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The relationship of residual feed intake and visceral organ size in growing lambs fed a concentrate- or forage-based diet

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ABSTRACT

We hypothesized that a portion of the individual differences observed for feed efficiency in ruminants can be attributed to gastrointestinal tract (GIT) size, which would vary based on diet type. The objective of this study was to determine GIT and visceral organ size in high and low efficiency growing lambs fed either a concentrate or forage-based diet. Growing wethers ($n=82$; 51.3 ± 1.2 kg body weight [BW]) were fed a concentrate (CONC; 12.1% crude protein [CP], 17.6% neutral detergent fiber [NDF], 2.98 Mcal/kg metabolizable energy [ME]) or forage-based pelleted diet (FOR; 16.2% CP, 36.3% NDF, 2.31 Mcal/kg ME) for 49 d. Individual intake was measured with the GrowSafe System to determine residual feed intake (RFI). The 20% highest efficiency (low RFI, $n=8$) and 20% lowest efficiency (high RFI, $n=8$) lambs from each diet were slaughtered (66.6 ± 2.3 kg BW; $n=32$ total), and the viscera was dissected and weighed. Data were analyzed as a 2×2 factorial with RFI class (high efficiency vs. low efficiency), diet type (FOR vs. CONC), and their interaction in the model. Organ masses were not affected ($P > 0.10$) by the RFI class x diet type interaction. High efficiency lambs tended to have greater ($P=0.09$) pancreas and spleen actual mass than low efficiency lambs, although RFI class did not affect ($P > 0.15$) other organ actual (g) or relative (g/kg BW) mass. Lambs fed FOR had greater ($P \leq 0.01$) actual and relative reticulum, omasum, large intestinal, and kidney mass and tended to have greater ($P \leq 0.09$) actual and relative small intestinal masses compared with lambs fed CONC. However, lambs fed CONC had greater ($P \leq 0.05$) actual rumen, heart, liver, and relative rumen mass than lambs fed FOR. All other visceral organ masses were unaffected ($P > 0.11$) by diet type. Diet type, RFI class, and their interaction did not affect small intestinal length ($P > 0.10$). Results of this study suggest that visceral organ size in growing lambs is more affected by diet type than individual feed efficiency. Based on this data, pancreas and spleen sizes may play a role in efficiency of feed utilization in lambs, however.

1. Introduction

Livestock feed costs have risen rapidly over the last decade, greatly impacting profitability of livestock producers and renewing industry and scientific interests in feed efficiency. It has been well-established that when external factors are similar, feed intake varies between individual animals due to differences in metabolic feed efficiency (Herd and Arthur, 2009). Residual feed intake (RFI) is gaining use as a measure of feed efficiency as it is moderately heritable and genetically independent of mature size (Herd et al., 2003; Arthur and Herd, 2012). More efficient (low or negative RFI)

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cattle and sheep have been shown to have reduced feed intake (O'Connor et al., 1999; Nkrumah et al., 2004; Kolath et al., 2006; Redden et al., 2014) and to produce less methane (Nkrumah et al., 2006; Muro-Reyes et al., 2011). Additionally, when beef cattle have been selected based on feed efficiency, growing cattle that are more efficient had similar growth and meat production while consuming less feed (Herd et al., 2003; Arthur et al., 2004), indicating potential for selection based on RFI to improve efficiency.

Although feed efficiency research in livestock has increased dramatically in recent years, little is known about the physiological mechanisms of feed efficiency in small ruminants. Herd and Arthur (2009) suggested that differences in feed efficiency can be attributed to tissue metabolism, turnover, and stress (37%), digestibility (10%), heat increment of feeding (9%), and body composition (5%), all of which have contributions from visceral organs. Of the visceral organs, the gastrointestinal tract (GIT) and liver not only serve as the main site for nutrient absorption and metabolism, respectively, but also are major energy and nutrient sinks due to high metabolic activity and rapid cell turnover. In fact, the GIT and liver account for 38–50% of energy use in ruminants even though they make up 6–13% of body mass (Burrin et al., 1990; Seal and Reynolds, 1993). Despite this, the role of visceral organ mass in feed efficiency of ruminant livestock, especially small ruminants, remains unclear. We hypothesize that a portion of individual differences observed for feed efficiency can be attributed to GIT organ size and function, which may vary based on diet. The specific objective of the current study was to determine GIT and visceral organ size in high and low efficiency growing lambs fed either a concentrate or forage-based pelleted diet.

