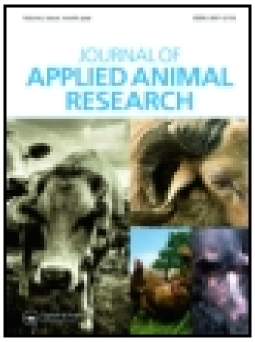

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Zilpaterol hydrochloride improves growth performance and carcass traits without affecting wholesale cut yields of hair sheep finished in feedlot

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ABSTRACT

Fourteen Dorper × Pelibuey ram lambs (initial body weight [BW] = 37.4 ± 1.0 kg and age = 4.5 mo) were housed in individual pens during a 30-d feeding period, and then slaughtered to determine the effects of zilpaterol hydrochloride (ZH) supplementation on productive performance, carcass characteristics and wholesale cut yields. Lambs were assigned under a randomized complete block design (initial BW as blocking factor) to one of two dietary treatments: basal diet without (control) or with 10 mg daily of ZH/lamb. Lambs fed ZH had greater ($P \leq .04$) final BW, average daily gain and dry matter intake, but similar ($P = .24$) feed efficiency compared with control lambs. Hot and cold carcass weight, dressing percentage, *longissimus* muscle area and leg perimeter were greater ($P \leq .05$) for ZH-fed lambs than for control lambs. With exception of blood percentage which decreased ($P < .01$) with ZH, wholesale cut yields and non-carcass components were unaffected ($P \geq .12$) by ZH supplementation. In conclusion, ZH can be used to improve growth rate and dressing percentage, but not to increase wholesale cut yields in feedlot finishing ram lambs.

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Ram sheep; β2-adrenergic agonists; carcass; wholesale cuts

1. Introduction

Growth of the sheep meat industry throughout the world has been slow compared with meat industries of other domestic animals. Therefore, increasing productivity and efficiency of sheep meat production are key factors to enhance the competitiveness of this industry (Montossi et al. 2013). The use of β2-adrenergic agonists (β_2-AA) as growth promoters has demonstrated to increase sheep meat production by improving protein deposition in muscle (Domínguez-Vara et al. 2013). The use of such technology in the lamb fattening systems could be a nutritional strategy to improve their competitiveness.

Over the last decade, zilpaterol hydrochloride (ZH) has been the most widely studied β_2-AA and is officially approved for cattle feeding in various countries. Studies done with ram lambs from hair genotypes have reported up to 43 and 35% more daily weight gain and feed efficiency, respectively, when ZH is supplemented (Ríos-Rincón et al. 2010; Lopez-Carlos et al. 2011). Carcass characteristics of economic importance (i.e. carcass weight, dressing percentage, *Longissimus dorsi* area) also increased up to 13% by effect of ZH (Lopez-Carlos et al. 2011). However, the level of response expected by ZH supplementation in lambs has not been consistent among studies related to growth, feed efficiency, dressing percentage and internal fat deposition.

It is noteworthy that there are few studies about effects of ZH on wholesale cut yields in finishing male lambs. Dávila-Ramírez et al. (2014) reported that ZH supplementation produced greater leg yield but lower plain loin yield in Dorper × Pelibuey ram lambs maintained under heat stress conditions. However, other studies completed with both ram (Macías-Cruz et al. 2016) and ewe (Dávila-Ramírez et al. 2015) lambs found that ZH did not alter wholesale cut yields. These results demonstrate the need for further studies on this topic. It was hypothesized that the addition of ZH in the finishing diet can improve growth, carcass characteristics and yield of some wholesale cuts in ram lambs. Therefore, the objective of this study was to evaluate the effect of daily supplementation of ZH on productive performance, carcass characteristics and wholesale cut yields of hair sheep ram lambs finished in intensive fattening.

