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Effect of sodium bicarbonate supplementation and 2 different ambient temperatures on growth performance and carcass characteristics of lambs fed concentrate diets

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Abstract: Twenty male Barbados lambs (3 months old) were used to evaluate the effects of sodium bicarbonate ($NaHCO_3$) supplementation on growth performance and carcass characteristics of lambs fed concentrate diets in controlled-environment chambers set at 20 °C and 30 °C. In the 35-week-long growth trial, the animals were divided into 4 groups (n = 5) and fed 2 dietary treatments: a basal diet (35:65 roughage and concentrate) or a basal diet supplemented with 4% $NaHCO_3$. Twelve lambs randomly selected from this trial were arranged in a 2 × 2 factorial design for a 10-day-long slaughter and carcass evaluation experiment. Lambs in the 20 °C ambient temperature group had higher ($P < 0.001$) feed intake (FI, g day^{-1}) and body weights ($P < 0.01$) than those of the other group. The $NaHCO_3$-supplemented group had higher ($P < 0.05$) FI g day^{-1} and average daily gain (ADG, kg^{-1}) ($P < 0.01$) than the other group. The 30 °C ambient temperature affected half carcass weights, body lengths, and bone lengths ($P < 0.05$, $P < 0.01$, and $P < 0.01$, respectively). In conclusion, incorporation of $NaHCO_3$ to concentrate diets at a 20 °C ambient temperature increased FI g day^{-1} and ADG kg^{-1}, resulting in improved growth performance of the lambs.

Key words: Temperature, sodium bicarbonate, growth performance, lambs

1. Introduction

The value of meat animals depends on their acceptability in the market. Many factors such as nutrition and dietary manipulation have been reported (1) to exert several influences on carcass conformation, organs, and certain muscles in sheep. These characteristics play a vital role in influencing customer decisions when selecting fresh meat products. Thus, the effect of feeding systems on carcass traits should be studied in order to avoid consumer meat rejection (2).

The current trends in fattening schemes are to wean lambs approximately 6–8 weeks after birth and feed them with high-concentrated diets for an additional 5–7 weeks until the desired market weight (approximately 25–30 kg) is achieved (3). Such concentrate diets are fed in order to obtain high energy intakes, rapid attainment of adequate slaughter weights, reduced days on feed, and a shortened slaughter cycle (3,4). These diets are subjected to modified digestion by microbial communities in the rumen, resulting in decreased ruminal pH and increased volatile fatty acids (VFA, mainly propionate), thereby reducing the buffering capacity of the rumen contents and increasing the risk of ruminal acidosis (5,6). To avoid such incidence, several nutritional therapies have been tried, including the use of dietary buffers.

The effect of sodium bicarbonate ($NaHCO_3$) supplementation on animal performance has been studied extensively in large ruminants but with apparently conflicting results. Animal responses have been inconsistent (7), including no effects (8,9) or negative effects (10,11). Furthermore, there is a paucity of information on the effects of $NaHCO_3$ supplementation in small ruminants, especially in growing lambs with ad libitum access to concentrate and roughage diets at different ambient temperature levels. High ambient temperatures elicit physiological changes in the digestive system. Exposure of sheep to temperatures above 30 °C has been reported to affect blood flow to vital organs, decrease blood pCO_2 and increase pH, suppress appetite, reduce feed intake, and reduce weight gain (12,13). Thus, the objective of this study was to evaluate the effect of ambient temperature with or without $NaHCO_3$ supplementation on feed efficiency and live weight changes of lambs.

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2. Materials and methods

2.1. Experimental site and animal management

The experiments were conducted in the small ruminant unit of the National Pingtung University of Science and Technology's innovation and practical training center.

