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Effect of energy and protein levels in supplemental diets on performance of Rayeni cashmere does and goat kids under natural grazing conditions

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ABSTRACT. The study was carried out to evaluate the effects of supplementary diets with different levels of metabolizable energy (ME) and crude protein (CP) on the performance traits of Rayeni does in the first gestation and their offspring. Animals were fed four supplementary diets during pregnancy and lactation. Supplementary pregnancy diets consisted of two levels of ME (9.20 and 10.12 MJ/kg) and two levels of CP (11.10 and 12.20%) based on dry matter (DM). Dietary treatments during the lactation period contained two levels of ME (10.04 and 11.05 MJ/kg) and two levels of CP (12.70 and 13.96%) based on DM. Kids were weighed from birth to 12 months of age. A patch of fleece was clipped from the left mid-side of each animal (area approx. 100 cm^2, weight ~18 g). Then fleece samples were tested for cashmere yield, washed fleece yield and mean cashmere fibre diameter. It was shown that the total fleece weight (469 vs 424 g) and final live weight (27.3 vs 25.4 kg) of does fed diet supplemented with higher energy level were improved ($P < 0.05$). The increase in dietary energy level increased also body weight gain of kids, greasy cashmere fleece weight (457 vs 419 g) and clean cashmere weight (327 vs 297 g) of kids. So, it can be concluded that supplementary feed with an increased level of energy, but not protein, for grazing does, in the critical period of the last month of pregnancy and birth time, is necessary to optimize the performance of the Rayeni cashmere goats and their offspring.

Introduction

Rayeni goats are one of the most famous productive breeds of cashmere in Iran which are kept by nomadic pastoralists under extensive conditions for their meat, cashmere and milk in Kerman Province, south-east of Iran (Ansari-Renani et al., 2012). Snyman (2010) describing Angora goats, stated that reproductive performance is the most important trait which affects the income and profitability of Cashmere goat breeders. Late-pregnancy nutrition may have a major impact on the reproductive efficiency and productivity (breeding) of Cashmere and Angora does (McGregor, 2017).

The main problems connected with breeding Rayeni goats are low birth rate, abortion, reduced milk production, high mortality and low survival rate of the kids to weaning age. These problems are mainly due to inadequate nutrition or lack of supplementary feeding of does during pregnancy and lactation (Ansari-Renani et al., 2012). The birth weight has been reported as the most important factor in the survival rate of Angora kids in the USA (Shelton and Groff, 1974), and the results of the Mohammadi et al. (2012) experiment showed that the survival rate of Rayeni kids was higher when the birth weight was higher. Snyman (2010) reported that the reproductive performance of Angora goats in South

Africa was low and the mortality of their kids was high. While inadequate feeding during pregnancy and low birth weight of the kids reduced the Angora kid's survival rate and increased mortality of kids before weaning from 28 to 45% (van der Westhuysen, 1980).

Poor nutritional conditions and energy deficiency during the last trimester of goat pregnancy may result in loss of body weight and death of dams. Studies on Angora goats and sheep indicate that energy intake is a major factor affecting birth weight, lactation performance and offspring productivity (McGregor, 2018). A study by Bell (1984) showed that the proper feeding of does from mid-pregnancy affects the growth of the placenta, birth weight and survival of kids. McGregor (2016) reported that there is a positive correlation between goat live weight before parturition and kids' birth weight.

It was also shown that kind of feeding before and after birth not only affects the live weight of does but also influences survival, growth rate, cashmere production and weight of kids' weaning (van der Westhuysen, 1980). Improved birth weight increases the survival of the neonates and, consequently, the rate of wool, mohair and cashmere production (McGregor, 2018). However, does fed supplementary diets had better productivity (McGregor, 1988). In a study of Australian cashmere goats it was observed that food shortage in rangelands over summer and autumn can reduce cashmere growth (McGregor, 1992). There is little information about the effect of supplemental nutrition during pregnancy and lactation on the fleece traits, live body weight and reproductive performance of female Rayeni goats and body growth and cashmere characteristics of their offspring under nomadic breeding conditions that may cause severe reproductive constraints, feed shortages and poor pasture conditions. Therefore, the purpose of this study was to investigate the effects of supplementary diets with different levels of metabolizable energy (ME) and crude protein (CP) during pregnancy and lactation on Rayeni cashmere does and their offspring performance.

Material and methods

Livestock and studied area

This experiment was carried out in nomadic herds in the Galoder-Haftadar area of Goshk village (56°44'5.6" East and 28°47'29.4" North), southwest of Kerman province, Iran. The annual precipitation varies from 130 to 480 mm. The climate in spring and summer is hot and relatively dry, with temperatures reaching 30 °C in summer and below −10 °C in winter.

