfa ((4 ± 1.9 ng/mL) and grass-fed (10 ± 1.9 ng/mL) lambs did not differ and are similar to those reported in September-born lambs (Revault and Courot, 1975). Effect of day of age on serum PRL was evaluated across diets within sampling time because a day of age × sampling time interaction was observed (P < .05; Figure 2). Among days of age, serum PRL was similar (P < .10) at 1 and 1.5 h postfeeding; however, by 2.5 h postfeeding, lambs at 35 and 49 d of age had elevated (P < .05) serum PRL. Similar differences (P < .05) were also detected at 4.5 and 6.5 h postfeeding. Of the metabolic hormones, PRL is the most responsive to change in photoperiod (Pelletier, 1973; Revault, 1976). Differences in PRL in this study, however, are likely not due to photoperiod because of the short length of this study (1 mo). Handling the lambs may have influenced serum PRL because stress associated with restraint has been shown to increase PRL secretion in sheep (Lamming et al., 1974).

Figure 2. Effect of day of age on serum prolactin and cortisol concentrations in lambs weaned at 42 d of age. Samples were collected after (h = 1) milk [35 and 42 d of age] or hay [49 and 56 d of age] consumption. The SE for serum prolactin and cortisol were 1.4 to 5.8 and 2.7 to 3.5 ng/mL, respectively.
Although a significant postweaning diet × sampling time interaction (P < .05) was detected for serum cortisol, there was only one time (3.5 h) at which a difference was observed (P < .05) between postweaning diets (Table 2). Similarly, Bassett (1974b) reported that corticosteroid concentration in plasma fluctuated during the day but was not affected by the level of feeding in adult sheep.

When effect of day of age on prefeeding cortisol concentrations was examined, serum cortisol values were lower (P < .05) at 35 and 42 d of age than at 49 and 56 d of age (day of age × sampling time, P < .05; Figure 2). Thirty minutes after feeding, cortisol continued to be lower (P < .05) in lambs at 35 d of age through h 4.5, and no difference occurred among the three older ages. Cortisol levels observed in this study are within ranges reported for lambs 15 to 25 d of age (Parraguez et al., 1989) and lambs 3 mo of age (Brinklow and Forbes, 1984). A variety of stressful stimuli such as jugular venipuncture and restraint increase serum cortisol (De Silva et al., 1983, 1986). Therefore, differences in cortisol among day of age in this study may be related to stress that occurred because of handling during sample collection.

Serum glucose concentrations across days of age were similar between lambs fed alfalfa (70.4 ± 2.0 mg/dL) and grass hay (71.3 ± 2.0 mg/dL) postweaning (postweaning diet × day of age and postweaning diet × sampling time, P > .10). The amount of grain in the diet rather than type of forage seems to contribute more toward serum glucose concentrations. Cole et al. (1988) reported that lambs receiving a high-energy diet had higher glucose concentrations than lambs fed a low-energy diet. Serum glucose was higher (P < .05) in lambs at 35 d of age than at 42, 49, or 56 d of age throughout the sampling period (day of age × sampling time, P < .05; Figure 3). Similar glucose values and patterns found at 35 d of age have also been demonstrated in young lambs receiving 250 or 500 mL of milk or milk replacer (Bassett, 1974a; Symonds et al., 1989). At all ages feeding resulted in an increase in serum glucose; however, only in lambs ingesting milk was a concomitant rise in serum insulin detected. In addition, although lambs at 35 and 42 d of age were still suckling, lambs at 42 d of age had much lower glucose concentrations that were similar to glucose concentrations of weaned lambs both before and following milk consumption. This observation may be an indication that lambs at this age have made

Table 2. Serum cortisol in samples collected hourly across days of age in lambs fed alfalfa or grass hay postweaningab

<table>
<thead>
<tr>
<th>Time after feeding, h</th>
<th>Alfalfa</th>
<th>Grass</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
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<td>20.6</td>
<td>21.4</td>
<td>2.2</td>
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</tr>
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<td>6.5</td>
<td>19.8</td>
<td>22.9</td>
<td>2.1</td>
</tr>
</tbody>
</table>

aSeven lambs per diet. Lambs were weaned at 42 d of age and received alfalfa or grass hay postweaning.

bSplit-split-plot revealed a postweaning diet × sampling time interaction (P < .05) but no postweaning diet × day of age interaction (P > .10). Therefore, postweaning diet effects were examined within sampling time across days of age.

c,dRow means without common superscripts differ (P < .05).

Figure 3. Effect of day of age on serum glucose and nonesterified fatty acids (NEFA) in lambs weaned at 42 d of age. Samples were collected before (h = 0) and after (h = 1) milk (35 and 42 d of age) or hay (49 and 56 d of age) consumption. The SE for serum glucose and NEFA were 3.0 to 4.2 mg/dL and 28 to 40 μm/L, respectively.
the transition from a predominantly milk diet to a forage diet, because Jarrett et al. (1964) reported that as animals develop a functional forestomach, blood glucose levels decrease and the half-life of glucose increases. However, Purser and Bergen (1969) suggested that this glucose change may be an age-dependent phenomenon associated with changes in hepatic enzyme activity and independent of rumen development and VFA production.

When daily glucose concentrations were examined for 1 wk after weaning (postweaning diet \( \times \) day of sampling, \( P > .10 \)), mean serum glucose was higher \( (P < .05) \) in lambs fed alfalfa hay \( (70.3 \pm 1.6 \text{ mg/dL}) \) than in lambs fed grass hay \( (62.6 \pm 1.6 \text{ mg/dL}) \) postweaning. Within diet, glucose values 1 d after weaning fell from preweaning levels, but by d 2 values returned to those observed preweaning (Table 3). Others (Poe et al., 1969; Lane and Albrecht, 1991) have reported a similar decline in serum glucose after weaning in early-weaned lambs and attributed it mainly to the stress of weaning and decrease in feed intake.