Twenty male Black Belly Barbados lambs (3 months old), all born and raised in the same environment, were used in this experiment. The lambs were balanced for body weight and housed in controlled-environment chambers in individual pens 1 m × 1.5 m in size with steel slatted floors. Each pen was equipped with overhead aluminum feeders and automatic waterers. Before the start of the experiment, all lambs were dipped in a Gematox solution to eliminate ectoparasites. All lambs were injected with Ivomec to control endo- and ectoparasites.

2.2. Diets

The lambs were allowed to adapt to the experimental diets for 1 week before the parameters were monitored. The experiment was conducted as a 2 × 2 factorial design. This design included 2 ambient temperatures (20 °C and 30 °C) and 2 diet types. The dietary sources were a basal diet (35:65 roughage and concentrate) or a basal diet supplemented with 4% $NaHCO_3$ for both experiments. The diet comprised dry matter (DM): 55%, net energy for milk: 1.092%, crude protein: 8.15%, Ca: 0.8%, P: 0.59%, and acid detergent fiber: 39.91%. Napier grass was used as the roughage source. In the growth trial, the lambs were randomly assigned to the experiment diets for a period of 35 weeks in 2 separate controlled-environment chambers set at 20 °C and 30 °C respectively. $NaHCO_3$ was added in the feed after preparation in the required proportion (4%) and thoroughly mixed with the concentrate before feeding the lambs. All lambs were fed ad libitum with free access to water and mineral salt licks.

2.3. Measurements

2.3.1. Growth trial

The growth trial lasted for 35 weeks, during which time daily feed intakes were recorded for each lamb. The lambs were weighed at the beginning of the experiment and every week thereafter before being offered feed. Values obtained from these measurements were used to determine body weight gains. Feed conversion ratio (FCR) was calculated by dividing the live weight gained in each week by the total quantity of feed consumed same period (kg live weight gained/kg DM). Data on daily feed offered and feed refused were also collected and the difference was calculated to determine feed intake (FI, g day^{-1}). The average daily gain (ADG, kg^{-1}) was calculated as the difference between end-of-trial weight and initial weight divided by the number of days on feed.

2.3.2. Animal slaughtering and carcass characteristics

Twelve lambs were randomly selected from the growth trial and arranged in a 2 × 2 factorial design experiment. At the end of the growth trial, the lambs were slaughtered at about 262 days of age (245 days of growth trial, 7 days of adaptation, and 10 days of experimental period) for carcass evaluation. Dietary treatments and environment conditions (ambient temperature) remained the same as were employed in the previous trial. The lambs were fasted for 6 h before slaughter. All lambs, however, had free access to water until being slaughtered in the abattoir following standard commercial slaughterhouse procedures. The lambs were transported in a truck and were subsequently held in the slaughterhouse lairage for about 1 h before slaughter. Each animal was carefully handled to minimize excitement. After 1 h the lambs were weighed again, stunned, bled, skinned, and eviscerated. The heads were removed at the occipital joint. The fore and hind feet were removed at the carpal and tarsal joints, respectively. Thereafter, the lambs were suspended by their hind legs for further skinning. Each carcass was split along the vertebral column into left and right halves using a knife. External and internal offal along with the hot carcass were separately weighed. The contents of the digestive tracts were removed, collected, and weighed. The empty body weights (EBWs) were obtained by subtracting the gut fills from the fasting body weights (FBWs). Dissection of the carcass segments (carcass width, half carcass weight, and bone) was carried out for each carcass and the relative weight of each segment was recorded. Physical bone characteristics were determined using a 3-point bending test commonly used to assess bone strength. Femoral bones were placed dorsal side up 30 cm apart. The center of each bone was aligned with the breaking probe, which approached at a testing speed of 200 mm/min. The ultimate bone breaking force (kg) was determined for each femoral bone.

2.4. Statistical analysis

Data on growth performance and carcass characteristics were analyzed using the general linear model (GLM) procedures of SAS 14 version 6.21. The data on all the carcass traits were subjected to analysis of variance by the GLM procedure. Means were compared using the least square means procedure in SAS, and the level of significance was set at $P < 0.05$.

