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Research Article

Influence of maternal dietary energy and protein levels during gestation on carcass and non-carcass parameters of Black Bengal kids

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Abstract

The study was aimed to know the effect of maternal dietary energy and protein levels during gestation on carcass and non-carcass traits of Black Bengal kids. The diets containing three levels of metabolizable energy i.e., low, medium, high energy (8.67, 10.4, 11.73 MJ/Kg DM, respectively) and three different levels of proteins i.e., low, medium, high protein (10%, 14% and 18%, respectively) were randomly assigned to stall-fed 45 pregnant Black Bengal does in nine treatment groups throughout the gestation period. At the age of six months, the male kids (n=45) were slaughtered to study carcass parameters. All data were analyzed by GLM procedures of SPSS software version 20. Results showed that at the time of slaughter the kids were heavier in the high-energy and high-protein group than others. Similarly, maternal dietary energy and protein also significantly increased carcass weight, total weight gain and rib eye area of kids. Body length, heart girth and length of the neck were higher in high energy and high protein group of kids than others. Maternal dietary energy and protein significantly influenced the weights of different parts of carcass including shoulder, loin, rack neck, fore limb, hind limb, thigh, head, heart, pluck, liver, kidney and skin. Thus, the present study suggests that maternal dietary energy and protein during gestation positively influence carcass and non-carcass parameters in Black Bengal kids.

Introduction

Goat production plays an important role in income generation, poverty alleviation, food security, and the socioeconomic development of rural communities in developing countries, including Bangladesh. Goats are particularly suitable for smallholder farming systems because of their small body size, relatively low maintenance requirements, adaptability to diverse environmental conditions, and ability to utilize a wide range of feed resources. They can be easily managed by women and children and are often considered an important source of income for resource-limited households. Among the indigenous goat breeds of Bangladesh, the Black Bengal goat is highly valued for its early sexual maturity, high prolificacy, excellent meat quality, superior skin characteristics, disease resistance, and adaptability to adverse agro-climatic conditions (Devendra and Burns, 1983; Husain et al., 1998). Despite these favorable characteristics, the productivity of Black Bengal goats remains relatively low, primarily because of inadequate nutrition, poor management practices, and limited availability of quality feed resources. Low birth weight, insufficient maternal nutrition, and poor growth performance, particularly among multiple-born kids, are important constraints to sustainable goat production (Sarkar et al., 2008; Kawsar et al., 2006). Nutritional inadequacy is therefore considered a major limiting factor affecting reproductive efficiency, growth, and productivity in small ruminants (Mira et al., 2019).

Maternal nutrition during gestation is a critical determinant of fetal development, birth weight, and subsequent growth performance of offspring. Pregnancy is characterized by increasing nutritional requirements to support maternal maintenance, placental development, fetal growth, and preparation for lactation. These requirements become particularly pronounced during the latter stages of gestation, when fetal growth and nutrient deposition accelerate. Insufficient maternal nutrient intake during this period may compromise fetal development and negatively affect the productive potential of offspring. Conversely, adequate maternal nutrition can improve fetal growth, enhance neonatal viability, and support postnatal development. Maternal dietary energy and protein are particularly important because they provide the essential nutrients required for fetal tissue synthesis, muscle development, and metabolic activity (Manso et al., 1998; Muwalla et al., 1998; Haddad et al., 2001; Bellof and Pallauf, 2004).

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Dietary energy is essential for maintaining maternal physiological functions and supporting fetal growth and tissue development. An inadequate energy supply during gestation may restrict fetal growth, reduce birth weight, and impair subsequent growth performance. Energy availability also influences nutrient utilization, protein synthesis, and the deposition of muscle and adipose tissues. Similarly, dietary protein provides amino acids required for fetal tissue formation, muscle development, and placental function. An adequate protein supply is therefore necessary to support fetal growth and maternal metabolic requirements throughout pregnancy. Previous studies have demonstrated that maternal protein supplementation during gestation can positively influence postnatal growth and adipose tissue deposition in male progeny, as well as reproductive performance in female offspring (Larson et al., 2009). Wang et al. (2020) also reported that higher dietary crude protein levels could improve production performance and meat-related characteristics in goats. Similarly, Hatfield et al. (1995) observed greater lamb birth weights when pregnant ewes received diets containing higher protein levels. These findings indicate that maternal dietary protein plays an important role in determining the growth potential and productive performance of offspring.

The concept of fetal programming suggests that nutritional conditions during pregnancy can induce long-term changes in the development, metabolism, and physiological characteristics of offspring. Maternal nutritional status may influence fetal muscle development, adipose tissue deposition, organ development, and metabolic regulation, with consequences extending beyond birth (Long et al., 2010; Radunz et al., 2012). Inadequate maternal nutrition has been associated with reduced fetal growth and alterations in muscle and adipose tissue development (Gao et al., 2008; Brameld et al., 2000). In particular, fetal muscle development is sensitive to nutritional conditions because the formation and proliferation of muscle cells occur during specific developmental stages. Reduced maternal nutrient availability may decrease myoblast proliferation and accelerate muscle fiber differentiation, potentially limiting the capacity for subsequent muscle growth (Brameld et al., 2000). Consequently, maternal nutritional management may influence not only birth weight but also postnatal growth rate, carcass composition, and meat production potential.