Serum NEFA values were similar between lambs fed alfalfa \( (360 \pm 20 \mu\text{M}) \) and grass hay \( (385 \pm 20 \mu\text{M}) \) postweaning (postweaning diet \( \times \) day of age and postweaning diet \( \times \) sampling time; \( P > .10 \)). Among days of age, serum NEFA values after milk or hay intake were lower \( (P < .01) \) in lambs at 35 and 42 d of age than at 49 and 56 d of age (day of age \( \times \) sampling time, \( P < .05 \); Figure 3). This difference \( (P < .05) \) continued for 30 min after feeding, after which no differences in NEFA values were detected until 4.5 h. At this time, lambs at 35, 42, and 49 d of age had higher \( (P < .05) \) concentrations than at 56 d of age, and these differences were detected through 8.5 h postfeeding.

When daily NEFA values were examined for 1 wk after weaning no diet effect was detected \( (484 \pm 71 \pm 33 \mu\text{M}) \) for alfalfa- and grass-fed lambs, respectively; postweaning diet \( \times \) day of sampling; \( P > .10 \)). However, both groups responded with a twofold increase in NEFA levels 1 d after weaning and these values remained above preweaned values for the 1st wk of weaning (Table 3). Because peak NEFA concentration was not affected by diet, this response suggests that, after weaning, body fat was mobilized in response to the decrease in energy intake.

When SUN concentrations were evaluated, postweaning diet \( \times \) day of age and postweaning diet \( \times \) time of sampling interactions were observed \( (P < .05; \text{date not shown}) \). At 35 and 42 d of age, SUN concentrations were similar between groups at all sampling times (values ranged from 16.5 to 20.0 mg/dL and 18.6 to 13.8 mg/dL on d 35 and 42 of age across groups, respectively). At 49 d of age, lambs fed alfalfa had higher \( (P < .05) \) prefeeding SUN concentrations \( (16.8 \pm 1.5 \text{ mg/dL}) \) than lambs fed grass hay \( (11.2 \pm 1.5 \text{ mg/dL}) \) and values differed \( (P < .05) \) through h 5 of sampling. At 56 d of age a similar response was demonstrated between groups except that values were numerically higher than those reported on d 49 (range 22.9 to 18.3 and 17.0 and 13.2 mg/dL for alfalfa- and grass-fed lambs, respectively). Results obtained in lambs after weaning likely reflect differences in N content between postweaning diets. Because a postweaning diet \( \times \) day of age interaction \( (P < .05) \) was detected, the effect of day on SUN values was examined within postweaning diet. Lambs fed alfalfa had higher \( (P < .05) \) SUN levels at 56 d of age than at the three younger ages \( (14.1, 16.3, 15.4, \text{ and } 20.9 \pm 1.3 \text{ mg/dL}) \) for lambs 35, 42, 49, and 56 d

### Table 3. Serum glucose, nonesterified fatty acids (NEFA), and urea nitrogen (SUN) in daily samples for 1 week following weaning\(^a\)

<table>
<thead>
<tr>
<th>Postweaning, d</th>
<th>Glucose, mg/dL(^b)</th>
<th>NEFA, (\mu\text{M})(^b)</th>
<th>SUN, mg/dL(^c)</th>
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<tbody>
<tr>
<td></td>
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<tr>
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<td>Overall mean</td>
<td>70.3(^a)</td>
<td>62.6(^c)</td>
<td>1.8</td>
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</table>

\(^a\)Seven lambs per diet. Lambs were weaned at 42 d of age and fed alfalfa or grass hay postweaning.

\(^b\)Split-plot analysis of variance revealed no postweaning diet \( \times \) sampling day interaction \( (P > .80) \); therefore, overall means were tested.

\(^c\)Split-plot analysis of variance revealed a postweaning diet \( \times \) sampling day interaction \( (P < .05) \). Diet effects were examined within sampling day.

\(^d\)Day of weaning.

\(^e\)Row means within metabolite with different superscripts differ \( (P < .05) \).
of age, respectively). In lambs fed grass hay, lambs at 35 and 49 d of age (12.0 and 11.3 mg/dL, respectively) had lower (P < .05) SUN than at 42 and 56 d of age (17.2 and 15.2 mg/dL, respectively).

Daily SUN concentration in both groups showed a sharp decrease after weaning (postweaning diet × sampling day, P < .05; Table 3), after which the alfalfa-fed lambs had increased SUN values, which remained higher (P < .01) than those of grass-fed lambs for the remainder of the week. The lack of increased SUN levels in grass-fed lambs suggests that energy deprivation did not cause a large catabolism of body protein in response to nutrient deprivation (Lane et al., 1986). This finding suggests that although the N content is lower than alfalfa hay, grass hay fed to weaned lambs is adequate to maintain growth because weight gains were observed the 1st wk after weaning.

**Implications**

Significant endocrine and metabolite changes were observed between pre- and postweaning and are, at least in part, reflective of dietary changes associated with the removal of milk from the diet after weaning. However, after weaning, forage diet fed postweaning did not alter growth-regulating hormones, although differences in growth were observed between alfalfa- and grass-fed lambs. Therefore, growth-controlling hormones seemed to be responsive to dietary change during the weaning transition; however, these hormones were not responsive to growth changes that were observed during the first 2 wk after weaning.

**Literature Cited**


Ravault, J. P. 1978. Prolactin in the ram: Seasonal variations in the concentration of blood plasma from birth until three
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