3. Results

The present study investigated the effect of $NaHCO_3$ supplementation on live weight changes and FCE of lambs fed a concentrate diet under different ambient temperatures. Lambs in the 20 °C ambient temperature group were heavier than those in the 30 °C ambient temperature group midway through the trial ($P < 0.01$). However, at end of the trial, there were no significant differences ($P > 0.05$) in live weights between the 2 groups (Figure 1a). A similar trend was observed for the dietary

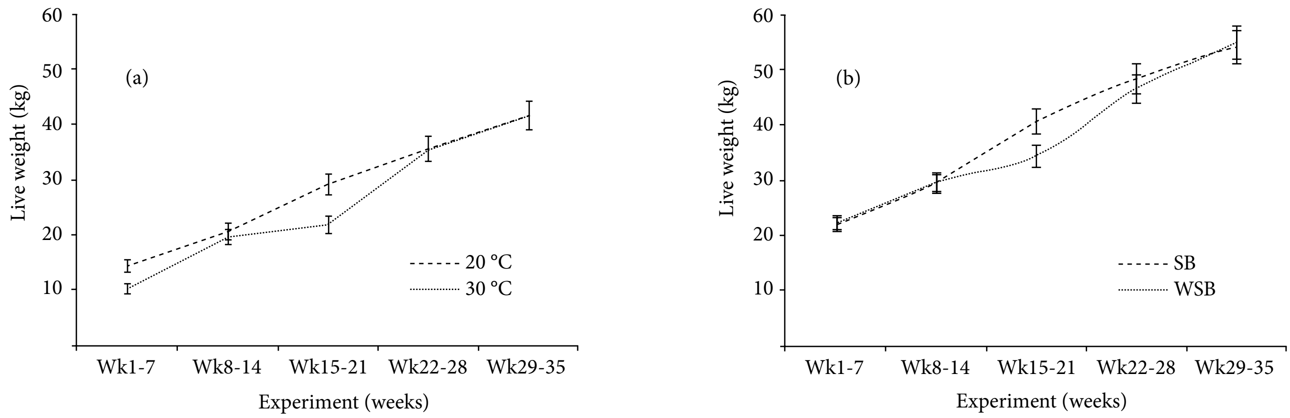

Figure 1. Live weight (kg) changes of lambs during the 35-week-long experimental feeding period as affected by (a) ambient temperature and (b) dietary treatments. SB = sodium bicarbonate; WSB = without sodium bicarbonate.
SB- sodium bicarbonate; WSB- without sodium bicarbonate

treatments in which lambs supplemented with $NaHCO_3$ had significantly ($P < 0.05$) higher growth rates than those without $NaHCO_3$ (Figure 1b). Data on FI g day^{-1} are presented in Figures 2a and 2b. At the initial stage of the experiment (weeks 1–7), FI g day^{-1} was higher for animals in the 30 °C ambient temperature ($P < 0.01$) (Figure 2a). However, above this point and as growth progressed, the 30 °C ambient temperature group had depressed FI g day^{-1}, whereas the 20 °C ambient temperature group had progressively increasing FI ($P < 0.001$). Figure 2b shows the effects of diets with or without the addition of $NaHCO_3$ on the FI g day^{-1} patterns of the lambs. The diet composed of concentrates and supplemented with $NaHCO_3$ increased FI g day^{-1} ($P < 0.05$). The highest FI g day^{-1} values were observed in lambs fed a concentrate diet supplemented with $NaHCO_3$ while the lowest values ($P < 0.05$) were recorded for lambs on a concentrate diet without $NaHCO_3$ supplementation. The effects of ambient temperature on the ADG kg^{-1} of lambs are shown in Figure 3a. Lambs in the 20 °C temperature had significantly ($P < 0.05$) higher ADG kg^{-1} values from weeks 22–28 through weeks 28–35 of the sampling periods. The ADG kg^{-1} value for the lambs exposed to both ambient temperatures plateaued at about 0.3 kg^{-1} between the 22nd and 28th sampling weeks. The effects of $NaHCO_3$ supplementation on the ADG kg^{-1} of concentrate-fed lambs are given in Figure 3b. From weeks 15–21 there were significant differences ($P < 0.05$) between the supplemented and nonsupplemented lambs. As was observed with ambient temperature (Figure 3a), the ADG kg^{-1} of the lambs fed concentrate diets supplemented with or without $NaHCO_3$ also plateaued at about 0.3 kg^{-1} between the 22nd and 28th sampling weeks Figure 3b. Significant interactions were recorded between ambient temperature and dietary treatment on live weights (Figure 4).