Carcass characteristics are important indicators of meat production efficiency and economic value in goats. Slaughter weight, carcass weight, dressing percentage, muscle development, and the distribution of carcass cuts determine the quantity and quality of meat available for consumption. Non-carcass components, including the head, skin, liver, heart, kidneys, lungs, and other organs, are also economically and nutritionally important, particularly in traditional goat production systems where these components are commonly consumed or marketed. Maternal nutritional management may influence the development and relative proportions of these components through its effects on fetal growth, organ development, and postnatal body composition. Previous research has demonstrated that prepartum nutritional treatments can significantly influence carcass composition and the deposition of muscle and fat in sheep (Radunz et al., 2012). Therefore, evaluating both carcass and non-carcass characteristics is essential for understanding the overall productive response of offspring to maternal nutrition. Although the effects of maternal nutrition on fetal development and offspring performance have been investigated in several livestock species, information regarding the combined effects of dietary energy and protein levels during gestation on carcass and non-carcass characteristics of Black Bengal goats remains limited. Given the importance of this indigenous breed to rural livelihoods and meat production in Bangladesh, identifying appropriate maternal nutritional strategies is essential for improving its productive potential. Therefore, the present study was designed to investigate the effects of different maternal dietary energy and protein levels during gestation on slaughter weight, growth performance, carcass characteristics, and non-carcass parameters of Black Bengal kids. The findings are expected to contribute to the development of improved nutritional management strategies for pregnant Black Bengal does and enhance the efficiency and profitability of goat production in Bangladesh.

Materials and Methods

Animals and their management

The experiment was carried out at the Goat, Sheep, and Horse Farm under the Department of Animal Science, Bangladesh Agricultural University, Bangladesh. Forty-five one-year-old pre-pubertal Black Bengal does with an average body weight of 11.68 ± 0.27 kg (mean ± SD) were divided into nine groups to equalize for initial weight and live weight of does. Does were fed individually on nine different treatments arranged as 3×3 factorial experiment in a completely randomized design feeding trial, as follows: Hh- ME 11.7 (MJ/Kg) and protein 18%, Hm- ME 11.7 (MJ/Kg) and protein 14%, Hl- ME 11.7 (MJ/Kg) and protein 10%, Mh- ME 10.4 (MJ/Kg) and protein 18%, Mm- ME 10.4 (MJ/Kg) and protein 14%, Ml- ME 10.4 (MJ/Kg) and protein 10%, Lh- ME 8.7 (MJ/Kg) and protein 18%, Lm- ME 8.7 (MJ/Kg) and protein 14%, Ll- ME 8.7 (MJ/Kg) and protein 10% (Table 1).

Nine diets were formulated using commonly available feed ingredients such as Napier grass, wheat bran, maize crushed, soybean meal, molasses, DCP (di-calcium phosphate) and common salt. The medium diet was formulated to contain ME 10.4 MJ/Kg DM and 14% crude protein (NRC, 2007). The other two different energy and protein levels were high energy (ME 11.7 MJ/Kg DM) and high protein (18% CP) and low energy (ME 8.7 MJ/Kg DM) and low protein (10% CP). The ingredients and chemical composition of formulated experimental diets are presented in Table 1. Every week, the amount and content of nutrients in the diet were modified based on changes in the live weight of animals across different treatments. Requirement for energy and protein was calculated depending upon the body weight of goats and the energy and protein requirements for pregnancy. Goats were fed two times in a day. The required amount of feed for individual goat was divided into two equal parts. One portion was provided in the morning and the rest of the feed was provided in the afternoon. Fresh water was supplied *ad-libitum.*

Kid management

After birth, dry clothes were used to gently touch the noses of kids in order to clear mucus. Kids were weighed with the help of a digital balance immediately after birth to know their birth weight. Within thirty minutes of delivery, the kids were permitted to suck colostrum. Kids were fed only milk from their mother for a month after birth. After one month, they were allowed to eat succulent roughage and concentrate mixture.

Table 1: The ingredients and chemical composition of all dietary combinations on a dry matter basis

Name of the ingredients (%)	Diet[1,2]								
[1]ME	High			Medium			Low		
[2]CP	high	medium	low	high	medium	low	high	medium	low
Napier	31.7	35.6	48.3	57.6	61	59.6	71.5	68.7	89
Soybean meal	20.4	10.3	1	21	9.5	1	25.2	12.6	1
Maize crushed	24.7	31	37.2	9.4	13.4	27.8	0.8	8.2	4
Wheat bran	20.6	19.9	10.4	9.4	13.4	8.1	0.8	8.2	4.5
Molasses	1.7	2.2	2.1	1.8	1.8	2.6	0.8	1.4	0.5
[3]DCP	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Common Salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100	100	100	100	100
Chemical Composition									
ME (MJ/Kg)	11.7	11.7	11.7	10.4	10.4	10.4	8.7	8.7	8.7
CP (%)	18	14	10	18	14	10	18	14	10
NDF (%)	37.5	39.7	44.4	49.4	52.9	50.4	54.9	55.8	67.2
ADF (%)	18.1	19.3	23.1	27.2	28.7	27.3	32	31.3	38.6
Ca (%)	0.3	0.2	0.4	0.5	0.3	0.4	0.5	0.5	0.5
P (%)	0.5	0.5	0.5	0.6	0.4	0.5	0.5	0.5	0.4
Feed intake (g/day) (Fresh basis)	2703.76	2668.90	2852.62	2830.19	2717.62	2669.05	2726.48	2618.24	2871.29

Goats were housed in separate pens. The floor space per does was 1.38 square meter. The house was well ventilated. All the goats where stall fed. Separate feeder was used for roughage and concentrate feeding. Before starting the experiment, the goats were allowed to adjust to the experimental conditions and diets for 15 days. The experimental feeding trial was conducted from conception to the parturition of goats. Does were mated with pure Black Bengal bucks once they showed signs of estrus.

