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Research Article

Carcass and Meat Quality of Growing Meat Goats as Influenced by Dietary Protein and Gastrointestinal Nematode Challenge

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Abstract

The effect of increased dietary protein supply on repeated Gastrointestinal Nematode (GIN) parasite *Haemonhus contortus* infection was assessed in growing meat goats. Using a 2×2 factorial design, 16 intact male bucks were divided into 4 groups based on presence of parasites and dietary protein level. Both Not Infected (NIF, control) and Infected (INF) goats were fed complete diets at 3.5% of Body Weight (BW) with either 200 (HP, high) or 100 (LP, low) protein (g/kg dry matter). INF goats were drenched with 400 infective third stage larvae (L3) three times a week for 12 consecutive weeks. The study lasted 90 days during which the experimental goats were maintained indoor sat all times and, at the end, twelve goats were harvested and processed. Each carcass was assessed for body weight, hot carcass weight, dressing percentage, organ weights and chemical composition. Meat quality was quantified as the tenderness of loin muscle measured as shear force (N/cm^2), HP goats showed better performance ($P < 0.01$) on clinical parameters (FAMACHA or anemic score, Fecal Egg Count (FEC) and Packed Cell Volume (PCV) to the parasite challenge. Increased dietary protein also improved ($P < 0.01$) weight gain (3.57 *vs* 2.86 kg) and carcass and meat quality over the course of the experiment. No differences were observed ($P > 0.05$) for pH or tenderness. This study suggests that high dietary protein content can offset the adverse impacts of GIN infection among growing bucks and yield acceptable carcass and meat quality.

Keywords: Growing meat goats; Dietary protein; Gastrointestinal nematodes; Carcass; Meat quality

Abbreviations

FAMACHA: FAffaMAlanCHArt; BW: Body Weight; BCS: Body Condition Score; FEC: Fecal Egg Count; GIN: Gastrointestinal Nematode; HP: High Protein; HE: High Energy; INF: Infected; LP: Low Protein; LE: Low Energy; NIF: Not Infected; PCV: Packed Cell Volume; LL: *Longissimus Thoracic Etlumborum*; VSU: Virginia State University

Introduction

In livestock production systems where animals are reared for their meat, carcass and meat quality traits are important since they can sway consumer's purchasing decision. Tenderness and sensory properties determine eating quality and therefore are important factors affecting meat acceptability [1-3]. Goat meat or Chevon is gaining popularity mainly because of its low-fat content [4], especially in developed countries where high fat diets are a health concern. Chevon has been reported to contain higher collagen content and consequent lower solubility compared to other red meats [5]. A comparative study found that goat meat is less tender than lamb due to its intramuscular connective tissue remaining unchanged during post-mortem ageing [6]. Meat quality is affected by both intrinsic factors such as the proportions of different muscle fibers [7] and extrinsic factors, such as nutritional status. Nutritional status is influenced by diet [3] and infection by economically important Gastrointestinal Nematodes (GIN), of which *Haemonchuscontortus* is the most important.

Goats, of which there are numerous breeds that serve diverse purposes, are known to be hardy and prolific animals that survive in various climatic zones and produce under different systems of husbandry [8]; consequently, they are a good livestock choice suitable in most agricultural areas. Meat goats are a good source of lean meat with a desirable fatty acid profile since they deposit relatively higher proportion of polyunsaturated fatty acids compared to other ruminants [9,10]. Moreover, goat meat is known to have attributes which makes it suitable for further processing, including higher water holding capacity, dark red color and low fat. Goat meat is preferred among other types of meat in many tropical countries based on the above mentioned benefits [11].

The effects of protein nutrition and its interaction with GIN parasite infection and meat quality is less studied in goats than in sheep [12]. Goats are more susceptible to parasitism than sheep because natural resistance develops later in life [12]. Improvement in protein nutrition can enhance an immunologic ability to regulate the GIN population and its negative effects while maintaining reasonable levels of production and reducing reliance on anthelmintic medications [13] to which the parasite has increasingly developed resistance. In sheep and goats, nutritional status and the type of feed have been found to have significant effects on slaughter and carcass weights [14], carcass measurements [14,15], muscle pH decline and

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Table 1: Composition of experimental diet fed to goats (on air dry basis).