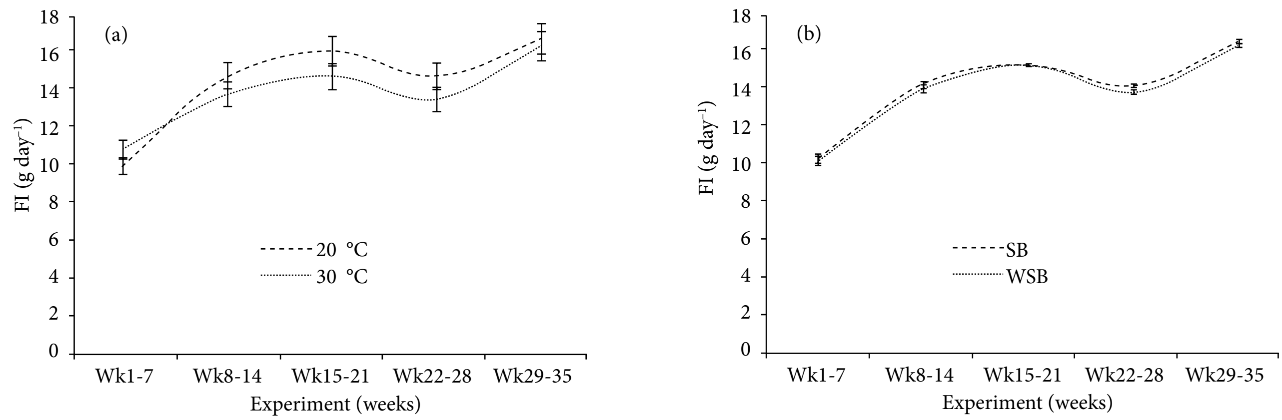

Figure 2. Effect of (a) ambient temperature and (b) diet on the feed intake of lambs fed a concentrate diet with or without sodium bicarbonate supplementation. SB = sodium bicarbonate; WSB = without sodium bicarbonate.

