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Influence of dietary zilpaterol hydrochloride on feedlot performance, carcass traits, chemical composition of *longissimus* muscle, and plasma metabolites of castrated male goats

Ali HATEFI[1,*], Armain TOWHIDI[1], Abolfazl ZALI[1], Saeed ZEINOALDINI[1], Mahdi GANJKHANLOU[1], Reza MASOUDI[1], Alejandro PLASCENCIA[2]

[1]Department of Animal Science, Faculty of Agricultural Science and Engineering, University of Tehran, Karaj, Iran
[2]Institute for Research in Veterinary Sciences, Autonomous University of Baja California, Mexicali, Baja California, Mexico

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Abstract: To evaluate the influence of zilpaterol hydrochloride (ZH) supplementation on growth performance, carcass traits, chemical characteristics of the *longissimus* muscle (LM), and plasma metabolites, 16 Mahabadi castrated goats (29.93 ± 1.84 kg) were individually fed a finishing diet without or with ZH supplementation dosed at 0.20 mg/kg BW daily. Zilpaterol was fed for 30 days with 3 days of withdrawal before harvest. Compared with the controls, ZH supplementation decreased dry matter intake and increased total weight gain, average daily gain, and gain for feed. Hot carcass weight, dressing percentage, and LM area were increased, but back fat thickness and kidney-pelvic fat were reduced in the group that received ZH. Supplemental ZH did not affect the full viscera mass or stomach complex, but it increased empty body weight (EBW) and reduced (as g/kg final EBW) the heart/lungs and kidney weights. Zilpaterol supplementation increased LM protein and moisture and decreased LM fat. The goats fed with ZH had lower serum concentrations of glucose, triglycerides, and cholesterol than the controls. It can be concluded that daily ZH supplementation at 0.20 mg/kg BW increases growth performance, feed efficiency, and dressing percentage in castrated goats as a result of greater muscle accretion and causes reduction of fat and visceral organ mass.

Key words: Carcass traits, growth performance, organ mass, β-adrenergic agonist, zilpaterol hydrochloride

1. Introduction

Zilpaterol hydrochloride (Zilmax, Intervet, South Africa) is an orally active type 2 β-agonist approved for use in feedlot cattle in South Africa, Mexico, and the United States (1). In feedlot cattle, feeding zilpaterol has been shown to improve average daily gain (ADG), feed efficiency, carcass yield grade, hot carcass weight (HCW), and dressing percentage in steers (2,3) and in Holstein steers (4) when administered (dosage estimated based on average dry matter intake (DMI) and average weight reported in those studies) from 0.13 to 0.15 mg/kg live weight per day in the last 20 to 42 days of the feeding period. Likewise, in finishing lambs, zilpaterol supplementation at rates of 0.15 to 0.30 mg/kg live weight per day in the last 30 days of the feeding period increased ADG, feed efficiency, HCW, and dressing percentage, and it increased HCW, dressing percentage, and *longissimus* muscle (LM) area in ewe lambs (5). Compared to male lambs, the male kids of milk/meat goat breeds generally have a lower growth rate and lower dressing percentage (6). The latter can be partially explained by the greater visceral mass of goats and the fact that an appreciable proportion of energy expenditure can be attributed to the maintenance of visceral organs, especially the liver and gastrointestinal tract (7). Researchers such as Lopez-Carlos et al. found that ZH supplementation to finishing lambs decreased the visceral organ mass and body fat, which would partially explain the role of zilpaterol in the enhancement of carcass dressing percentage and energetic efficiency (5). Therefore, ZH supplementation could be expected to achieve a greater response in goats. Since ZH is approved as a food additive for feedlot cattle but is currently not approved for use in small ruminants, there is no available information about the effect of ZH supplementation on growth performance and carcass characteristics in male goats. Thus, the objective of this study was to evaluate feedlot performance, carcass traits, visceral mass, and the chemical composition and plasma metabolites of the LM of castrated goats fed ZH at 0.20 mg/kg of live bodyweight during the last 30 days of the finishing period.

2. Materials and methods

This trial was conducted at the University of Tehran Agricultural Research Center. All procedures involving

* Correspondence: hatefi.ali@gmail.com

live animals were conducted within guidelines approved by the Institutional Animal Care and Use Committee of the Department of Animal Science of the University in Karaj, Iran.

