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Growth performance and hormonal status during feed restriction and compensatory growth of Small-Tail Han sheep in China

L.M. Ding[a,*], J.Q. Chen[a], A.A. Degen[b], Q. Qiu[a], P.P. Liu[a], Q.M. Dong[c], Z.H. Shang[a], J.J. Zhang[a], S.J. Liu[c,*]

[a] State Key Laboratory of Grassland Agro-Ecosystem, Institute of Arid Agroecology, School of Life Sciences, Lanzhou University, Lanzhou 73000, China
[b] Desert Animal Adaptations and Husbandry, Wyler Department of Dryland Agriculture, Blaustein Institutes for Desert Research, Ben-Gurion University of Negev, Beer Sheva 84105, Israel
[c] National Key Laboratory of Cultivating Base of Plateau Grazing Animal Nutrition and Ecology of Qinghai Province, Qinghai Academy of Animal and Veterinary Sciences, Xining 810016, China

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ABSTRACT

Average daily gain (ADG), hormonal status and gain:feed intake ratio were determined in Small-Tail Han lambs (initially 24 ± 1.8 kg; 90 ± 11 days of age) during feed restriction and compensatory growth. An adaptation period of 14 days was allowed during which time the sheep consumed feed (crude protein = 148 g/kg; metabolizable energy = 15.9 MJ/kg DM) ad libitum. This was followed by 30 days of feed restriction in which three groups of lambs (n = 10 per group) received approximately 85 (Tr1), 75 (Tr2) and 60% (Tr3) of ad libitum intake; a fourth group (control, CK; n = 10) continued to receive ad libitum feed. After the restriction period, all lambs were fed with ad libitum intake for 60 days. During feed restriction, the control sheep had higher ADG than the other three groups ($P < 0.01$). The gain:feed intake ratios of CK and Tr1 were higher than for Tr2 and Tr3 ($P < 0.01$). But during re-alimentation, ADG of Tr2 and Tr3 were higher than control lambs ($P < 0.01$) while final body weight (BW) was similar among groups. Gain:feed intake did not differ among the four groups. Following feed constriction, there was no difference in dry matter intake (DMI) among the four groups during the 60-days feed re-alimentation period. There was no difference in plasma concentrations of growth hormone, insulin and insulin-like growth factor 1, triiodothyronine, thyroxine or cortisol. Within restricted groups, GH generally decreased during the restricted feeding period and increased with ad libitum feed intake. In addition, plasma IGF-1 concentration of all experimental lambs generally increased in the latter stages of the ad libitum feed intake. These changes were most pronounced in the two most feed restricted groups. In conclusion, the lambs in the highest feed restriction group (60% of ad libitum intake) were able to compensate completely for the reduced BW. The total DMI over the whole period of the highest restricted feed intake group was 14.2% lower than the control group ($P < 0.05$). Therefore, the strategy of restricted feed would be economical for fattening lambs in China.

1. Introduction

The sheep industry in China has been gaining popularity in recent years. The main limiting constraint for the enterprise has been feed quality and quantity, especially in Northern China. While compensatory growth has been used widely in the livestock industry to improve the efficiency of utilization of energy intake and of growth performance in many places (Hornick et al., 2000; Mitchell, 2007), few farms have adopted this strategy in China.

During compensatory growth, less energy is required for body maintenance and, therefore, more energy can be allocated for growth (Murphy and Loerch, 1994; Choi et al., 1997; Li et al., 2012). The reduced requirement for maintenance is due mainly to a decrease in mass and metabolic activity of the vicera (Ortigues and Durand, 1995; Hornick et al., 2000) and to hormones involved in the regulation of metabolism during feed restriction and re-alimentation (Lapierre et al., 1992; Hayden et al., 1993; Yambayamba et al., 1996). The aim of this study was to determine the effect of feed restriction and re-alimentation on compensatory growth, feed efficiency and blood hormonal changes of fattening lambs of the Small-Tail Han breed, and to examine whether a novel

* Corresponding authors.
E-mail addresses: dinglm@lzu.edu.cn (L.M. Ding), mkylshj@126.com (S.J. Liu).

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Table 1
Ingredient and nutrient compositions of the treatment rations (DM basis).

Item[a]	Diet composition (g/kg)
Fermented flax straw	400
Whole corn	200
Wheat bran	100
Flax meal	300
Nutrients	
CP, g/kg	148
NDF, g/kg	457
ADF, g/kg	342
ME[b], MJ/kg of DM	15.9

[a] CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; ME = metabolic. energy.
[b] Estimated according to Weiss et al. (1992).

practice to reduce feed costs without affecting productive performance could be introduced in China.

2. Materials and methods

2.1. Animals and experimental procedures

Forty three-months old Small-Tail Han ram lambs (BW: 24 ± 1.8 kg) were divided randomly into four groups of 10 animals each. The sheep were fed free choice twice daily, once in the morning and once in the afternoon, for 14 days. Sheep within each group were then penned individually (1.5 × 2.0 m) and were allowed 14 days to adapt to their pens and diets, during which time they had access to feed free choice. Then, three groups were offered restricted feed for 30 days so that the intake would be approximately 85% (Tr1), 75% (Tr2) and 60% (Tr3) of ad libitum intakes; the fourth group received ad libitum feed and acted as a control (CK). Following feed restriction, all sheep were offered feed free choice for 60 days. The sheep were fed twice daily, at 07:00 and 19:00 h, had free access to water and salt blocks and were weighed weekly in the morning before feeding (Table 1). The feed samples were collected each week, mixed and dried at 65 °C to determine crude protein (CP; AOAC, 1990; method 981.10), neutral detergent fiber (NDF; Van Soest et al., 1991) and acid detergent fiber (ADF; Van Soest et al., 1991). The study, including the adaptation period, was carried out from May 3 to August 15, 2014, that is, for a total of 104 days.