Pre-slaughter body measurement of kids

Kids were weighed before slaughter by electric balance to measure slaughter weight. Body length, heart girth, height at wither, circumference of neck and length of the neck of kids were measured before slaughtering of kids. Body measurement records of kids were taken individually by using a measuring tape. The distance between the base of the ear and the base of the tail was known as body length. Wither height was measured from the highest point of the wither to the ground when the animal was standing squarely on all four feet, all of its legs extended vertically toward the ground, and its head held erect but relaxed. Heart girth was measured as a circumferential measurement across the chest, directly behind the front legs and withers. Neck length was the distance between the base of head and point of shoulder. Circumference of the neck was measured from three distinct parts namely apex, middle and base of the neck.

Slaughtering method

Kids were slaughtered to study the carcass and non-carcass parameters. Before slaughtering kids were fasted for whole night. The "Halal" method of slaughtering was followed. By this method kids were bled by cutting throat and then slaughtered by severing the head at its articulation on the occipitoatlantal space. The conventional procedure of flaying was followed.

Post-slaughter measurements

After sacrificing, slaughtered kids were hoisted by the ropes. The head was removed and weighed. The weight of skin, feet, entire digestive tract and after removing gut fill, the empty gut weight was measured and recorded. Liver, kidney, heart, pluck, spleen, lung with trachea were removed and weighed separately. Warm carcass weight was recorded immediately after completing dressing and evisceration. Rib-eye area (REA) was also determined measuring both "X" and "Y" and then applying the values into the following equation: $(X/2 \times Y/2) \times \pi$, where "X" is the maximal length (cm) of the longissimus dorsi muscle and "Y" is its maximal depth (cm); both measurements were taken perpendicularly from one another; π equals to 3.1416 (Osório and Osorio, 2005).

Carcass characteristics and dressing percentage

After flaying and evisceration, different carcass cuts (shoulder, neck, rack, fore shank, hind shank, loin, rump, thigh) were separated and weights were recorded using digital balance. Dressing percentage was measured from the warm carcass weight using following equation:

Dressing percentage (%) = (Hot carcass weight/live weight) × 100

Statistical analysis

Data were analyzed by the General Linear Model (GLM) procedures of SPSS software, version 20. The model used to analyze the data was as follows:

$Yij = \mu + \alpha i + \beta j + (\alpha\beta)ij + \varepsilon ij,$

Where Yij = individual observation, μ = the overall mean

αi = dietary ME effect

βj = dietary CP effect

$(\alpha\beta)ij$ = interaction effect between ME and CP

εij = error component.

Data were presented as mean ± SEM (Standard Error of Mean). Dunkan's multiple range test (DMRT) was conducted to compare the means of the values.

Results

Growth performance of kids

Maternal dietary energy and protein levels during gestation positively influenced the growth performance of Black Bengal kids (Table 2).

Table 2: Effect of different levels of maternal dietary energy and protein during gestation on live weight (Kg) changes of kids

Parameters	Treatments									Level of significance
	Hh	Hm	Hl	Mh	Mm	Ml	Lh	Lm	Ll	
Birth weight (kg)	1.4^{a} ± 0.05	1.3^{ab} ± 0.08	1.1^{bcd} ± 0.08	1.2^{abc} ± 0.05	1.2^{bc} ± 0.03	1.1^{bcd} ± 0.05	1.0^{cd} ± 0.1	1.0^{cd} ± 0.05	0.9^{d} ± 0.05	*
Slaughter weight (kg)	8.6^{a} ± 0.2	7.7^{b} ± 0.1	7.2^{bc} ± 0.16	7.0^{bc} ± 0.2	6.8^{cd} ± 0.1	6.2^{de} ± 0.14	5.9^{ef} ± 0.06	5.2^{fg} ± 0.4	4.9^{g} ± 0.40	*
Total live weight gain (kg)	7.3^{a} ± 0.2	6.36^{b} ± .06	6.0^{b} ± 0.2	5.8^{bc} ± 0.2	5.6^{bcd} ± 0.08	5.13^{cd} ± 0.18	4.9^{de} ± 0.13	4.23^{ef} ± 0.4	4.0^{f} ± 0.35	*
Weight gain (g/d)	0.04^{a} ± 0.2	0.03^{b} ± .06	0.03^{b} ± .06	0.03^{bc} ± 0.2	0.03^{bcd} ± .08	0.02^{cd} ± .18	0.02^{de} ± .13	0.02^{ef} ± 0.4	0.02^{f} ± .35	*

*= significant (p<0.05)

^{a,b,c} means on the same column with different superscripts differ significantly (p<0.05)