2. Materials and methods

2.1. Animals and diet

All animal procedures were approved by the University of Wyoming Institutional Animal Care and Use Committee. Growing wethers ($n=82$; 51.3 ± 1.2 kg body weight [BW]) of Rambouillet, Hampshire, and Suffolk breed types were randomly allocated by BW to receive either a pelleted concentrate-based diet (CONC; Table 1; $n=40$) or pelleted forage-based diet (FOR; Table 1; $n=42$). Lambs were acclimated to diets using a 20% increase in proportion of new feed to old feed every 4–5 d until the diet consisted of 100% treatment diet, fed ad libitum. Individual feed intake was then measured by the GrowSafe™ System for a 49-d trial period. At least a 42-d feed intake test is necessary to determine RFI in sheep (Cockrum et al., 2013).

Body weight was collected weekly, and 2-d average initial and final BW were obtained to calculate average daily gain (ADG). Residual feed intake was calculated as the expected feed intake subtracted from the actual feed intake (Cammack et al., 2005). Expected feed intake for each individual was determined by regressing ADG and metabolic midweight (Mid-$BW^{0.75}$) on actual feed intake. Breed was not accounted for in the RFI calculation, because multiple breeds were selected for slaughter from each diet type based on calculation of RFI without inclusion of breed.

Table 1
Ingredient and nutrient composition of pelleted diets fed to growing lambs.

Item	FOR[a]	CONC[b]
Ingredient, % dry matter (DM)		
Alfalfa	67.7	–
Corn	–	50.2
Wheat middlings	27.5	31.0
Corn gluten	–	10.0
Cane molasses	2.50	2.50
Salt	1.34	1.76
Calcium carbonate	0.60	2.30
Dried distillers grains with solubles	–	1.0
Calcium sulfate	–	0.75
Potassium chloride	–	0.19
Trace minerals and vitamins	0.34	0.36
Analyzed nutrient composition		
Crude protein, % DM	16.2	12.1
Neutral detergent fiber, % DM	36.3	17.6
Acid detergent fiber, % DM	25.1	6.6
Metabolizable energy, Mcal/kg DM[c]	2.31	2.98

[a] FOR = pelleted forage diet.
[b] CONC = pelleted concentrate diet.
[c] Calculated from NRC (2007) values.

Lambs were removed from the study if they had intact testicles, became injured, or had health complications. This left 77 wethers that were ranked within diet type by their RFI (CONC, $n=39$; FOR, $n=38$). The 20% highest efficiency (low RFI; $n=8$) and 20% lowest efficiency (high RFI; $n=8$) wethers from each diet type were selected for slaughter (66.6 ± 2.3 kg BW; $n=32$ total) at the University of Wyoming Meat Laboratory. The 10% highest and 10% lowest RFI ranking wethers from each diet were slaughtered 1 d after the conclusion of the feed intake test; the next 10% highest and 10% lowest RFI ranking wethers were slaughtered 5 d post-test but remained on designated diets until slaughter.

2.2. Measurement of visceral organ size

Lambs were slaughtered using standard conventional methods, and the visceral organs were removed for dissection and data collection. Using procedures of Meyer et al. (2012), viscera were removed and dissected. The liver and pancreas were removed and weighed, then the stomach complex and intestine were dissected, gently stripped of fat and digesta, and weighed. The stomach complex was divided into the reticulum, rumen, omasum, and abomasum based on anatomical structures. Additionally, the small intestine was dissected using the following demarcations. The duodenum began at the pylorus and ended at the point adjacent to the junction of the gastrosplenic vein and mesenteric vein. The jejunum began here and ended 300 cm (non-stripped intestine) after a point adjacent to the mesenteric vein, 10 cm caudal from its junction with the ileocecal vein. The ileum comprised the remaining small intestine and concluded at the ileocecal junction. Stripped small intestinal length was determined after connective tissue and fat were removed. Total GIT mass was calculated as the sum of the empty stomach complex, small intestine, and large intestine individual masses.