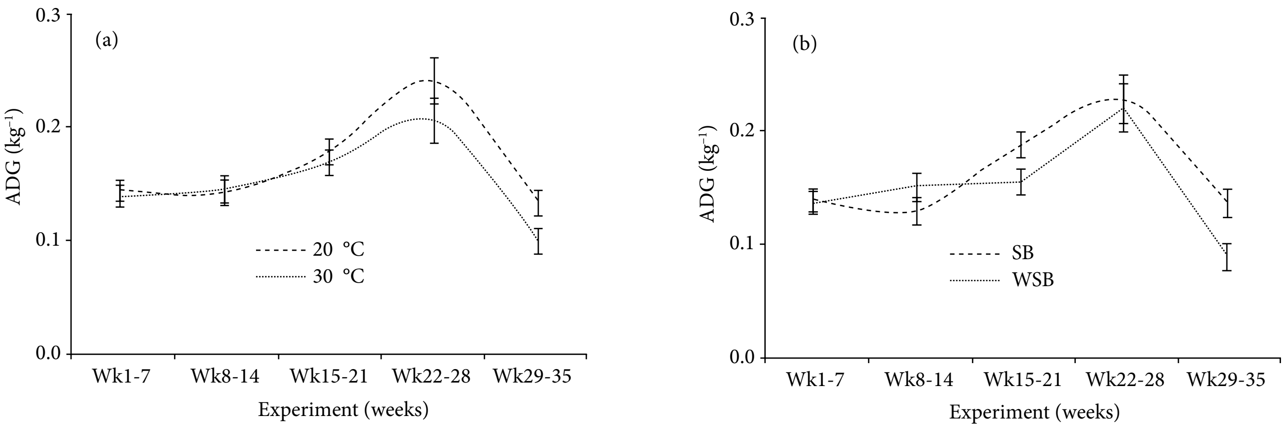

Figure 3. Effect of (a) ambient temperature and (b) diet on the ADG kg^{-1} of lambs fed a concentrate diet with or without sodium bicarbonate supplementation. SB = sodium bicarbonate; WSB = without sodium bicarbonate.

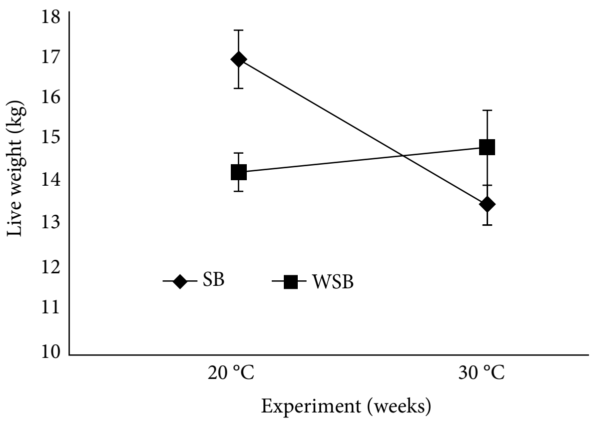

Figure 4. Interactions between ambient temperature and dietary treatments on live weight (kg). SB = sodium bicarbonate; WSB = without sodium bicarbonate.

The effects of ambient temperature and diet on FCR are shown in Table 1. FCR was significantly better ($P < 0.001$) for the group in the 30 °C ambient temperature compared with those under the 20 °C temperature regime. The results further showed that FCR decreased as the lambs got older. However, these effects ($P < 0.01$ and $P < 0.001$) of diet on FCR were only seen in the last 2 phases (weeks 22–28 and weeks 29–35) of the experimental period (Table 2).

The effects of ambient temperature on the mean values of the whole carcass characteristics are shown in Table 3. Lambs under the 30 °C ambient temperature treatment had significantly ($P < 0.01$) longer bodies (97.833 vs. 114.167 cm) while those in the 20 °C ambient temperature recorded significantly higher carcass weights, half carcass weights, and bone lengths ($P < 0.05$, $P < 0.05$, and $P < 0.01$, respectively). The effects of the diets on whole carcass characteristics are shown in Table 4. Antemortem and postmortem examination of the lambs and their carcasses did not show any marked abnormality. The supplemented lambs also had significantly heavier ($P < 0.05$) half carcasses and stronger femoral bones. The interactive effects of ambient temperature and diet were found to affect carcass weights ($P < 0.01$).

4. Discussion

Santra et al. (15) reported that total live weight gain and average daily gain were higher in lambs supplemented with sodium bicarbonate. In agreement with this, the lambs in our study receiving the $NaHCO_3$-supplemented diet had higher finishing body weights. Supplementation of sodium bicarbonate in the diet of animals is known to increase the number of total ruminal as well as cellulolytic bacteria, which could have contributed to better cellulose digestibility (15).

Mandebvu and Galbraith (16) found no effect on weight gain after testing diets supplemented with 15 g $NaHCO_3$/kg concentrate. Inclusion of $NaHCO_3$ at a higher level (22.5 g/kg feed DM) reduced DM intake and weight gains (9). It was suggested (9,15) that higher $NaHCO_3$ can induce respiratory alkalosis because the blood is usually saturated with bicarbonate, which may reduce FI; hinder acidification; reduce VFA absorption; reduce postruminal starch, protein, and mineral digestion; induce an osmotic imbalance; and consequently affect animal performance.