Hh= High Energy High Protein, Hm= High Energy Medium Protein, Hl= High Energy Low Protein

Mh= Medium Energy High Protein, Mm= Medium Energy Medium Protein, Ml= Medium Energy Low Protein

Lh= Low Energy High Protein, Lm= Low Energy Medium Protein, Ll= Low Energy Low Protein

Among the treatment combinations, kids from the high-energy and high-protein (Hh) group had the highest birth weight, slaughter weight, and total live weight gain, whereas the lowest values were observed in the low-energy, low-protein (Ll) group ($p < 0.05$). Maternal dietary energy level significantly influenced slaughter weight, and total live weight gain of kids ($p < 0.001$). Maternal dietary protein level also affected growth performance. Birth weight ($p = 0.040$), slaughter weight ($p < 0.001$), and total live weight gain ($p = 0.001$) increased with increasing dietary protein level, with the highest values recorded in kids from does feed high-protein diets.

Significant energy × protein interactions were observed for slaughter weight and total live weight gain ($p < 0.01$). The combination of high dietary energy and high protein resulted in the greatest growth performance, whereas the low-energy, low-protein combination produced the lowest values.

Pre- slaughter body measurements of kids

Pre-slaughter body measurements of kids are affected by maternal dietary energy and protein are illustrated in Table 3.

Table 3: Effect of maternal dietary energy and protein levels during gestation on pre-slaughter body measurements of Black Bengal kids

Parameters	Diet[1,2]									Probability[3]		
	[1]ME	High			Medium			Low					
	[2]CP	high	medium	low	high	medium	low	high	medium	low	ME	CP	ME×CP
Body length (cm)		44.3^{a}± 25.6	41.3^{ab}± 0.7	36.3^{bc}± 0.9	37.3^{abc}± 1.5	38.3^{abc}± 0.3	38.3^{abc}± 0.3	38.0^{b}± 0.6	34.0^{d}± 2.1	33.7^{d}± 1.9	0.000	0.005	0.000
Height at wither (cm)		39.3± 22.7	35.7± 0.3	36.0± 2.0	36.3± 1.9	37.3± 1.5	37.3± 1.5	39.0±1. 2	35.3± 2.4	34.7± 1.2	0.857	0.111	0.417
Heart girth (cm)		48.3^{a}± 27.9	41.7^{bc}± 0.3	42.3^{bc}± 0.3	42.3^{bc}± 0.3	39.3^{bc}± 1.8	39.3^{bc}± 1.8	40.7^{bc}± 2.3	39.0^{bc}± 2.1	37.7^{c}± 2.0	0.002	0.008	0.004
Length of neck (cm)		14.7^{a}± 8.5	13.3^{ab}± 0.3	13.7^{ab}± 0.7	14.0^{ab}± 0.6	13.3^{ab}± 0.3	13.3^{ab}± 0.3	13.3^{ab}± 0.3	12.7^{ab}± 0.7	12.0^{b}± 1.0	0.059	0.144	0.040
Neck circumferences													
Apex		19.0^{a}± 11.0	18.3^{ab}± 0.3	18.0^{ab}± 0.0	18.0^{ab}± 0.0	18.7^{ab}± 0.3	17.7^{ab}± 0.9	17.3^{ab}± 0.7	17.3^{ab}± 0.9	16.7^{b}± 0.7	0.029	0.648	0.040
Middle		20.3^{a}± 11.7	19.7^{ab}± 0.3	19.3^{ab}± 0.3	20.0^{ab}± 0.0	19.3^{ab}± 0.3	19.0^{ab}± 1.0	18.0^{bc}± 0.6	18.3^{abc}± 0.9	16.7^{c}± 1.5	0.007	0.221	0.041
Base		26.0^{a}± 15.0	23.7^{ab}± 0.3	23.3^{b}± 0.3	23.0^{bc}± 0.6	24.3^{ab}± 0.3	23.0^{b}± 1.0	23.7^{ab}± 0.9	21.7^{bc}± 1.2	20.3^{c}± 1.3	0.006	0.026	0.009

$^{a-f}$Mean values in the same row with different superscripts differ (P<0.05) for the interaction between energy and protein.

[1]ME levels: H = High energy (11.7 MJ/Kg), M = Medium energy (10.4 MJ/Kg), L = Low energy (8.7 MJ/Kg).

[2]CP levels: h = high protein (18%), m = medium protein (14%), l = low protein (10%).

[3]Probability of treatment effects: ME = main effects of energy; CP= main effect of protein: ME×CP = interaction between energy and protein

There were significant (p<0.05) differences in body length, heart girth and neck length among different treatment groups. Interaction between dietary ME and CP significantly (p<0.05) influences the body length, heart girth, neck length and circumference of the neck (apex, middle and base) except wither height of kids. In the high- and low-ME diets, body length and neck circumference at the base increased when CP levels grew from low to high, but in the medium-ME diet, these parameters stayed mostly constant. Similarly, neck length and neck circumference at the apex and middle remained largely unaffected by CP level within the high- and medium-ME diets but increased with increasing CP level within the low-ME diet. Heart girth showed a somewhat similar pattern, rising as CP level increased in the high-ME diet, staying mostly unchanged in the medium-ME diet, and slightly rising in the low-ME diet.