2.1. Animal processing, housing and feeding

Fifty-four Mahabadi male goats (9 to 10 weeks of age) from the University of Tehran Agricultural Research Center were fed ad libitum twice daily with a diet for early-weaned goats with moderate growth potential, containing alfalfa hay, corn grain, soybean meal, and a commercial mix of vitamins and trace elements. On a DM basis the formulated diet provided 17.4% crude protein and 8.91 MJ NE_m/kg. At 14 weeks of age the kids were castrated (castration-band method), dewormed (Albendazole 2.5%, Damloran Razak Pharma, Borujerd, Iran), and vaccinated against *Clostridium* spp. (Enterotoxemia polyvalent, Razi Vaccine and Serum Research Institute, Karaj, Iran). Two weeks later, 16 kids were selected based on similar body weight and size and were randomly assigned to individual pens. The 16 pens used in the study were 0.96 m^2 with overhead shade, concrete floor, automatic waterers, and 0.40-m metallic feed bunks. Selected kids were fed the basal diet for 60 days before the trial started. During the pretrial period (60 days) and throughout the experiment (33 days), kids were fed twice daily at 0800 and 1600 hours. Daily feed allotments to each pen were adjusted to allow minimal (<5%) feed refusals in the feed bunk. The amounts of feed offered and feed refused were weighed daily. Feed bunks were visually assessed between 0740 and 0750 hours each morning, refusals were collected and weighed, and feed intake was determined. Adjustments to either increase or decrease daily feed delivery were provided at the afternoon feeding. Feed and refusal samples were collected daily for DM analysis, which involved oven drying the samples at 105 °C until no further weight loss occurred (8).

2.2. Experimental design and diets

The 16 Mahabadi goats (29.93 ± 1.84 kg) selected for the study were randomly assigned to one of two dietary treatments in a completely randomized design. Dietary treatments consisted of the basal finishing-diet supplemented without or with ZH dosed at 0.20 mg/kg BW daily. The composition of the basal finishing diet is presented in Table 1. Dietary composition was determined by analyzing subsamples collected and composited throughout the experiment. Samples was subjected to the following analysis: DM (oven drying at 105 °C until no further weight loss; method 930.15 (8)), ash (method 942.05 (8)), Kjeldahl N (method 984.13 (8)), NDF [(corrected for NDF-ash) incorporating heat stable α-amylase (Ankom Technology, Macedon, NY, USA) at 1 mL per 100 mL of NDF solution (Midland Scientific, Omaha, NE, USA)], calcium (method 927.02 (8)), and phosphorus (method 964.06 (8)). Goats that received ZH were fed the β-agonist for 30 days with a 3-day withdrawal period before harvest. To maintain the planned daily dosage of ZH, all kids were individually weighed weekly using electronic scales (PX 9000, Pand Ltd., Tehran, Iran) before the morning feed (0730 hours). The daily dosage of ZH was adjusted weekly based on the body weight and feed intake observed in the previous week.

Table 1. Composition of experimental diets fed to goats (% of dry matter).

Item	Control	ZH
Ingredient composition (%)		
Alfalfa hay	25.00	25.00
Corn silage	5.00	5.00
Cracked corn	5.00	5.00
Barley grain	45.00	45.00
Wheat bran	5.00	5.00
Soybean meal	6.00	6.00
Canola meal	7.20	7.20
Mineral and vitamin supplement	1.80	1.80
Zilmax	-	+
Nutrient composition (DM basis)		
Net energy (MJ/kg)		
Maintenance	8.91	8.91
Gain	6.06	6.06
CP (%)	17.40	17.40
NDF	28.50	28.50
Ether extract (%)	2.50	2.50
Calcium (%)	0.90	0.90
Phosphorus (%)	0.42	0.42

ZH, Zilpaterol hydrochloride; mineral and vitamin supplement contained 56% limestone, 22% NaCl, and 22% vitamin and mineral premix containing: (mg/kg) Fe 1500, Cu 150, Mn 1000, Zn 1500, Cu 50, and I 50; and 500,000 UI vitamin A and 250,000 UI vitamin E. Zilmax was fed to provide 0.20 mg ZH/kg of BW daily (Zilmax, Intervet, South Africa). With the exception of net energy, which was estimated based on tabular net energy values for individual feed ingredients, the dietary composition was determined by analyzing subsamples collected and composited throughout the experiment.