In the experiment, 48 does aging 17–18-months in the first pregnancy with mean live weight 25.6 ± 2.28 kg ranging from 21.20 to 30.10 kg were used for natural mating. Does were selected based on their initial live weight and date of birth, and they were randomly assigned to four treatments. Along with female goats, 16 bucks (17–18-month old) were used for mating (four bucks per treatment). Bucks weight was 30.5 ± 2.69 kg and ranged 26.7–37.0 kg.

Reproduction

The total weight of female goats in the four treatments was not significantly different at the beginning of the experiment. Albendazole was given to the goats two weeks before starting the experiment. The does were subjected to flushing with whole barley grain (300 g per day) for two weeks before inserting vaginal insert (CIDR; EAZL-BREED CIDR Sheep Insert, Pfizer New Zealand Ltd, Auckland, New Zealand) constructed with a silicone elastomer impregnated with 0.3 g natural progesterone. CIDERs were inserted into the vagina for 19 days, during the mating season of nomadic herds in July–August months. After removing the CIDER, 200 IU of equine chorionic gonadotropin (eCG) was injected. Six hours later, the does in each animal group were mated in wire netting cages with dimensions of 3 × 2 × 1.5 m and with the ratio of 1 to 3 (4 bucks to 12 does). The mating period was 72 h. After mating, the goats were separately taken for grazing for one month with two castrated bucks to identify the oestrous cycle of the livestock. Approximately 70–80% of does became pregnant in different treatments during the first oestrous cycle. The feed yard of does in each group was separately fenced with wire mesh fences to 1.5 m height. All the goats were fed supplementary diet at 9:00. Two hours after feeding, the goats grazed in the rangeland until the end of the day.

Experimental diets

Eight supplementary diets (four supplementary diets for pregnancy and four supplementary diets for lactation) were fed to pregnancy and lactation does (Table 1). Supplementary pregnancy diets consisted of two levels of ME (9.20 and 10.12 MJ/kg) and two levels of CP (11.1 and 12.2%) based on a dry matter (DM) basis. Experimental diets for the lactation period contained two levels of ME (10.04 and 11.05 MJ/kg) and two levels of CP (12.7 and 14.00%)

Table 1. Ingredients and composition of pregnancy and lactation diets fed to Rayeni cashmere does

Indices	Pregnancy diets[1]				Lactation diets[1]			
	LL	LH	HL	HH	LL	LH	HL	HH
Differentiating factors								
ME levels[2], MJ/kg DM	9.20	9.20	10.12	10.12	10.04	10.04	11.04	11.04
CP levels, %	11.10	12.20	11.10	12.20	12.70	13.97	12.70	13.97
Ingredients, %								
alfalfa	27.0	33.0	19.3	25	29.8	34.9	22.0	30.9
wheat straw	39.0	34.0	29.5	25.0	23.4	19.5	13.0	7.2
barely grain	18.0	16.1	27.0	33.0	25.0	21.0	30.1	29.0
wheat bran	4.0	5.3	8.0	6.0	11.0	12.5	13.5	15.0
maize grain	3.5	1.8	8.8	2.2	3.0	2.5	14.0	10.3
soybean meal	3.0	3.7	2.8	3.0	3.0	3.9	2.8	3.0
cotton seed meal	3.7	4.0	2.6	3.8	3.2	4.0	2.5	2.8
MCP[3]	0.26	0.48	0.07	0.19	0.06	0.16	0.06	0.02
limestone	0.04	0.12	0.43	0.31	0.04	0.04	0.54	0.28
salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
vitamin permix[4]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Chemical composition, % DM								
Ca	0.53	0.65	0.51	0.55	0.50	0.56	0.56	0.56
P	0.31	0.38	0.30	0.32	0.33	0.36	0.36	0.37
S	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.33
Ca/P	1.70	1.70	1.70	1.70	1.55	1.55	1.55	1.55

DM – dry matter; ME – metabolizable enery; CP – crude protein; [1] treatments: LL – low energy and protein, LH – low energy and high protein, HL – high energy and low protein, HH – high energy and protein; [2] measured by gas test method, Menke and Steingass (1988); [3] monocalcium phosphate contained 15% of Ca and 22.7% of P; [4] provided per 100 g: IU: vitamin A 100.000, vitamin D_3 16.60 and vitamin E 8.33

based on a DM basis. The diets ingredients were alfalfa, wheat straw, barley grain, wheat bran, maize grain, soybean meal, monocalcium phosphate, salt and vitamin premix.