Carcass characteristics of kids

The effect of the dietary ME and CP levels on carcass characteristics of kids are shown in Table 4.

Table 4: Effect of maternal dietary energy and protein on carcass characteristics of Black Bengal kids

Parameters	Diet[1,2]									Probability[3]		
	High			Medium			Low					
[1]ME / [2]CP	high	medium	low	high	medium	low	high	medium	low	ME	CP	ME×CP
Total weight gain (Kg)	7.3[a] ± 0.2	6.36[b] ± 0.06	6.0[b] ± 0.2	5.8[bc] ± 0.2	5.6[bcd] ± 0.08	5.13[cd] ± 0.18	4.9[de] ± 0.13	4.23[ef] ± 0.4	4.0[f] ± 0.35	0.000	0.001	0.001
Slaughter weight	8.6[a] ± 0.2	7.7[b] ± 0.1	7.2[bc] ± 0.2	7.0[bc] ± 0.2	6.8[cd] ± 0.1	6.2[de] ± 0.1	5.9[ef] ± 0.1	5.2[fg] ± 0.4	4.9[g] ± 0.4	0.000	0.000	0.000
Carcass weight (Kg)	4.0[a] ± 0.2	3.50[ab] ± 0.1	3.2[bc] ± 0.2	3.1[bc] ± 0.1	3.0[bcd] ± 0.2	2.7[cde] ± 0.2	2.7[cde] ± 0.2	2.5d[ef] ± 0.1	2.2[ef] ± 0.3	0.000	0.004	0.000
Dressing percentage	46.1 ± 1.0	45.9 ± 1.6	44.6 ± .4	44.7 ± 1.5	44.3 ± 2.6	43.5 ± 2.6	43.5 ± 2.6	42.3 ± 2.2	41.4 ± 2.1	0.045	0.596	0.428
Rib eye area (mm^2)	568.3[a] ± 52.3	438.0[bc] ± 19.1	463.7[a bc] ± 64.3	522.0[ab] ± 70.1	398.7[bcd] ± 6.7	308.3[d] ± 55.0	352.7[de] ± 28.0	316.0[de] ± 34	277.0[e] ± 30.1	0.001	0.006	0.002

[a-f]Mean values in the same row with different superscripts differ (P<0.05) for the interaction between energy and protein.

[1]ME levels: H = High energy (11.7 MJ/Kg), M = Medium energy (10.4 MJ/Kg), L = Low energy (8.7 MJ/Kg).

[2]CP levels: h = high protein (18%), m = medium protein (14%), l = low protein (10%).

[3]Probability of treatment effects: ME = main effects of energy; CP= main effect of protein: ME×CP = interaction between energy and protein

Both energy and protein had significant ($p<0.05$) impact on slaughter weight, carcass weight, and rib-eye area except dressing percentage. Slaughter weight, carcass weight, and REA decreased as CP level declined from high to low within each ME level. The highest values for these traits were observed in kids receiving the high-ME and high-CP diet, whereas the lowest values were recorded in those fed the low-ME and low-CP diet. Within each CP level, slaughter weight, carcass weight, and REA generally decreased with decreasing ME level.

Post- slaughter body measurements of kids

Different part of carcass

The effects of different levels of dietary energy and protein during gestation on different parts of carcass of kids are shown in Table 5.

Table 5: Effect of maternal dietary energy and protein on carcass parts of Black Bengal kids

Parameters	[1]ME	Diet[1,2]									Probability[3]		
		High			Medium			Low					
	[2]CP	high	medium	low	high	medium	low	high	medium	low	ME	CP	ME×CP
Weight of Shoulder (g)		648[a]	618[a]	565[ab]	539[abc]	540[abc]	477[bcd]	421.3[cde]	360.3[de]	338.7[e]			
		±	±	±	±	±	±	±	±	±	0.000	0.099	0.000
		30.3	15.0	44.2	31.1	56.9	35.5	29.1	49.1	56.3			
Rack (g)		1016[a]	847[b]	738[bcd]	821.7[b]	780[bc]	679[bcde]	625.3[cde]	589.3[de]	535.7[e]			
		±	±	±	±	±	±	±	±	±	0.000	0.006	0.000
		49.4	56.1	12	15.9	79.6	79.2	31.4	82.4	50.4			
Loin (g)		396[a]	367[a]	338[ab]	256.3[ab]	293[ab]	275.3[b]	172[ab]	220.3[b]	161.7[ab]			
		±	±	±	±	±	±	±	±	±	0.002	0.727	0.040
		136.5	18.6	29.6	31.8[a]	28.1	33.2	28.2	27.5	33.9			
Neck (g)		371[a]	351[a]	321[ab]	306.3[ab]	308[ab]	220.3[cd]	269.3[bc]	208.0[cd]	169[d]			
		±	±	±	±	±	±	±	±	±	0.000	0.002	0.000
		12.8	21.6	28.1	23.1	35.5	10.9	22.8	22.5	16.7			
Fore limb (g)		180.7[a]	151.7[ab]	142[abc]	143[abc]	130.3[bcd]	113.7[bcd]	127.7[bcd]	99.3[cd]	84.3[d]			
		±	±	±	±	±	±	±	±	±	0.001	0.024	0.011
		32.7	3.3	8.9	10.1	9.3	9.7	19.9	12.0	8.4			
Hind limb (g)		233[a]	223.3[a]	203[ab]	203.3[ab]	187[ab]	170[bc]	168.3[bc]	133.7[cd]	120.3[d]			
		±	±	±	±	±	±	±	±	±	0.000	0.020	0.000
		9.5	3.7	10.2	8.2	19.7	11.7	28.9	13.4	10.1			
Fore shank (g)		124.7[a]	103[ab]	101[ab]	108.7[a]	101.3[ab]	117.3[a]	106.7[a]	81.3[ab]	61.7[b]			
		±	±	±	±	±	±	±	±	±	0.036	0.143	0.040
		9.1	6.4	12.1	3.8	6.4	28.9	14.2	10.7	6.9			
Hind shank (g)		101.0	104.0	101.3	95.0	85.7	85.0	90.0	93.3	76.3			
		±	±	±	±	±	±	±	±	±	0.075	0.486	0.378
		4.7	13.8	6.4	7.6	5.9	4.0	13.0	9.6	4.4			
Rump (g)		431.7	329.3	346	375.0	356.0	246.3	246.7	207.7	242.0			
		±	±	±	±	±	±	±	±	±	0.083	0.450	0.395
		153.7	38.1	34.6	37.1	99.0	50.0	45.8	43.7	46.5			
Thigh (g)		652[a]	652[a]	435[bc]	662.7[a]	492.7[b]	486.7[b]	442.3[bc]	324.3[cd]	281.3[d]			
		±	±	±	±	±	±	±	±	±	0.000	0.000	0.000
		43.6	23.7	10.7	85.2	64.2	33.2	23.7	41.6	38.0			