2.3. Growth performance data

The performance data were calculated from weights registered before the morning feed on day 1 and day 33 of the feeding trial. Initial BW was reduced by 4% to adjust for gastrointestinal tract contents, and all kids were fasted for 16 h before recording the final BW. Average daily gains were computed by subtracting the initial live

shrunk BW from the final shrunk BW and dividing the result by the number of days on feed. The efficiency of BW gain was computed by dividing ADG by the daily DMI. The corrected DMI was calculated from the as-fed intake of feed multiplied by the DM percentage obtained from lab analysis.

2.4. Plasma metabolite sampling and analysis

Ten milliliters of blood was collected [21G (green hub) needle, MediPlus, UK] from the jugular vein of each individual in heparinized tubes (Venojet, Terumo Europe, Belgium) on days 1 and 30, 1 h before the morning meal. Samples were immediately centrifuged for 15 min at 3000 × *g* at a temperature of 5 °C, and plasma was stored at –20 °C until analysis of glucose, triglycerides, and cholesterol. Plasma metabolites were quantified by spectrophotometry (UV-2100, Shimadzu, Kyoto, Japan) using a Diagnostic Chemicals Ltd. kit (Pars Azmoon, Iran, for glucose, triglycerides, and cholesterol).

2.5. Slaughter process and carcass data collection

At the end of the experiment, all kids were harvested. Kids were transported to the Rac industrial abattoir in the city of Karaj located 10 km from the research facilities. The time from unloading to harvest was 6 h. At the time of harvest gastrointestinal organs were separated and weighed, and HCWs were recorded. After carcasses were chilled for 48 h, lambs were utilized for measurement of fat thickness, LM area, and kidney-pelvic (KP) fat, which was removed from the hind saddle and weighed and reported as a percentage of carcass weight (9). The dressing percentage was calculated by expressing HCW as a percentage of final live BW (9). The difference between HCW and cold carcass weight (CCW) was used to calculate the percentage of cooling loss (9). Each carcass was split down the midline of the vertebral column into two sides. The right side was used for the chemical and quality analysis of the LM. After carcass analyzing, they were immediately vacuum sealed and carried to the laboratory under cool conditions.

2.6. Data on organ mass

All tissue masses are reported on a fresh tissue basis. Organ mass was expressed as grams of fresh tissue per kilogram of final empty BW. Final empty BW (EBW) represents final BW minus the total weight of the digesta. Full viscera mass was calculated by the summation of all viscera components (stomach complex + small intestine + large intestine + liver + lungs + heart), including the digesta. Stomach complex was calculated as the digesta-free sum of weights of the rumen, reticulum, omasum, and abomasum. To express organ mass on an EBW basis, fresh organ mass (g) was divided by final EBW (kg).

2.7. Chemical analyses of *longissimus* muscle

Muscle samples were collected at 48 h postmortem from the LM from the right side of each carcass for assessment of muscle protein, DM, ash, and fat concentrations. The protein, dry matter, ash, and fat content in LM samples from all kids were determined using standard AOAC procedures 981.10, 950.46, 923.03, and 960.39, respectively (8). For protein determination, meat protein was measured from 1 g of blended samples using the Kjeldahl procedure (Kjeltec 1030 Autoanalyzer, Foss Tecator AB, Hogans, Sweden). The meat moisture content was measured by drying 10-g samples at 100 °C for 20 h in a drying oven (Plus oven, Weis-Gallenkamp, Loughborough, UK). The ash content was determined by incineration in a muffle furnace (KR 170, Heraeus, Germany) at 550 °C for 1 h, followed by cooling to room temperature. The LM fat was determined in a 4-g sample using the ether extraction technique (Soxtec system, HT, Foss Tecator 1043, Hillerød, Denmark).

2.8. Statistical analysis

Performance, carcass data, and LM chemical composition were analyzed using the MIXED procedure of SAS (version 9.1, 2002–2003, SAS Institute Inc.) for a completely randomized design. Treatment was considered as the fixed effect and goat as the random effect. The effects of treatments on visceral organ mass data (expressed as g/kg EBW) were evaluated using a one-way classification model. Goats were used as experimental units. In all cases, least square means and standard error are reported, with significance at $P < 0.05$ and main trends at $P < 0.10$.

3. Results

3.1. Feeding performance

The ADG, DMI, and gain efficiency (gain for feed, G:F) during the 60-day pretrial period were similar ($P \geq 0.32$) among preassigned treatment groups, averaging 0.135 ± 0.03 kg/day, 1.29 ± 0.08 kg/day, and 0.11 ± 0.004, respectively. The effects of zilpaterol supplementation on growth performance are presented in Table 2. In comparison with the controls, ZH increased total weight gain (48.1%, $P < 0.01$) and ADG (47.9%, $P = 0.02$.) and reduced DMI (10.9%, $P < 0.01$); therefore, supplementation of ZH increased ($P < 0.01$) G:F by 65.2%.