The pregnancy and lactation diets were: low-energy and protein (LL), low-energy and high-protein (LH), high-energy and low-protein (HL) and high-energy and protein (HH). The goat adaptation period was set for 15 days. Pregnancy and lactation diets were formulated based on National Research Council recommendations (NRC, 2007) and 10% more than recommended ME and CP requirements for pregnant and lactating goats were used. Supplementary feeding of does began from the week 3 of pregnancy till the end of it and then, continued until week 16 of lactation. The goats from each treatment consumed the supplementary diet in a 5 × 5 m temporary cage before pasture grazing. The amount of daily diets in the first, second, third, fourth and fifth month of pregnancy were 200, 250, 300, 350 and 400 g/day/head, respectively. In the first four months of lactation, the amount of pelleted diets of does was 400, 350, 300 and 250 g/day/head, respectively. The goats in the experimental treatments were grazed together on rangeland after receiving supplementary feeding.

Chemical composition of diet ingredients

The samples of feed ingredients were dried in a forced-air oven at 65 °C for 48 h and ground to a size of 1-mm before analysis. The standard method was used to measure the DM (method 934.01) and CP (method 976.05) according to AOAC International (2005).

The ME of the dietary ingredients was calculated with the gas test method based on the results of the gas production at 24 h incubation (GP, ml/24 h) using Menke and Steingass equation (1988):

$$ME\ (MJ/kg\ DM) = 2.2 + 0.136\ GP + 0.057\ CP + 0.0029\ CP^2.$$

Fleece sampling and kids weighing

The total fleece of goat kids and Rayeni cashmere does were sheared (first cashmere harvesting) by traditional scissors at the age of ~15-month and 25–26-month in late April and mid-May, respectively. A patch of fleece was clipped from the left mid-side of each animal (approx. area 100 cm^2, weight ~18 g). Prepared snippets of the greasy cashmere fleece weight (GCFW) were weighed, and then they were hand-dehaired. The dehaired cashmere was washed in the solvent and dried so clean cashmere content weight (CCW) was measured. Then clean cashmere was reconditioned and tested using an optical fibre diameter analyzer for each snippet to determine mean cashmere fibre diameter (MCFD, μm) (method ASTM D2130 by microprojection) (Ansari-Renani et al., 2012). These samples (snippet) were tested for cashmere yield (% w/w, % unscoured weight of cashmere in greasy fleece), cashmere content was determined as total raw fleece weight × cashmere yield (%) as a proportion (McGregor and Butler, 2008). Cashmere yield was measured by the percentage of the weight of cashmere fibres in the total greasy fleece snippets.

From the time they were born, the kids were weighed at one, two, three, four, five, seven, nine and twelve months.

Statistical analysis

A 2 × 2 factorial experiment was applied to investigate the effect of supplementary diets containing two levels of ME and two levels of CP on the performance of does and their kids, there were four pregnancy rations and four lactation rations. The effect of sex was fitted to the model analysis as a fixed effect. The growth traits including body weight measured at different ages and cashmere characteristics were analyzed using the following model:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \delta_k + e_{ijkl},$$

where: Y_{ijk} – observation on different growth traits, μ – population mean, α_i – i^{th} level of energy, β_j – j^{th} level of protein, $(\alpha\beta)_{ij}$ – interaction between energy and protein levels, δ_k – k^{th} level of sex, and e_{ijklm} – remaining variance. A SAS software (version 9.1, SAS Institute, Cary, NC, USA) was used for the analysis. The Tukey's test was used to compare the means at the 5% level of significance.

Table 2. Summary of reproductive and productive data of Rayeni maiden does fed supplemental diets differing in metabolizable energy (ME) and crude protein (CP) during pregnancy and lactation

Indices	Treatment[1]			
	LL[2]	LH	HL	HH
Number of does mated	12	12	12	12
Number of pregnant does	10	11	10	11
Number of non-pregnant does	1	1	1	1
Number of does died before kidding	1	-	1	-
Abortion number	1	-	-	1
Twin-born kids	-	-	1	1
Number of kids born	9	11	11	11
Kidding rate, %	75	91	91	91
Number of female kids born	7	6	5	4
Number of male kids born	2	5	6	7
Mean birth weight of female kids, kg	2.12	1.94	1.87	1.98
Mean birth weight of male kids, kg	2.36	2.16	2.34	2.39
Number of male kids lost until weaning	0	0	2	3
Number of female kids lost until weaning	2	2	0	0
Number of kids eaten by wolves	1	1	1	0
Total number of kids lost until weaning	3	3	3	3
Kid viability rate to weaning, %	66	72	72	72
Kid mortality rate, %	33	27	27	27
Mean live weight of kids at weaning, kg	11	12	13	14
Total live weight of kids at weaning[3], kg	67	95	103	111
Number of kids for selling at 7 months	6	8	8	8
Total live weight of kids for selling at 7 months, kg	75.6	102	108	114
Remaining kids at the end of the experiment	6	8	8	8
Total live weight of kids at 12 months, kg	90	119	133	136