	Diet Composition (%)	
	Low Protein	High Protein
Ingredients		
Alfalfa pellets	64.0	53.0
Cracked corn	29.0	29.0
Soybean meal	5.0	16.0
Feed lime	2.0	2.0
Decox	0.5	0.5
Chemical analysis (DM basis)		
Dry matter	92.0	92.0
Crude protein (CP)	12.0	20.0
Acid detergent fiber (ADF)	24.0	24.0
Neutral detergent fiber (NDF)	30.0	30.0
Ash	10.0	10.0
Calcium (Ca)	1.4	1.4
Phosphorus (P)	0.4	0.4
Calculated		
Metabolizable Energy (ME) $MJ^{-1}kg$ DM[a]	3.20	2.80

[a]ME content is calculated based on 67% digestibility of the diets; ME MJ^{-1} kg DM=Digestible OM (kg/kg DM) x 18.5 x 0.81 (AAC, 1990).

possibly the rate of carcass cooling postmortem [5].

Diet energy content and animal growth and their interaction influence the composition of tissue being lost or gained. A study of tissue gain or loss with yearling meat goat wethers reported that energy concentration in tissue (23.9 MJ/kg [16-18]) mobilized in wethers with initially high BW, BCS and on a high plane of nutrition was found to be considerably lower than the energy concentration in tissue gained by wethers that previously had low BW and BCS [19]. Another study involving two consecutive 12-wk feeding periods reported no change in observed BW gain or meat characteristics in goats fed two protein and energy levels (LP-LE (12% CP, 10.5 MJ/kg) and HP-HE (18% CP, 12.1 MJ/kg)) [5]. The findings of previous studies demonstrate that interactions between dietary energy and protein levels are common but may not always be observed due to method of diet formulation [5,19], which does not take into consideration the energy cost of parasitism.

GIN infection in sheep and goats reduces feed intake, increases nitrogen flow in GI tract and reduces the efficiency of dietary nutrients for production in the host [20]. In addition to the desirability of knowing the chemical composition of tissue lost or gained, it is also of interest to know how factors such as diet and parasitism influence growth and mass of specific organs and tissues, particularly ones such as the GI tract and liver, which are metabolically expensive. Therefore, the objectives of this experiment were to assess the effects of dietary protein levels on GIN parasite challenge and its relationship with growth and carcass and meat quality in growing meat goats.

Materials and Methods

Animals, management and parasite challenge

The study was conducted at the Randolph Farm of VSU Small Ruminant Research Facility, located in Chesterfield County, Virginia; U.S.A. The protocol for the experiment was approved by the Virginia State University Animal Care and Use Committee. All experimental animals received standard management practices approved by the University. A total of 16 intact male growing meat goats similar in age and weight were selected from the VSU Small Ruminant Research herd for this study. The animals were assigned to individual indoor feeding pens (8'x10') with cement flooring covered with sawdust. The pens were equipped with nipple waterers and portable feed bunks and trace mineral salt blocks were available at all times. The selected goats were acclimatized for three weeks to the indoor facility and the experimental feed. Three weeks before the start of the adaptation period all animals were treated with Albendazole (5 mg/kg BW) to eliminate *H.contortus.*

At the onset of the study and at weekly intervals, animals were weighed, FAMACHA recorded and blood samples taken for PCV values. Grab fecal samples were taken from the rectum for FEC that was monitored using the modified McMaster technique (with a lower limit of detection of 50 eggs/g) [21]. Eight goats were randomly selected and infected every week with 1,000 infective third stage larvae (L3) of *H.contortus*. These larvae were harvested by incubating eggs from fecal material collected from the VSU meat goat research herd and were administered as an oral drench.

Experimental diet and feeding

Using a 2×2 factorial design, 16 intact male bucks were divided into 4 groups based on parasites infestation and dietary protein level. Both not infected (NIF, control) and infected (INF) goats were fed complete diets at 3.5% of Body Weight (BW) with either 200 (HP, high) or 100 (LP, low) g protein /kg dry matter (Table 1). The amounts of feed offered and feed refused (orts) were weighed and recorded daily. Feed and orts were collected and sub-samples taken weekly. Weekly sub-samples for each animal were combined and a final sub-sample taken for the entire study.