[a-f]Mean values in the same row with different superscripts differ (P<0.05) for the interaction between energy and protein.

[1]ME levels: H = High energy (11.7 MJ/Kg), M = Medium energy (10.4 MJ/Kg), L = Low energy (8.7 MJ/Kg).

[2]CP levels: h = high protein (18%), m = medium protein (14%), l = low protein (10%).

[3]Probability of treatment effects: ME = main effects of energy; CP= main effect of protein: ME×CP = interaction between energy and protein

Both energy and protein had significant ($p<0.05$) impact on weight of shoulder, rack, neck, fore limb, hind limb and thigh of kids. Weights of the shoulder, rack, neck, fore limb, hind limb, and thigh decreased as CP level declined from high to low within all ME levels. Similarly, the weights of these cuts generally decreased with decreasing ME level within each CP level, with the highest values observed in kids fed the high-ME, high-CP diet and the lowest values in those fed the low-ME, low-CP diet.

Loin weight also tended to decrease with decreasing ME level; however, the response to CP level was less consistent within ME levels. Likewise, fore shank weight declined with decreasing ME level, although its response to CP level varied among ME levels.

Edible by-products

The effects of different levels of dietary energy and protein during gestation on edible by products in Black Bengal kids are shown in Table 6.

Table 6: Effect of maternal dietary energy and protein during gestation on edible by products in Black Bengal kids

Parameters	[1]ME	Diet[1,2]							Probability[3]				
		High			Medium			Low					
	[2]CP	high	medium	low	high	medium	low	high	medium	low	ME	CP	ME×CP
Weight of Head (g)		681.7^{a} ± 57.9	629.0^{ab} ± 17.3	613.3^{ab} ± 15.9	587.7^{bc} ± 13.5	599.7^{abc} ± 20.5	546.7^{bc} ± 21.3	556.7^{bc} ± 7.7	516.3^{cd} ± 30.6	448.3^{d} ± 28.5	0.000	0.015	0.001
Pluck (g)		411.3^{a} ± 24.9	389.0^{ab} ± 21.7	361.0^{ab} ± 25.1	357.3^{ab} ± 7.7	328.7^{b} ± 29.6	319.7^{bc} ± 6.7	324.3^{b} ± 36.9	254.3^{c} ± 10.4	254.0^{c} ± 8.6	0.000	0.021	0.001
Heart (g)		47.0^{a} ± 2.0	41.3^{a} ± 4.0	34.3^{bc} ± 2.6	41.0^{a} ± 4.2	35.3^{ab} ± 4.5	39.7^{a} ± 6.7	41.3^{a} ± 6.2	24.3^{b} ± 3.4	24.7^{b} ± 3.2	0.017	0.081	0.019
Spleen (g)		26.7^{a} ± 7.7	16.3^{ab} ± 2.3	14.3^{b} ± 1.5	13.7^{b} ± 1.5	20.0^{ab} ± 4.5	19.3^{ab} ± 4.1	17.0^{ab} ± 3.6	12.0^{b} ± 0.6	9.3^{b} ± 1.2	0.113	0.295	0.047
Liver (g)		223.7^{a} ± 16.5	193.3^{ab} ± 21.3	188.3^{ab} ± 20.5	190.7^{ab} ± 1.5	171.7^{bc} ± 18.7	154.7^{bcd} ± 9.1	163.3^{bcd} ± 18.8	134.7^{cd} ± 0.9	122.3^{d} ± 4.6	0.000	0.018	0.004
Kidney (g)		94.7^{a} ± 18.1	49.7^{bc} ± 0.3	50.0^{bc} ± 5.1	56.0^{b} ± 8.6	44.0^{bc} ± 5.1	39.0^{bc} ± 4.7	39.7^{bc} ± 5.7	37.3^{bc} ± 3.7	29.7^{c} ± 2.2	0.001	0.003	0.001
Lung+Trachea (g)		146.3^{a} ± 14.4	148.7^{a} ± 2.3	138.3^{bc} ± 6.9	125.7^{abc} ± 9.9	121.7^{abc} ± 13.4	125.3^{abc} ± 4.1	119.7^{abc} ± 14.8	95.3^{c} ± 9.8	107.0^{bc} ± 4.0	0,001	0.537	0.022

[a-f]Mean values in the same row with different superscripts differ ($P<0.05$) for the interaction between energy and protein.