[1] treatments: LL – low energy and protein, LH – low energy and high protein, HL – high energy and low protein, HH – high energy and protein; [2] data from one female kid of LL treatment was eliminated due to low birth weight and growth rate; [3] total live weight of kids at weaning = kid number × mean live weight

Results

Reproductive characteristics

The kidding rate was 91% for HH, HL and LH treatments, and 75% for LL treatment (Table 2). The mean kidding viability rate of low-energy treatment was 83% and for the high-energy one 91%. Kid viability rate to weaning in the supplemented high- and low-energy treatments was 72 and 69%, respectively. The kid mortality rate at weaning age in LL treatment was 33%, while in other treatments it was 27%. The mortality rate of female and male kids to the weaning age was 18 and 25%, respectively. The total live weight of kids at weaning was 111 kg for the HH treatment, thereby making the total live weight increase by 44.2, 8.1 and 16.9 kg in comparison to the LL, HL and LH treatments, respectively. The mean live weight of kids at weaning of high- and low-energy treatments was 107.6 and 81.1 kg, respectively.

Effect of supplementary diet on does live weight and fleece

The selected does had similar initial live weight between periods with feeding supplementary diets, while the final live weight of the does in the low-energy treatment was significantly lower than of those in high-energy one at the end of week 16 after kidding (Table 3, $P < 0.05$). The does fleece weight was higher when they were fed high-energy diets ($P < 0.05$). No effect of protein level was observed for both final live weight and fleece weight of does.

Goat kid body weights

The body weight of the goat kids at birth was not affected by supplemental levels of energy and protein. Live body weights of kids fed low-energy diets were lower than of those fed high-energy diets ($P = 0.003$, $P < 0.01$, $P = 0.032$, $P < 0.01$,

Table 3. Effects of supplementary diets differing in metabolizable energy (ME) and crude protein (CP) during pregnancy and lactation periods on final live weight and fleece weight (mean ± standard error) of goat does

Parameters	Experimental diets[1,2]				Main effect of energy (E)		Main effect of protein (P)		*P*-value		
	LL	LH	HH	HL	low	high	low	high	E	P	E × P
Initial live weight, kg	25.3 ± 0.50	24.4 ± 0.51	25.8 ± 0.82	26.1 ± 0.64	-	-	-	-	-	-	-
Final live weight[3], kg	25.2 ± 1.19	25.6 ± 1.04	27.8 ± 0.88	26.9 ± 1.20	25.4 ± 0.80[b]	27.3 ± 0.76[a]	26.7 ± 0.73	26.1 ± 0.78	0.043	0.551	0.131
Fleece weight, g	426 ± 42.0	423 ± 46.0	442 ± 40.0	497 ± 45	424 ± 30[b]	469 ± 28[a]	432 ± 27	461 ± 29	0.050	0.766	0.174

[1] treatments: LL – low energy and protein, LH – low energy and high protein, HL – high energy and low protein, HH – high energy and protein; [2] pregnancy and lactation diets; [3] at the end of 16 weeks of lactation; [ab] – means with different superscripts in a row (separately for energy and protein effect) are significantly different at $P < 0.05$

$P < 0.01$, $P = 0.032$, $P = 0.024$ and $P = 0.014$ at 1, 2, 3, 4, 5, 7, 9 and 12 month, respectively, Table 4). The body weight of kids was not affected by the different protein levels regardless of the time of weighing after kidding.

Cashmere characteristics of yearling kids

The cashmere yield (%), greasy cashmere fleece weight (GCFW) and clean cashmere content weight (CCW) were affected by sex and were considerably higher in male than in female kids (Table 5).

Table 4. Effects of supplementary diets differing in metabolizable energy (ME) and crude protein (CP) during pregnancy and lactation periods on live weights of goat kids, kg