3.2. Concentration of plasma metabolites

The effects of treatments on the plasma concentration of glucose, triglycerides, and cholesterol measured 1 h before feeding are shown in Table 3. On day 1, the plasma levels of glucose, triglycerides, and cholesterol did not differ ($P > 0.18$) between treatments, averaging 114.76 ± 6.0, 49.52 ± 2.66, and 79.02 ± 4.85 mg/dL, respectively. However, on day 30, the goats fed with ZH had lower ($P < 0.05$) serum concentrations of glucose (12.5%), triglycerides (9.2%), and cholesterol (11.8%) than the controls.

3.3. Carcass characteristics and LM chemical and qualitative characteristics

The effects of treatments on carcass characteristics and the chemical composition of the LM are presented in

Table 2. Effect of zilpaterol hydrochloride (ZH) on feedlot performance of castrated male goats.

Treatments[1]				
Items	Control	ZH	SEM	Significance level
Live BW (kg)				
Initial[2]	29.84	30.00	0.71	0.87
Final[3]	33.77	35.82	0.54	0.02
Total weight gain (kg)	3.93	5.82	0.172	0.01
ADG (g)	119	176	15	0.02
DMI (kg/days)	1.288	1.161	0.022	<0.01
Feed for gain	0.092	0.152	0.016	<0.01

[1] Control = no zilpaterol supplementation, ZH = supplemental zilpaterol at 0.20 mg/kg BW daily.
[2] Initial weight reduced 4% to account for fill.
[3] Goat kids were withdrawn 16 h before weighing and slaughtering.

Table 3. Effect of zilpaterol hydrochloride (ZH) on blood metabolites of castrated male goats.

Treatments[1]				
Items	Control	ZH	SEM	Significance level
Serum metabolites, day 1 (mg/dL)				
Glucose	116.81	112.71	2.054	0.18
Triglycerides	49.44	49.60	0.97	0.91
Cholesterol	78.97	79.07	1.77	0.97
Serum metabolites, day 30 (mg/dL)				
Glucose	119.43	104.55	1.72	<0.01
Triglycerides	49.42	43.25	1.67	0.02
Cholesterol	80.85	71.31	2.36	<0.01

[1] Control = no zilpaterol supplementation, ZH = supplemental zilpaterol dosed at 0.20 mg/kg BW daily.

Table 4. Dietary ZH had no effect (P = 0.45) on cooling loss and increased (P < 0.01) HCW by 9.9%. As a result of an increase (P < 0.01) of the LM area by 20.4% and a reduction (P < 0.01) of KP fat by 33.3%, dressing percentage was increased (P < 0.01) by 3.7% in goats fed ZH. The composition of gain was also modified by ZH. The LM of goats fed ZH showed an increase (13.3%, P < 0.01) in protein concentration and a decrease (20.3%, P < 0.05) in fat content.

3.4. Visceral organs mass

The effects of treatments on fresh organ mass are presented in Table 5. Supplemental ZH did not affect (P ≥ 0.14) the full viscera or stomach complex mass. The relative value of EBW/final BW was not affected by ZH supplementation, averaging 84.3%, but the EBW increased (6.1%, P = 0.03) and the relative values (g/kg final EBW) of heart/lungs and kidney weights decreased (P ≤ 0.04) by 10.4% and 13.9%, respectively.

4. Discussion

4.1. Feeding performance

Mahabadi is a native goat breed from western Iran for which there is limited information about growth performance and carcass characteristics. Nevertheless, the rate of gain and the carcass traits observed here for the control group in the last 33 days are similar to those reported for intact male Mahabadi goats finished at a similar initial BW and a comparable diet (10). The results from the current study are

Table 4. Effect of zilpaterol hydrochloride (ZH) on carcass characteristics and LM chemical characteristics.