Increased FI rates seen at the initial stage of the trial (Figure 2a) are consistent with other reports that FI often increases for ruminants fed ad libitum in cold environments (17). This also agrees with the results obtained by Round (18), who observed that $NaHCO_3$ had no early effect on ad libitum feed intake but, later on, 3% $NaHCO_3$ significantly ($P < 0.05$) increased FI. Others authors (19,20) observed an interactive relationship between year and environment

Table 1. Effect of ambient temperature on feed conversion ratio (kg live weight gained/kg DM) of the experimental lambs.

	Ambient temperature			
Period	20 °C	30 °C	SEM	Sig.
Weeks 1–7	0.40[a]	0.32[b]	0.01	***
Weeks 8–14	0.44[a]	0.35[b]	0.01	***
Weeks 15–21	0.47[a]	0.35[b]	0.01	***
Weeks 22–28	0.55[a]	0.39[b]	0.01	***
Weeks 29–35	0.64[a]	0.38[b]	0.01	***

[a,b]Means within a row without a common superscript differ (P < 0.05). *** = P < 0.001.

Table 2. Effect of and diet on feed conversion ratio (kg live weight gained/kg DM) of the experimental lambs.

	Diet			
Period	SB	WSB	SEM	Sig.
Weeks 1–7	0.35	0.36	0.01	NS
Weeks 8–14	0.39	0.40	0.01	NS
Weeks 15–21	0.42	0.40	0.01	NS
Weeks 22–28	0.51[a]	0.44[b]	0.01	**
Weeks 29–35	0.55[a]	0.48[b]	0.01	***

[a,b]Means within a row without a common superscript differ (P < 0.05).
** = P < 0.01, *** = P < 0.001, NS = not significant (P > 0.05), SB = sodium bicarbonate, WSB = without sodium bicarbonate.

Table 3. Effect of ambient temperature on mean values of morphological and cold carcass characteristics.

	Ambient temperature				Interactions
Parameters	20 °C	30 °C	SEM	Sig.	T × D
Preslaughter weight (kg)	52.79	50.75	0.70	NS	NS
Empty live weight (kg)	51.36	48.87	0.65	NS	NS
Body length (cm)	97.833[b]	114.167[a]	3.02	**	NS
Body width (cm)	44.00	40.17	2.56	NS	NS
Height (cm)	73.17	75.33	1.15	NS	NS
Buttock width (cm)	11.00	10.60	0.41	NS	NS
Buttock perimeter (cm)	30.20	28.60	0.51	NS	NS
Hot carcass weight (kg)	40.38	39.13	1.19	NS	NS
Carcass length (cm)	80.00	86.17	2.51	NS	NS
Carcass width (cm)	37.17[a]	34.67[b]	0.57	*	NS
Half carcass weight (kg)	15.60[a]	13.50[b]	0.34	*	**
Bone length (cm)	22.32[a]	21.07[b]	0.37	**	NS
Bone strength	291.47	286.36	13.47	NS	NS

[a,b]Means in the same row with different superscripts are significant (P < 0.05). * = P < 0.05, ** = P < 0.01, NS = not significant (P > 0.05), T = temperature, D = diet.

Table 4. Effect of diet on mean values of morphological and cold carcass characteristics.