2.2. Blood sampling and analysis

Heparinized jugular blood samples were collected from four lambs of each group on days 15, 19, 29, 44, 49, 59, 74, 89 and 104. The blood samples were centrifuged at 3000 × *g* for 15 min at 4 °C, and plasma samples were stored at −80 °C until analyzed at Beijing Kangjia Hongyuan Biotechnological Technology Co., LTD. Plasma growth hormone (GH), insulin-like growth factor 1 (IGF-1), insulin, the thyroid hormones (triiodothyonine [T_3] and thyroxine [T_4]) and cortisol concentrations were determined by an automatic radioimmunoassay counter (sn-69513, Shanghai Hesuo Rihuan Photoelectric Instrument Co., LTD, Shanghai). All kits for hormone analyses were from Nanjing Jiancheng Bioengineering Institute.

2.3. Statistical analysis

A randomized complete block design was used to examine the effect of feed restriction and re-alimentation on BW and plasma hormone concentrations of the lambs. Four groups of lamb acted as blocks with period as a subplot and repeated measure. Dependent variables measured (body weight gain, hormones) were examined by covariance analysis and Duncan's multiple range test, allowing for tests of dietary treatment, period, and period × treatment (SAS software, version 9.2, SAS Institute Inc., Cary, NC). A mixed model (Proc MIXED) was used with treatment (CK, Tr1, Tr2, Tr3) as a fixed effect by least square means, and lamb as a random effect.

Table 2
The effect of feed restriction and re-alimentation on growth performance of Small-Tail Han sheep.

	Treatment					
Period and item[1]	CK	Tr1	Tr2	Tr3	SEM	*P*-value
Restriction (30 days)						
Initial BW (kg)	23.1	23.6	24.1	24.9	0.31	0.538
Final BW (kg)	29.9[a]	28.5[a]	27.8[a]	26.2[b]	0.53	0.004
ADG (g/day)	227[a]	162[b]	123[b]	45[c]	14.2	<0.001
DMI (kg/day)	1.57[a]	1.35[b]	1.14[c]	0.93[d]	0.03	<0.001
Gain:feed intake	0.11[a]	0.12[a]	0.07[b]	−0.01[c]	0.01	<0.001
Re-alimentation (60 days)						
Initial BW (kg)	29.9[a]	28.5[a]	27.8[a]	26.2[b]	0.53	0.004
Final BW (kg)	41.6	43.4	42.3	41.4	0.63	0.688
ADG (g/day)	195[b]	248[a]	242[a]	253[a]	7.35	0.016
DMI (kg/day)	1.96	2.00	1.95	1.89	0.06	0.70
Gain:feed intake	0.11	0.12	0.12	0.13	0.01	0.32

Different superscripts ([a],[b],[c],[d]) within rows signify significant differences between means ($P < 0.05$).
[1] BW = bodyweight; ADG = average daily gain; DMI = dry matter intake.

3. Results

3.1. Bodyweight gain

Final BW after the 30 days restriction period was lower ($P < 0.01$) for the highest feed restricted group (Tr3) than for controls (CK), but did not differ among the CK, Tr1 and Tr2 groups. The ADG during this period was also lowest in the Tr3 group ($P < 0.01$); ADG did not differ between Tr1 and Tr2 groups but both were lower than the CK group (Table 2). All feed offered to the three restricted groups was consumed and averaged 86.0%, 72.6% and 59.2% of ad libitum intakes for the Tr1, Tr2 and Tr3 groups, respectively. During feed restriction, the gain:feed intake ratios of CK and Tr1 were higher than those of Tr2 and Tr3 ($P < 0.01$); Tr3 sheep had the lowest ratio. After the 60 days re-alimentation period, there was no difference in BW among the four groups. There was no significant difference in ADG among the three restricted groups during feed re-alimentation, but their values were higher than for the CK group ($P < 0.05$). There was no difference in DMI among groups during the re-alimentation period and the gain:feed intake ratios did not differ among the four groups after the 60-days re-alimentation period.

3.2. Blood hormone and metabolic concentrations

There were no significant treatment effects, but there were significant day effects in plasma GH, insulin and IGF-1 concentrations (Fig. 1). Plasma GH concentrations were significantly higher on day 104 than on days 19, 29 and 74. The IGF-1 concentrations on days 15 and 104 were significantly higher than on days 44–59, and the IGF-1 concentration was higher on day 29 than on days 49 and 59.

After ad libitum feeding, the plasma insulin concentrations of Tr3 on days 49 and 74 were greater than on day 44 ($P < 0.05$) and in Tr2 was higher on day 74 than on day 44. In both groups, there was a decline in plasma insulin concentrations after day 74 ($P < 0.05$).

Neither T_3 nor T_4 showed a significant overall treatment or day effect (Fig. 2). There was only a significant day effect on plasma cortisol concentrations, which were higher on days 15 and 19 than on days 29 and 49 (Fig. 2).