Goat kid age	Experimental diets[1,2]				Main effect of energy (E)		Main effect of protein (P)		*P*-value		
	LL	LH	HL	HH	low	high	low	high	E	P	E × P
Birth	2.26 ± 0.10	2.07 ± 0.09	2.12 ± 0.10	2.18 ± 0.09	2.17 ± 0.07	2.15 ± 0.07	2.19 ± 0.06	2.13 ± 0.07	0.410	0.541	0.554
Month											
1	3.36 ± 0.19	3.48 ± 0.14	3.68 ± 0.16	3.95 ± 0.17	3.08 ± 0.12[b]	3.80 ± 0.12[a]	3.51 ± 0.12	3.70 ± 0.11	0.003	0.076	0.407
2	5.04 ± 0.36	5.06 ± 0.30	5.64 ± 0.31	5.93 ± 0.33	5.02 ± 0.24[b]	5.79 ± 0.28[a]	5.34 ± 0.24	5.49 ± 0.22	<0.01	0.425	0.091
3	7.05 ± 0.52	7.39 ± 0.45	7.75 ± 0.45	8.97 ± 0.48	7.20 ± 0.35[b]	8.35 ± 0.34[a]	7.40 ± 0.34	8.18 ± 0.33	0.032	0.146	0.101
4	9.49 ± 0.63	9.73 ± 0.54	10.98 ± 0.54	11.98 ± 0.58	9.60 ± 0.42[b]	11.47 ± 0.39[a]	10.24 ± 0.41	10.84 ± 0.40	<0.01	0.414	0.195
5	11.3 ± 0.73	11.8 ± 0.63	12.9 ± 0.60	14.0 ± 0.67	11.5 ± 0.48[b]	13.4 ± 0.45[a]	12.1 ± 0.47	12.9 ± 0.46	<0.01	0.270	0.280
7	12.6 ± 0.77	12.8 ± 0.66	13.6 ± 0.71	14.4 ± 0.71	12.6 ± 0.51[b]	14.0 ± 0.50[a]	13.1 ± 0.52	13.6 ± 0.49	0.031	0.422	0.284
9	14.1 ± 0.72	14.1 ± 0.62	15.6 ± 0.65	15.8 ± 0.66	14.00 ± 0.61[b]	15.7 ± 0.56[a]	14.9 ± 0.59	14.9 ± 0.57	0.024	0.841	0.257
12	15.0 ± 0.77	15.0 ± 0.67	16.7 ± 0.70	17.1 ± 0.72	15.1 ± 0.62[b]	16.9 ± 0.58[a]	15.9 ± 0.61	16.0 ± 0.59	0.014	0.928	0.361

[1] treatments: LL – low energy and protein, LH – low energy and high protein, HL – high energy and low protein, HH – high energy and protein; [2] pregnancy and lactation diets; [ab] – means with different superscripts in a row (separately for energy and protein effect) are significantly different at $P < 0.05$

Table 5. Effects of supplementary diets differing in metabolizable energy (ME) and crude protein (CP) during pregnancy and lactation periods on cashmere characteristics of yearling goat kids

Indices	Sex		Experimental diets[1,2]				Main effect of energy (E)		Main effect of protein (P)		*P*-value		
	male	female	LL	LH	HL	HH	low	high	low	high	E	P	E × P
Cashmere yield, %	71.1[a]	65.7[b]	66.3	71.5	67.4	71.8	68.9	69.6	66.80	71.6	0.921	0.904	0.263
Washed fleece yield, %	72.8	74.6	75.9	73.0	74.3	74.2	74.5	74.2	75.10	73.6	0.860	0.315	0.461
MCFD, μm	18.6	18.4	18.7	19.3	18.7	18.1	19.1	18.6	18.7	18.9	0.244	0.625	0.276
GCFW, g	477[a]	399[b]	426	412	421	494	419[b]	457[a]	424	453	0.022	0.665	0.318
CCW, g	346[a]	268[b]	295	300	291	363	297[b]	327[a]	293	331	0.040	0.111	0.510
Hair, %	27.9	33.3	33.3	28.5	32.6	28.2	30.9	30.4	32.9	28.3	0.244	0.135	0.262
Mean clean male kids fleece, g	477	-	460	420	458	573	440[b]	515[a]	459	496	0.036	0.581	0.226
Mean clean female kids fleece, g	-	399	390	392	400	425	391	412	395	408	0.727	0.824	0.275

[1] treatments: LL – low energy and protein, LH – low energy and high protein, HL – high energy and low protein, HH – high energy and protein; [2] pregnancy and lactation diets; MCFD – mean cashmere fibre diameter, GCFW – greasy cashmere fleece weight, CCW – clean cashmere content weight; [ab] – means with different superscripts in a row (separately for energy and protein effect, and sex) are significantly different at $P < 0.05$

The GCFW and CCW were higher when high-energy treatments were fed to animals. However, neither the energy nor protein levels had significant effects on cashmere yield (%). Also, MCFD was not affected by sex or energy and protein levels.

Discussion

Reproduction and production performance of does. Digestibility of nutrients and digestible energy of pastures decreases significantly in autumn and winter, which subsequently results in a restriction in the quantity and quality of feed consumed by the livestock (Gao et al., 2008), which is in line with the current study conditions because birth time and critical period of the last two months of pregnancy of female Rayeni goats happened in late autumn to mid-winter. In this period, the rangelands had low-quality forage; therefore, female Rayeni goats in nomadic herds were faced with shortages of feed and live weight loss during the winter. The does which were selected for this study had similar initial live weight. It was noted that the final body weight of does was affected by the levels of energy in the supplementary diets and it was significantly higher when does were fed high-energy diets.