Treatments[1]				
Items	Control	ZH	SEM	Significance level
Carcass characteristics				
HCW (kg)	13.76	15.13	0.24	<0.01
Dressing percentage	40.74	42.23	0.24	<0.01
CCW (kg)	13.22	14.73	0.19	<0.01
Cooling loss (%)	2.82	2.67	0.15	0.45
LM area (cm^2)	7.30	8.79	0.29	<0.01
LM chemical characteristics				
Protein (%)	22.35	25.33	0.27	<0.01
Fat (%)	2.31	1.92	0.09	0.02
Ash (%)	1.41	1.57	0.08	0.09
Moisture (%)	70.62	72.74	0.32	<0.01
Fat thickness (cm)	0.75	0.62	0.03	<0.01
KPH (% of HCW[2])	2.40	1.80	0.10	<0.01

[1] Control = no zilpaterol supplementation, ZH = supplemental zilpaterol dosed at 0.20 mg/kg BW daily.
[2] KPH = kidney-pelvic-heart fat, measured perpendicular to the 13th rib and 7.6 cm ventral to the *longissimus* muscle.

Table 5. Effects of zilpaterol hydrochloride (ZH) on visceral organ mass of castrated male goats.

Treatments[1]				
Items	Control	ZH	SEM	Significance level
Final BW (kg)[2]	33.77	35.82	0.54	0.02
Full viscera (kg)[3]	6.38	6.81	0.27	0.14
Empty BW (kg)	28.53	30.16	0.68	0.03
EBW (% of Final BW)	84.52	84.17	6.1	0.58
Organs (g/kg EBW)				
Stomach complex[4]	67.62	63.89	4.12	0.38
Liver	17.04	17.18	0.43	0.76
Kidney	3.03	2.66	0.08	<0.01
Heart/Lungs	19.40	17.58	0.55	0.04
KPH fat[5]	28.10	21.36	1.17	<0.01

[1] Control = no zilpaterol supplementation, ZH = supplemental zilpaterol dosed at 0.20 mg/kg BW daily.
[2] Goat kids were withdrawn 16 h before weighing and slaughtering.
[3] Full viscera = full viscera mass = (stomach complex + small intestine + large intestine + liver + lungs + kidney + heart) including digesta.
[4] Stomach complex = (rumen + reticulum + omasum + abomasum), without digesta.
[5] KPH = kidney-pelvic-heart fat.

consistent with results reported in feedlot cattle (1,2) and in feedlot lambs (5,11) where ZH supplementation enhanced ADG and gain efficiency. We observed that the magnitude of the responses to ZH supplementation in terms of ADG and gain efficiency (Table 2) in the present study were greater (45.9% and 63.3%) than the average (32.95% and 26.17%) previously reported for ZH-fed finishing male lambs (5,12). The effects of ZH supplementation on DMI were less consistent. Although in the majority of studies involving feedlot cattle (13) ZH supplementation did not affect DMI, some reports indicated effects on DMI when cattle were fed ZH. To the best of our knowledge (1,2), only one study reported that zilpaterol supplementation increased feed intake, and it was reported in lambs (11). There is no information regarding the effect of ZH on DMI in goats; however, as in the present study, in some studies ZH supplementation has been reported to result in depression of DMI in feedlot cattle. Vasconcelos et al. (2) reported a linear decrease in the DMI of steers as the length of ZH supplementation increased from 20 to 40 days. In contrast, Montgomery et al. (1) observed that ZH supplementation decreased DMI by 6% in heifers but not in steers when ZH was included in the diet for 40 days. In a subsequent study, Montgomery et al. (1) reported a decrease in DMI in steers when ZH was fed for 30 days. The reasons for decreased feed intake when β-agonists are fed has not been elucidated, but it may involve both direct (e.g., tissue-specific) and indirect (e.g., endocrine) changes associated with fat and muscle metabolism (14).

4.2. Concentration of plasma metabolites

According to plasma metabolite results (Table 3), the decrease in plasma glucose in the current study may be due to the fact that the rate of energy metabolism increases directly in relation to muscle mass; however, in ruminants, the effects of agonists on plasma metabolites are inconsistent. Although data on the effects of IGF-I on energy metabolism in ruminants are lacking, studies in hypophysectomed rats have shown that IGF-I exerts insulin-like effects on glucose metabolism and stimulates glycogen synthesis in skeletal muscle (15). In accordance with our findings, significantly higher levels of net glycogen synthesis from glucose were observed in LM strips from clenbuterol-fed animals than in muscle strips from control sheep (16). In contrast, Beermann et al. (16) observed that feeding cimaterol to growing lambs increased growth hormone and T4 concentrations but decreased insulin and IGF-I concentrations after 6 weeks. However, in subsequent studies, cimaterol supplementation in lambs did not affect IGF-I concentration but decreased T4 and markedly decreased (50%) insulin concentrations after 3 weeks of treatment (17). Claeys et al. (18) also reported no change in IGF-I following chronic administration of clenbuterol to sheep. In the same manner, no effect on blood glucose content was detected when terbutaline or metaproterenol, both β-adrenergic agonists, were offered to sheep (19). In nonruminant species, zilpaterol increased plasma glucose levels within 72 h, but significantly decreased glucose levels after 14 days (20). As in the present study, Galbraith et al. (21) recorded significant reductions in plasma-free fatty acids at day 9, but observed an increase in plasma glucose concentration at day 49 in lambs treated with cimaterol. Likewise, Kim et al. (22) observed significant increases in the plasma concentrations of fatty acids and triglycerides following supplementation with 10 ppm of cimaterol.