Harvest, carcass and meat quality assessment

At the conclusion of the experiment, three bucks from each of the four treatment combinations were randomly selected for harvest and then transported to a commercial abattoir for processing. Bucks were weighed with a full gut the morning before slaughter and then again after a 12-h fasting period. At slaughter, bucks were stunned via electric shock and exsanguinated following transection of the jugular vein. Blood was collected and weighed. The head, hooves and skin were removed and weighed. The pH was measured at the rounds using a portable pH-meter (Oakton pH 700 with probes and NIST calibration). The entire alimentary tract was removed and weighed before separation into components. The intestine and stomach components were weighed after emptying the contents, washing and blotting with paper towels. The intestinal fat is considered to be a combination of omental fat and kidney-knob-channel fat. These measurements determinations were made within 30 min of exsanguination.

Hot carcass weight and that of the GI tract and its contents were recorded to calculate dress-out or killing percentage. The carcasses were kept refrigerated at 4°C for 24h before being re-weighed (cold carcass weight). Each carcass was split sagitally along the mid-line

Table 2: Plane of nutrition and parasite infection effects on clinical parameters of goats.

Parameter	High Protein		Low Protein		SEM[5]	Significance of main effcects		
	INF[1]	NIF[2]	INF	NIF		ProtL[4]	Infecn[3]	Inter-action
FAMACHA[6]	2.25b	1.40c	3.00a	1.40c	0.72	NS	NS	**
FEC[7]	26.80b	2.00c	90.62a	2.00c	27.44	**	**	**
PCV[8]	32.75b	35.80a	27.25c	36.60a	4.06	NS	NS	**

1 INF=Infected; 2 NIF=Not Infected; 3 Infecn=Infection; 4 ProtL=Protein Level in Diet; 5 SEM=Standard error of Mean; 6 FAMACHA=Anemic score; 9 FEC=Fecal egg count; 10 PCV=Packed Cell Volume; NS=Not Significant. a, b, c Means in the same line with different superscripts are significantly different. *: P < 0.05; **: P < 0.01; NS: P > 0.05.

Table 3: Plane of nutrition and parasite infection on growth and performance of goats.

Parameter	High Protein		Low Protein		SEM	Sig.	Significance of main effects		
	INF[1]	NIF[2]	INF	NIF			ProtL[6]	Infecn[5]	Infecn x ProtL
Growth performance (kg)									
Final Weight	25.73c	30.80a	23.86c	27.41b	1.68	Sig	**	**	NS
Gain	2.96c	4.18a	1.82d	3.91b	1.60	Sig	NS	NS	**

1 INF=Infected; 2 NIF=Not Infected; 3 Infecn =Infection; 4 ProtL=Protein Level in Diet; 5 SEM=Standard error of Mean; NS=Not Significant. a, b, c Means in the same line with different superscripts are significantly different. *: P < 0.05; **: P < 0.01; NS: P > 0.05.

through the center of the vertebral column. The left -side was used for dissection and sampling and the right side for analysis of meat tenderness. Samples for chemical composition analysis were packed in vacuum and stored at -8°C until analyzed.

Muscle sampling for meat tenderness analysis

The LL muscle was excised from the right side of each carcass from between the 6th rib and last lumbar vertebrae and was chilled at 4°C overnight prior to analysis of meat tenderness. Meat tenderness was quantified as the maximum shear force (N/cm^2) measured perpendicular to muscle fiber orientation on each of three replicate 1-cm^3 pieces of uncooked LL muscle from each goat. The analysis was accomplished using a TAXT Plus texture analyzer (Texture Technologies, Hamilton, MA) fitted with a Warner-Bratzer blade (Warner-Bratzler shear force, WBSF) with a triangular cutting surface. Each test was run at 1.67 $mm \cdot s^{-1}$ with a penetration distance of 15 mm. Data acquisition was initiated at of 0.147 N (15g) and the data acquisition rate was 250 pps.