It was reported that Australian pregnant Angora goats were likely to face energy restrictions in the middle of pregnancy in winter. But with supplemented energy, they had significantly compensated weight loss and decreased embryonic mortality rates and kidding loss (McGregor, 2016). Increasing energy levels in goat feeding led to increased live weight and improved reproductive performance of does (Snyman, 2010). The final body weight of goat does in the low-energy group was significantly reduced in comparison to the high-energy group. Reproduction is critical in terms of nutritional needs because fertility increases the nutritional requirements of the livestock. Also, providing the nutrients needed by the livestock can affect its reproductive processes (Rastogi et al., 2003).

Birth weights of the kids. The birth body weight of the kids in four treatments was not affected by the different levels of energy and protein. Fernandez et al. (1989) did not observe significant changes in birth weight of kids in response to the energy and protein changes during the pregnancy period, which is in agreement with the results of the current study. Hossain et al. (2003) reported that the birth weight of the kids increased with increasing levels of energy in supplementary diets. The energy and protein requirements of does increase during the early, mid and especially late phases of pregnancy (NRC, 2007). Increased dietary energy and supplementary protein led to a proper balance of nutrients consumed by the animal and this may have resulted in a higher supply of nutrients to the fetus, which was subsequently reflected as higher birth weight (Hossain et al., 2003).

Energy levels had no significant effect on goat kids birth weight in four treatments, which is in agreement with findings from Sahlu et al. (1995), but it is contrary to the results of the study by Ivey et al. (2000) that was conducted on the Spanish cashmere goats, in which the mean birth weight was higher in single kids born from does receiving diets with higher energy levels.

Emami Meybodi et al. (1993) reported that the birth weight of the Rayeni kids from does in their first kidding at the age of 2 years was 2.1 ± 0.028 kg, which was lower than the mean birth weight of the kids born from does that received supplementary diets during pregnancy.

Live weight of kids after birth. The mean body weight of the kids measured in their first month and at the later ages was affected by the energy levels. The body weight of the kids measured from month 1 to month 12 of age was greater in high- than in low-energy level diets. The results of the present study showed that the kid's weight gain with high-energy level increased in comparison to the low-energy level from the first month after birth to the age of twelve-month-old. This result was consistent with studies conducted on other breeds of goats (McGregor, 2018).

Deficiency of energy causes slow growth of the kids (Hossain et al., 2003). The results of Ríos-Rincón et al. (2014) research showed that dietary energy level improved feed efficiency more than protein level in finishing diet for hair lambs. However, after birth, undernutrition of does can cause low milk production, impaired maternal bonding with her kid and reduced numbers of kids reared (Idamokoro et al., 2017).

In the current study, the live weight gain of kids born from female Rayeni goats, which received high-energy supplemental feed during lactation, was significantly higher than in animals from other dietary treatments. Such an increase could be due to the better nutrition status of does and so better milk production, which may directly influence the growth of kids (Idamokoro et al., 2017).

In the present study, Rayeni does had a higher final live weight on high-energy level diets than low-energy one during lactation, it could be because higher levels of energy may have prevented the reduction of maternal body fat deposit (McGregor, 2017). In line with our study, there are the results of Gül et al. (2016) who fed Kilis goats kept in pasture supplementary concentrate diet and noted improved milk production, birth weight, kid survivability and daily gain of the kids.

It was observed that the protein levels in diet had no significant effect on the live weight of kids after birth. Perhaps, the examined different protein levels were not sufficiently different from each other. Therefore, maybe higher protein variations should be tested in the future with regard to the weight of the goat kids.

Fleece production and characteristics. High-energy feeding of Rayeni does caused a significant increase in final live weight and fleece weight in does in comparison to the low-energy diets. It was reported that there was a significant correlation between live weight and cashmere fibre production showing that the heaviest goats that were gaining weight, produced the highest amount of cashmere (McGregor, 1992). In Spanish cashmere goats the production of fleece was not affected by protein levels but by the increased amount of energy in the diet, which linearly increased the production of fleece (Ivey et al., 2000), simillary as in the current study. Moreover, findings on Australian cashmere goats confirm that the feeding restriction of cashmere goats during the cashmere growth period leads to a reduction of live weight and a decrease in cashmere production (McGregor, 1988).

The GCFW of kids from does receiving high-energy supplemental feed was significantly higher than in those from does fed a low-energy diet. Also, there was a significant difference between the fleece weight of male and female kids. Nutrition affects the body weight of cashmere goats, and also body weight and nutrition are effective in the production of clean cashmere fibre (McGregor, 2018). McGregor (1992) showed that by every kg of body weight gain, there was 4.7 g increase in cashmere growth and 0.08 μm increase in cashmere fibre diameter. But for one kg of live weight loss, cashmere growth was reduced by 11 g. For maximum cashmere production, it is necessary to prevent live weight loss of goats in the winter. In the current study, at the end of the experiment, the lowest kids live weight was in groups in which does received low-energy diets. These results indicate that inadequate feeding of energy for the Rayeni does, whose kidding and first six weeks of lactation occur in the mid to late winter, can lead to reduced live weight and fleece production because the vegetation of the rangeland is very poor. The results of the current study indicate that the live body weight of kids increased when their does were fed a high-energy diet as compared to a low-energy one, resulting in a significant increase in cashmere production of kids. However, in the present study, the MCFD was not affected by energy and protein levels, which is in contrast to the findings from McGregor's (1992) study.