4.3. Carcass characteristics

The increased dressing percentage in goats fed ZH explained 72.8% of the differential increase in gain observed in the ZH treatment. Increased carcass weight and dressing percentage and decreased KP fat has been a consistent response to ZH supplementation in lambs (6). However, in the current study, the magnitude of these responses was two-fold greater for HCW and 22% lower for dressing percentage, and KP fat was decreased by 4% when compared to other studies. The potential for increased LM area as a result of ZH supplementation in feedlot cattle is well documented (1). However, in lambs, the magnitude of the response has been variable, ranging up to 30% (12). The factors that affect the magnitude of responses to zilpaterol supplementation in terms of growth performance and carcass characteristics in small ruminants require further study, but may include growth potential, age at time of feeding zilpaterol, nutritional background, initial weight at the start of the finishing program, number of previous days on feed in feedlot, and final weight at time of harvest (23).

4.4. LM chemical and qualitative characteristics

About data gained for LM chemical characteristics in Table 4, most of the β-agonists used in livestock result in increased lipolysis, decreased lipogenesis, or increased protein deposition by binding to the β_1- or β_2-adrenergic receptors (23). The mechanism of these in vivo effects of β-agonists is not completely understood. Protein accretion is strongly influenced by calpastatin, which is one of the factors causing skeletal muscle hypertrophy (24). Some studies indicated that the activity of calpastatin, the endogenous inhibitor of μ- and m-calpain, increases substantially during supplementation with type 2 β-agonists (25), whereas others have suggested that improvements in protein accretion are due to an increase in protein. Like the present study, Baker et al. (26) reported an increase in protein and moisture content with a reduction in fat content in the hindquarter muscle of lambs fed clenbuterol (a β-agonist type 2). Byrem et al. (27) evaluated the direct action of a type 2 β-agonist on muscle protein accretion in vivo by closed arterial infusion of cimaterol into a single hindlimb for 21 days in growing

steers. Net protein accretion in the treated limb was estimated to have increased by 65% compared with that in the contralateral, saline-infused limb. Hilton et al. (28) reported that the estimated carcass fat from the 9th, 10th, and 11th rib dissections was significantly less in steers, whereas estimated carcass moisture was significantly greater by zilpaterol supplementation. The apparent improvement in the efficiency of energy retention per unit DMI in finishing lambs may be due to the direct action of the ZH on net protein retention and hence lean tissue growth (29).

4.5. Visceral organs mass

Based on Table 5, increases in EBW with no differences in the relative value of EBW as a percentage of final BW were observed when sheep were fed zilpaterol. Previous data suggest that the repartitioning effects due to type 2 β-agonists are not restricted to carcass tissues because the amount of internal fat was significantly less in lambs fed clenbuterol than in controls (26). Supplementation with a type 2 β-agonist caused a decrease in visceral organ mass (gastrointestinal tract and/or liver) in rats (30). Similarly, a reduction in kidney (7.5%) and heart (15.4%) mass was previously reported in lambs fed with type 2 β-agonist cimaterol (26). ZH supplementation decreased liver weight by 9.5% in lambs (12). However, in contrast to the present report, there was no effect of ZH supplementation on organ mass (expressed as percentage of BW) in steers (3).

In summary, daily ZH supplementation of 0.20 mg/kg BW for the last 30 days of the finishing phase improved daily gain and feed efficiency in castrated goats. In addition, this compound increased HCW and dressing percentage and decreased visceral fat. The increases in dressing percentage and LM chemical characteristics can be direct results of greater muscle accretion, and reduction in organ weights, and decreased visceral fat.

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