[1]ME levels: H = High energy (11.7 MJ/Kg), M = Medium energy (10.4 MJ/Kg), L = Low energy (8.7 MJ/Kg).

[2]CP levels: h = high protein (18%), m = medium protein (14%), l = low protein (10%).

[3]Probability of treatment effects: ME = main effects of energy; CP= main effect of protein: ME×CP = interaction between energy and proteinWeight of head and pluck decreased as CP level declined from high to low within all ME levels, with the highest values observed in kids fed the high-ME and high-CP diet and the lowest values in those fed the low-ME and low-CP diet. Similarly, both traits generally decreased with decreasing ME level within each CP level.

Heart weight showed a significant decrease with decreasing ME level, particularly within the medium- and low-ME diets, while its response to CP level was less consistent. Spleen weight did not show a clear pattern in response to dietary treatments. Liver and kidney weights decreased as CP level declined from high to low within all ME levels, and also decreased with decreasing ME level within most CP levels. In contrast, lung and trachea weight showed no consistent response to dietary ME or CP levels, and only the interaction effect was significant.

Non- edible by-products

Effect of maternal dietary energy and protein during gestation on non-edible by-products of Black Bengal kids are shown in Table 7.

Table 7: Effect of maternal dietary energy and protein during gestation on non-edible by-products of Black Bengal kids

Parameters	[1]ME	Diet[1,2]									Probability[3]		
		High			Medium			Low					
	[2]CP	high	medium	low	high	medium	low	high	medium	low	ME	CP	ME×CP
Weight of Skin (g)		671[a] ± 36.5	596.7[ab] ± 72.4	511.3[bc] ± 28.1	521.3[bc] ± 7.7	589.0[ab] ± 39.6	516.0[bc] ± 11.5	469.7[bc] ± 15.2	435.7[bc] ± 71.8	397.3[c] ± 36.7	0.001	0.072	0.006
Empty gut (Kg)		0.7[a] ± 0.1	0.6[ab] ± 0.1	0.5[b] ± 0.1	0.5[b] ± 0.0	0.5[b] ± 0.0	0.5[b] ± 0.0	0.5[b] ± 0.0	0.4[b] ± 0.1	0.5[b] ± 0.0	0.055	0.221	0.024
Gut fill (Kg)		1.8[a] ± 0.2	1.7[ab] ± 0.2	1.7[ab] ± 0.1	1.7[ab] ± 0.2	1.5[ab] ± 0.1	1.4[ab] ± 0.1	1.3[bc] ± 0.1	1.0[cd] ± 0.2	0.8[d] ± 0.1	0.000	0.100	0.000
Gut (Kg)		2.3[a] ± 0.1	2.3[a] ± 0.2	2.2[ab] ± 0.1	2.2[ab] ± 0.0	2.0[bc] ± 0.1	1.9[c] ± 0.1	1.8[c] ± 0.0	1.4[d] ± 0.1	1.3[d] ± 0.0	0.000	0.002	0.319
Feet (g)		315.3[a] ± 2.9	283.3[b] ± 4.4	271.0[c] ± 2.1	267.7[c] ± 4.6	266.0[c] ± 3.1	250.0[d] ± 2.9	250.0[d] ± 2.9	243.7[de] ± 2.4	238.0[de] ± 4.4	0.000	0.000	0.000

[a-f]Mean values in the same row with different superscripts differ (P<0.05) for the interaction between energy and protein.

[1]ME levels: H = High energy (11.7 MJ/Kg), M = Medium energy (10.4 MJ/Kg), L = Low energy (8.7 MJ/Kg).

[2]CP levels: h = high protein (18%), m = medium protein (14%), l = low protein (10%).

[3]Probability of treatment effects: ME = main effects of energy; CP= main effect of protein: ME×CP = interaction between energy and protein

Weight of skin decreased as CP level declined from high to low within all ME levels, with the highest values observed in kids fed the high-ME and high-CP diet and the lowest values in those fed the low-ME and low-CP diet. Similarly, skin weight generally decreased with decreasing ME level within each CP level, although the CP effect was not statistically significant.

Empty gut weight showed a slight decreasing pattern with decreasing CP and ME levels. Gut fill and gut weight both decreased as CP level declined from high to low within all ME levels, with the most pronounced reduction observed at the lowest ME and CP combination. Both parameters also decreased with decreasing ME level within most CP levels. Feet weight decreased as CP level declined from high to low among high, medium and low ME levels, and also decreased with reducing ME level, showing highly significant effects of ME, CP, and their interaction ($P < 0.01$).