Experimental results (McGregor, 1988) showed that supplemental feeding of energy could increase the live weight of livestock and the growth of cashmere, while inadequate nutrition during lactation may led to a decrease in live weight and mohair growth rate of Angora does as well (McGregor, 2017). Wang et al. (2019) reported that the positive relationship between cashmere production and increase in live body weight will benefit the breeding of Inner Mongolia cashmere goats. In the present study, the mean body weight of does from low- and high-energy treatments was 25.4 and 27.3 kg, respectively, and the fleece weight was 424 and 469 g, respectively, which may indicate an insufficient feeding during pregnancy and lactation in low-energy treatments. McGregor (2017) showed that improving the feeding of Angora does by increasing energy intake, increased the production of mohair by 16%. McGregor (2017) also reported that cashmere goats fed on rangeland with energy supplementation increased the cashmere growth by 10–15%.

The feeding of Rayeni does with the high-energy supplementary diet caused an increase in the clean male kids' fleece in the first cashmere shearing in comparison to the kids from does fed low-energy diet (510 vs 440 g), while Ansari-Renani et al. (2012) showed that the average clean cashmere production of Rayeni goats was 286 g.

Conclusions

The results obtained in the present study showed a significant increase in live body weight and fleece weight in does fed high-energy supplementary diets. Therefore, a positive relationship between dietary energy and performance traits beneficial for the breeding of Rayeni goats may be suggested. Moreover, with high-energy supplementary diets, the reproductive performance of Rayeni does was improved during pregnancy and lactation, which was confirmed by increased goat kids' body weight gain, greasy cashmere fleece weight and clean cashmere weight. So, it can be concluded that supplementary feed with an increased level of energy, but not protein for grazing does, in the critical period of the last month of pregnancy and birth time, is necessary to optimize the performance of the Rayeni cashmere does and their offspring.

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Conflict of interest

The authors declare that there is no conflict of interest.

References

Ansari-Renani H.R., Mueller J.P., Rischkowsky, Seyed Momen S.M., Alipour O., Ehsani M., Moradi S., 2012. Cashmere quality of Raeini goats kept by nomads in Iran. Small Ruminant Res. 104, 10–16, https://doi.org/10.1016/j.smallrumres.2011.11.003

AOAC International, 2005. Official Methods of Analysis of AOAC International. 18th Edition. Gaithersburg, MD (USA)

Bell A.W., 1984. Factors controlling placental and fetal growth and their effects on future reproduction. In: D.R. Lindsay, D.T. Pearce (Editors). Reproduction in Sheep. Australian Academy of Science and Australian Wool Corporation. Canberra (Australia), pp. 1144–1152

Emami Meybodi M.A., 1993. The estimate genetic parameters for some economic traits in Raieni Cashmere goats. MS Thesis. Ferdowsi University. Mashhad (Iran)

Fernandez J.M., Lu C.D., Potchoiba M.J., Loetz E., 1989. Dietary energy allowance and incidence of pregnancy toxemia in dairy goats. Fed. Am. Soc. Exp. Biol. J. 3, A1256 (Abstr.)

Gao F., Hou X.Z., Liu Y.C., Wu S.Q., Ao C.J., 2008. Effect of maternal under-nutrition during late pregnancy on lamb birth weight. Asian-Australas. J. Anim. Sci. 21, 371–375, https://doi.org/10.5713/ajas.2008.70187

Gül S., Keskin M., Göçmez Z., Gündüz Z., 2016. Effects of supplemental feeding on performance of Kilis goat kept on pasture condition. Ital. J. Anim. Sci. 15, 110–115, https://doi.org/10.1080/1828051X.2015.1132542

Hossain M.E., Shahjalal M., Khan M.J., Hasanat M.S., 2003. Effect of dietary energy supplementation on feed intake, growth and reproductive performance of goats under grazing condition. Pak. J. Nutr. 2, 159–163, https://doi.org/10.3923/pjn.2003.159.163

Idamokoro E.M., Muchenje V., Masika P.J., 2017. Peri- and post-parturient consequences of maternal undernutrition of free ranging does: a review. Livest. Res. Rural Dev. 29, 202, http://www.lrrd.org/lrrd29/10/mond29202.html