	Diets				Interactions
Parameters	SB	WSB	SEM	Sig.	T × D
Preslaughter weight (kg)	51.85	51.69	0.70	NS	NS
Empty live weight (kg)	49.70	49.53	0.65	NS	NS
Body length (cm)	106.17	105.83	3.02	NS	NS
Body width (cm)	43.17	41.00	2.56	NS	NS
Height (cm)	72.83	75.67	1.15	NS	NS
Buttock width (cm)	12.60	11.90	0.41	NS	NS
Buttock perimeter (cm)	42.00	39.00	0.35	NS	NS
Hot carcass weight (kg)	37. 02	35.60	1.13	NS	NS
Carcass length (cm)	81.50	84.67	2.51	NS	NS
Carcass width (cm)	36.67	35.17	0.57	NS	NS
Half carcass weight (kg)	15.01[a]	14.30[b]	0.34	*	**
Bone length (cm)	21.60	21.78	0.37	NS	NS
Bone strength	294.60	283.23	13.47	NS	NS

[a,b]Means in the same row with different superscripts are significant ($P < 0.05$). * = $P < 0.05$, ** = $P < 0.01$, NS = not significant ($P > 0.05$), SB= sodium bicarbonate, WSB = without sodium bicarbonate, T = temperature, D = diet.

concerning concentrate intake, where lambs raised in a cold environment had higher FI values compared to those in a warm environment. Denek et al. (21) also reported that high ambient temperatures and relative humidity decreased FI in Awassi wethers; day temperatures reaching 32 °C and 98% relative humidity adversely affected ad libitum FI and nutrient utilization in sheep. According to these authors (21), the depressions became increasingly severe with increasing forage levels in the diet. Voluntary FI is reduced, so heat production resulting from metabolic processes is also decreased (21). However, the reported effects of supplemental $NaHCO_3$ on FI have been variable. Studies in which animals were offered all-concentrate diets (22) observed an increased DM intake with the addition of 30.0 g $NaHCO_3$/kg feed DM.

The effects on ADG kg^{-1} are determined by concentrate intake. Therefore, the decreased ADG kg^{-1} seen in the lambs exposed to 30 °C temperatures stemmed from the depression in feed intake due to heat stress and not inclusion of $NaHCO_3$. In lambs, ADG kg^{-1} values were lower in summer than in winter. Suffolk sheep in a psychrometric chamber (30–40 °C) also had lower ADG kg^{-1} values than those in a sheltered environment (20–30 °C) (23).

The smaller the FCR, the more efficient the animals are at converting feed into growth and meat. The efficiency at which lambs in the 30 °C ambient temperature converted feed was expected. Low temperatures reduce the digestibility of feed, thus increasing the maintenance requirements to maintain homeostasis and lower FCR (24). In a study with cattle and sheep during the winter or during a prolonged exposure in climatic chambers, Demircan et al. (25) reported decreased dry matter digestibility per degree decrease in temperature as 0.31% per 1 °C for sheep, 0.21% per 1 °C for calves, and 0.08% per 1 °C for steers. The poorer FCR for lambs exposed to the 20 °C ambient temperature in this experiment agrees with the findings of Tripathi et al. (9). Increased gut motility, higher passage rate, and shortened exposure time of digesta to microbial degradation have been observed in lambs under such conditions (9). $NaHCO_3$ dissociates into sodium and bicarbonates in the rumen and an excess of sodium increases the digesta outflow rate from the rumen, with an adverse effect on metabolic efficiency and growth (9).

Animals of better conformation tend to have better carcass growth rates and heavier carcasses (26). This is in line with our findings in which lambs in the lower temperature had significantly ($P < 0.05$) heavier carcasses. Evaluating the effect of dietary $NaHCO_3$ supplementation on carcass and meat quality of high concentrate fed lambs, Sen et al. (7) reported that preslaughter weights were higher in the $NaHCO_3$ supplemented groups than in the control group.

In conclusion, the results obtained in this experiment demonstrated that live weight changes in growing lambs are affected by ambient temperatures. An ambient temperature of 20 °C promoted better growth performance. The results further indicated that $NaHCO_3$ supplementation in concentrate diets for lambs is beneficial as it increased feed intake and average daily gain, resulting in improved performance and carcass conformation.

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