Meat composition analysis

Representative samples taken from the left side of the carcass were ground, minced, subsampled, packed and frozen for subsequent chemical analysis. Dry matter for meat samples was determined by lyophilization (model Eco E139 FreeZone 6 liter Freeze Drier, Labanco, MO). Proximate chemical composition analysis of minced meat samples was performed to determine ash, crude protein and fat content [22].

Statistical analyses

Data were analyzed using the General Linear Model (GLM) procedure of SAS 9.4 [23]. Models consisted of main effects of diet protein level (HP, LP) and GIN parasite infection (INF, NIF) and protein level×infection interaction. One-way ANOVA and Duncan test were applied to compare treatment groups in which protein level×GIN infection interaction was not significant.

Results and Discussion

Parasite challenge, growth and performance

Table 2 presents the mean values for FAMACHA, FEC and PCV of experimental goats. There was significant interaction (P < 0.01) between protein level and parasite infection for each of the clinical parameters. All the three parameters showed improved scores in the NIF-HP group compared to the INF-LP group.

The results of the study showed that goats maintained on feed with high protein supplementation were able to mount a measure of resistance against early establishment of the infection as evidenced by very low egg output in their feces. Inadequacy of metabolisable protein among the LP diet goats was probably responsible for their inability to mount sufficient immunological response against early parasite establishment. This is largely in agreement with an earlier report in which goats given high protein diet had significantly lower fecal egg output and number of adult worms recovered postmortem [24]. This observation differs with those of [25], where the level of protein intake had no effect on parasite establishment. They, however, used a single primary infection dose in contrast to trickle infection doses of L3 in this study. It should be noted, that in our study the HP group did not completely suppress parasite establishment but succumbed as the dose of infection built up, suggesting that high protein diet may have only limited benefit in the resistance of infection. [26] Stated that the main effect of protein supplementation is to increase the rate of acquisition of immunity and resistance against re-infection following recovery from primary infection. It would, therefore, appear that with increasing buildup of infective larvae over time the earlier resistance by HP diet group was overcome resulting in eventual parasite establishment but a delay in the prepatent period. This seems to be more consistent with natural infections under field (grazing) conditions.

Final BW analyzed using initial BW as a covariate, is shown in (Table 3). Final BW of INF goats on LP diet was significantly lower (P < 0.01) compared to that of the NIF group on HP diet. Live weight gain of goats was significantly (P < 0.01) affected by both the level of protein in the diet and the GIN infection.

Experimental work concerning the relationship between nutrition and parasitism in meat goats has been focused on the effect of protein and energy sources. The severity of GIN infection in goats depends on their resistance (the ability physiologically and immunologically either to prevent or limit establishment or development progression? of infection) and resilience (the ability to maintain a reasonable level of production when subjected to parasitic challenge) [12,25,26].

Dressing percentage, meat tissue composition and tenderness

Carcass quality and meat chemical composition of the experimental bucks is shown in (Table 4). Carcass weight and dressing percentage were significantly higher (P < 0.01) in the NIF-HP treatment group. This result is similar to a study with lambs that reported that supplementation with dietary protein reduced GIN parasitism and produced quality carcasses [25-27].

Table 4: Plane of nutrition and parasite infection on carcass composition and meat chemical composition of goats.

Parameter	High Protein		Low Protein		SEM[5]	Significance of main effects		
	INF[1]	NIF[2]	INF	NIF		ProtL[4]	Infecn[3]	Infecn x ProtL
Carcass quality								
Hot carcass weight (kg)	15.46b	17.05a	13.64c	15.15c	1.82	**	**	NS
Dressing %	45.23	47.23	43.51	47.12	4.52	NS	NS	NS
Meat Chemical composition (%)								
Dry matter	93.19	93.35	93.77	93.60	0.99	NS	NS	NS
Protein	39.65	41.35	39.43	41.09	1.60	NS	NS	NS
Fat	4.81	4.80	4.80	4.89	0.34	NS	NS	NS
Ash	2.04b	2.11a	1.70c	2.07b	0.23	NS	NS	**
Meat pH								
pH	6.62b	6.78a	6.56c	6.56c	0.21	**	NS	NS
Tenderness (N)	50.24	51.75	51.33	52.15	9.00	NS	NS	NS

1 INF=Infected; 2 NIF=Not Infected; 3 Infecn=Infection; 4 ProtL=Protein Level in Diet; 5 SEM=Standard error of Mean; NS=Not Significant. a, b, c Means in the same line with different superscripts are significantly different. *: P < 0.05; **: P < 0.01; NS: P > 0.05.