Ivey D.S., Owens F.N., Sahlu T., Teh T.H., Dawson L.J., Campbell G.A., Goetsch A.L., 2000. Influences of the number of fetuses and levels of CP and ME in gestation and lactation supplements on performance of Spanish does and kids during suckling and post-weaning. Small Ruminant Res. 35, 123–132, https://doi.org/10.1016/S0921-4488(99)00083-8

McGregor B.A., 1988. Effects of different nutritional regimens on the productivity of Australian Cashmere goats and the partitioning of nutrients between cashmere and hair growth. Aust. J. Exp. Agric. 28, 459–467, https://doi.org/10.1071/EA9880459

McGregor B.A., 1992. Effect of supplementary feeding, seasonal pastoral conditions and liveweight on cashmere production and cashmere fiber diameter. Small Ruminant Res. 8, 107–119, https://doi.org/10.1016/0921-4488(92)90012-S

McGregor B.A., 2016. The effects of nutrition and parity on the development and productivity of Angora goats: 1. Manipulation of mid pregnancy nutrition on energy intake and maintenance requirement, kid birth weight, kid survival, doe live weight, and mohair production. Small Ruminant Res. 145, 65–75, https://doi.org/10.1016/j.smallrumres.2016.10.027

McGregor B.A., 2017. The effects of nutrition and parity on the development and productivity of Angora goats: 2. Effects of six combinations of mid pregnancy and postnatal nutrition on energy intake and doe live weight, body condition, and mohair production. Small Ruminant Res. 156, 42–49, https://doi.org/10.1016/j.smallrumres.2017.08.014

McGregor B.A., 2018. The effects of nutrition and parity on the development and productivity of Angora goats: 3. Effects of six combinations of mid pregnancy and postnatal nutrition on udder development, lactation, milk composition and net energy of milk production. Small Ruminant Res. 161, 13–23, https://doi.org/10.1016/j.smallrumres.2018.02.005

McGregor B.A., Butler K.L., 2008. The effects of cashmere attributes on the efficiency of dehairing and dehaired cashmere length. Text. Res. J. 78, 486–496, https://doi.org/10.1177/0040517507087679

Menke K.H., Steingass H., 1988. Estimation of the energetic feed value obtained from chemical analysis and in vitro gas production using rumen fluid. Anim. Res. Develop. 28, 7–55

Mohammadi H., Moradi Shahrebabak M., Moradi Shahrebabak H., 2012. Genetic parameter estimates for growth traits and prolificacy in Raeini Cashmere goats. Trop. Anim. Health Prod. 44, 1213–1220, https://doi.org/10.1007/s11250-011-0059-z

NRC (National Research Council), 2007. Nutrient Requirements of Small Ruminants: Sheep, Goats, Cervids, and New World Camelids. The National Academies Press. Washington, DC (USA), https://doi.org/10.17226/11654

Rastogi A., Dutta N., Sharma K., 2003. Effect of strategic feed supplementation during gestation on intake, blood-biochemical profile and reproductive performance of goats. Asian-Australas. J. Anim. Sci. 16, 1725–1731, https://doi.org/10.5713/ajas.2003.1725

Ríos-Rincón F.G., Estrada-Angulo A., Plascencia A., López-Soto M.A., Castro-Pérez B.I., Portillo-Loera J.J., Robles-Estrada J.C., Calderón-Cortes J.F., Dávila-Ramos H., 2014. Influence of protein and energy level in finishing diets for feedlot hair lambs: growth performance, dietary energetics and carcass characteristics. Asian-Australas. J. Anim. Sci. 27, 55–61, https://doi.org/10.5713/ajas.2013.13307

Sahlu T., Hart S.P., Le-Trong T., Jia Z., Dawson L., Gipson T., Teh T.H., 1995. Influence of prepartum protein and energy concentrations for dairy goats during pregnancy and early lactation. J. Dairy Sci. 78, 378–387, https://doi.org/10.3168/jds.S0022-0302(95)76646-2

Shelton M., Groff J.L., 1974. Reproductive efficiency in Angora goats. Report PR 1136. Texas Agricultural and Mechanical University. College Station, TX (USA)

Snyman M.A., 2010. Influence of body weight, age and management system on reproduction of South African Angora goat does. S. Afr. J. Anim. Sci. 40, 41–53, https://doi.org/10.4314/sajas.v40i1.54129

van der Westhuysen J.M., 1980. Reproductive efficiency of Angoras in South Africa. S. Afr. J. Anim. Sci. 10, 99–101, https://www.ajol.info/index.php/sajas/article/view/139764/129474

Wang Z., Li H., Su R., Liu Z., Wang R., Zhang Y., Du C., Li J., 2019. Relationships between cashmere production and other important economic traits of Inner Mongolia cashmere goats. Ital. J. Anim. Sci. 18, 1154–1160, https://doi.org/10.1080/1828051X.2019.1626776