Discussion

The higher liveweight gain of kids from the Hh treatment was reflected in their carcass characteristics. These kids had greater slaughter weight, carcass weight, and rib-eye area than those from the other maternal dietary treatments. The larger rib-eye area may indicate greater development of the *Longissimus dorsi* muscle, while the greater slaughter and carcass weights reflect the higher overall body mass attained by these offspring. These findings were consistent with Zhou et al. (2019), who reported that 40% maternal nutrient restriction during mid-gestation reduced liveweight, body size, and hot carcass weight. These findings indicated that maternal nutrient supply during gestation is important for growth and carcass development of offspring.

Carcass characteristics are important indicators of productive performance and are influenced by factors such as live weight and nutritional status (Luo et al., 2019; Wang et al., 2019; Francisco et al., 2020). Francisco et al. (2020) reported that liveweight and dietary composition were associated with variation in carcass characteristics. In the present study, maternal dietary energy and protein levels during gestation significantly affected several pre-slaughter body measurements of the offspring. Kids from the Hh treatment had greater body length, heart girth, and neck length than those from the other treatment groups. Similarly, Arafath et al. (2024) reported greater body length, heart girth, and wither height in Black Bengal kids born to dams receiving 18% CP compared with those receiving 14% or 10% CP. The greater body dimensions observed in the present study were consistent with the higher slaughter weight of kids from the Hh treatment. Because body length and heart girth are positively associated with liveweight in goats (Dorantes-Coronado et al., 2015), variation in these measurements may partly reflect differences in overall growth among the treatment groups. However, wither height did not differ significantly among the maternal dietary treatments, indicating that the response of individual body dimensions to maternal nutrition was not uniform.

The absence of a significant interaction between maternal dietary energy and protein levels on dressing percentage in the present study contrasts with findings from studies involving direct nutritional manipulation of growing animals. Dressing percentage has been reported to increase with increasing carcass fatness (Preston and Willis, 1975), while Gaili et al. (1972) observed an increase in dressing percentage from approximately 45% to 54% with fattening. Differences between these findings and the present results may be related to differences in the timing and duration of nutritional exposure, animal breed, slaughter age and weight, and carcass composition. In the present experiment, nutritional treatments were imposed on the does during gestation rather than directly on the growing offspring, which may partly explain the absence of a significant interaction effect on dressing percentage.

Maternal dietary energy and protein also affected the different parts of carcass. The weights of the shoulder, rack, neck, forelimb, hindlimb, and thigh were significantly higher ($p<0.05$) in kids from the Hh treatment. Kioumarsi et al. (2008) reported greater shoulder and thigh weights and rib-eye area in sheep receiving higher dietary energy. Similarly, Ebrahimi et al. (2007) observed greater back weight with higher dietary protein and greater neck weight with higher dietary energy in sheep. The greater weights of these parts in the present study were consistent with the higher slaughter weight of kids from the Hh treatment and may reflect greater overall tissue development. Significant differences were also observed in the weights of several edible by-products, including the head, heart, liver, kidney, and lung with trachea. Ibrahim (1996) reported that reducing dietary energy from 12.0 to 8.0 MJ/kg in male goats reduced dressing percentage and increased the proportion of body components such as the head, skin, feet, liver, and heart. This differs from the present findings, in which the absolute weights of several edible by-products were greater in kids from the Hh treatment. Such differences may be attributable, at least partly, to variation in overall body size and slaughter weight. Supporting this interpretation, Milis et al. (2005) reported greater kidney size and pelvic fat deposition in lambs receiving higher dietary energy, whereas Fluharty et al. (1997) observed greater liver and kidney weights and faster tissue accretion in lambs fed 18% CP than in those fed 14% CP.

The weights of several non-edible body components, including skin, empty gastrointestinal tract, gut contents, and feet, also differed significantly among treatments. These differences might partly reflect variation in body size and slaughter weight among the offspring. Silva et al. (2020) reported a positive association between crude protein intake and skin collagen abundance and found reduced skin thickness in pigs receiving a low-protein diet without supplemental glycine and serine. Similarly, Dawson and Milne (1978) demonstrated an effect of dietary nitrogen level on collagen characteristics in rat skin. Although these studies involved different species and experimental conditions, they provide evidence that protein availability can influence tissue development and composition.

Overall, the maternal dietary energy and protein treatments were associated with differences in kids' growth, body dimensions, carcass traits, and body-component weights. Kids from the Hh treatment had greater final body weight, body length, heart girth, and neck measurements, together with greater slaughter weight, carcass weight, rib-eye area, and weights of several carcass parts and organs. In contrast, kids from the Ll treatment generally exhibited lower values for these traits, consistent with their lower final body weight. Thus, maternal energy and protein supply during gestation may be associated with differential patterns of postnatal growth and carcass development in Black Bengal kids.

Conclusion

The results indicate that energy and protein concentration of maternal diet during pregnancy period have positive effect on carcass and non-carcass parameters of Black Bengal kids. Kids from the Hh treatment had greater final body weight, body length, heart girth, and neck measurements, together with greater slaughter weight, carcass weight, rib-eye area, and weights of several carcass parts and organs. In contrast, kids from the Ll treatment generally exhibited lower values for these traits, consistent with their lower final body weight. Thus, maternal dietary energy and protein during gestation increased slaughter weight, live weight gain and carcass characteristics in Black Bengal kids.

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