Table 5: Plane of nutrition and parasite infection on tissue and organ mass of goats.

Parameter	High Protein		Low Protein		SEM[5]	Significance of main effects		
	INF[1]	NIF[2]	INF	NIF		ProtL[4]	Infecn[3]	Infection x ProtL
Organ mass (kg)								
Blood	1.03b	1.04b	1.25a	1.03b	0.14	**	NS	**
GIT[7]	1.61c	1.84a	1.56d	1.73b	0.18	NS	**	NS
Intestinal Fat	1.39	1.63	1.04	0.92	0.33	**	NS	NS
Head	2.25	2.51	2.32	2.38	0.18	NS	**	NS
Skin	3.09	3.96	3.14	3.58	0.39	NS	**	NS
Lung	0.55	0.67	0.47	0.63	0.10	NS	**	**
Liver	0.46c	0.51b	0.40d	0.56a	0.10	NS	**	**
Kidney	0.08b	0.09a	0.07c	0.09a	0.01	**	**	NS
Heart	0.13	0.14	0.12	0.14	0.03	NS	NS	NS
Spleen	0.04b	0.05a	0.04b	0.05a	0.01	NS	NS	**
Testicle	0.17c	0.25a	0.17c	0.20b	0.02	**	**	**

1 INF=Infected; 2 NIF=Not Infected; 3 Infecn =Infection; 4 ProtL=Protein Level in Diet; 5 SEM=Standard error of Mean; 6 NS=Not Significant; 7=GIT=Gastrointestinal Tract. a, b, c Means in the same line with different superscripts are significantly different. *: P < 0.05; **: P < 0.01; ***: P < 0.001; NS: P > 0.05.

Chemical analyses of the meat revealed that ash, crude protein and fat content remained unchanged (P > 0.01) among treatment groups, which is important considering the contribution of fat and protein to the nutritional value of meat. Although meat tenderness and postmortem pH values were slightly elevated, no statistically significant difference (P > 0.01) were found among treatment groups. The observed values for tenderness and pH are within the range considered as acceptable for carcass quality [28,1]. A high ultimate pH is generally indicative of stress in animals [28,1].

Organ mass

Mass of the various organs of goats is shown in (Table 5). The interaction between GIN infection and protein level was statistically significant (P < 0.01) for blood, lung, liver, kidney and testicles. The HP-NIF goats had higher blood, lung, liver, kidney and testicles. Organ weights observed in the present study are similar to those reported by others [16,29-31]. Intestinal fat is important in goats because goats are said to grow from inside out (i.e. internal organ fat is deposited before subcutaneous fat) unlike sheep which grow from outside in which is associated with the lower carcass and meat fat. This is important since it also contributes to meat quality.

Conclusion

The results of this study showed that dietary protein supplementation influenced the establishment of *H. contortus* in growing meat goats. It improved resilience (subsided clinical symptoms, better growth performance) and also enabled the goats to better cope with some of the consequences of parasitism such as efficiency of live weight gain and performance. On the contrary, a LP diet subjected the animal more vulnerable to *Haemonchus* infection and adversely affected its performance. Such an effect could be of significant importance in field conditions, where suboptimal nutrition commonly occurs. Improving resilience against GI parasitism through supplemental dietary protein could certainly improve production performance against protein deficit animals. The interactions between protein nutrition and haemonchosis and

development of resistance against chemotherapy by host animals may thus suggest for strategic protein supplementation that would contribute towards a non-chemical, sustainable parasite control in goat production systems. Further studies are needed to explore role of dietary protein level, supplementation and possible interaction with carcass and meat quality characteristics in a larger population of meat goats. There is little evidence that nutritional strategies could shorten the time for acquisition of immunity to GI nematode parasites and it should also include impact on lifetime productivity.

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