2. Material and methods

2.1. Animals

Animal care and management procedures involving lambs were conducted according to the guidelines approved by the Mexican Official Norms (NOM-051-ZOO-1995: humanitarian care of animals during mobilization; NOM-033-ZOO-1995: slaughter of domestic and wild animals). The study was conducted at the Sheep Metabolic Unit, at the Centro Universitario Temascaltepec of the Universidad Autónoma del Estado de México (CUT-UAEM), located in the Estado de México, central

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Mexico (latitude 19.03°N and longitude 100.02°W). Fourteen Dorper × Pelibuey male lambs (37.4 ± 1.0 kg initial body weight [BW] and age = 4.5 mo) were adapted to individual pens and basal diet (Table 1) for 15 d before starting the experimental phase. The dimensions of the pens were 1.0 m wide × 1.2 m long, and each one was equipped with feed trough, automatic waterer and shade. Also, animals were treated with vitamin A-D-E (Vigantol; Bayer, Mexico City, Mexico; 1 mL/animal) and against internal and external parasites (Invermectin; Sanfer Laboratory, Mexico City, Mexico; 0.5 mL/animal) at the beginning of the adaptation period.

The first day of the experimental phase, lambs were weighed (37.36 ± 1.0 kg) and organized into blocks of two animals of similar BW (blocking factor = BW), resulting in a total of seven blocks. Animals from each block were randomly assigned to one of the following two dietary treatments ($n = 7$ each): (1) basal diet without ZH (control) and (2) basal diet with 10 mg of ZH/lamb/d. The daily dose of ZH per animal for treated lambs was weighed and placed into a gel capsule, while control lambs were fed an empty capsule daily (without ZH). To ensure the daily intake of the capsules before the morning feeding according to each treatment, capsules were smeared with molasses and placed at the bottom of the oral cavity using a bolus gun (one capsule/lamb/d). Additionally, a person supervised visually each day that no lamb discarded the capsule.

The experimental phase lasted 30 d, and the male lambs fed ZH were treated with the β_2-AA during the first 28 d followed by a 2-d withdrawal period before slaughter. Feed was offered three times daily at 600, 1300 and 2000 h in proportions of 40%, 30% and 30%, respectively. Fresh water was offered *ad libitum*. Two samples per week of feed were collected, dried in forced-air oven at 60°C for 24 h and stored for analysis.

Table 1. Ingredients and chemical composition of the basal diet.

Item	
Ingredient, as-feed basis	%
Yellow corn meal	37.5
Polished rice	10.0
Dried distillers grains	10.0
Soybean hulls	8.0
Cane molasses	8.0
Canola meal	7.5
Soybean meal	7.0
Wheat bran	6.0
Corn gluten meal	2.0
Mineral salts for lambs	1.5
Calcium carbonate	1.0
Urea	0.5
Common salt	0.5
Bypass fat	0.5
Chemical composition, DM basis	%
Dry matter	92.0
Organic matter	90.0
Crude protein	14.5
Ether extract	8.5
Neutral detergent fibre	17.1
Neutral acid fibre	8.2
Dietary energy, DM basis[a]	Mcal/kg
Digestible energy	3.5
Metabolizable energy	2.9
Net energy for maintenance	1.9
Net energy for gain	1.3

[a]All dietary energies were calculated using formulas from NRC (1985).

Samples were ground (2-mm screen, Wiley mill model 4; Thomas Scientific, Swedesboro, NJ, USA) and mixed to obtain two subsamples, which were analysed for dry matter (DM; ID 930.15), ash (ID 942.05), ether extract (ID 945.16) and crude protein (ID 984.13) according to the methodology of the AOAC (1997). Organic matter content was estimated by subtracting the ash content to DM content. Concentrations of neutral detergent fibre and acid detergent fibre were determined using the filter bag technique (Ankom 200 Fiber Analyzer; Ankom Technology, Macedon, NY, USA; Van Soest et al. 1991). Total digestible nutrients (Alves et al. 2011) and digestible energy (DE; NRC 1985) were calculated to estimate metabolizable energy (ME) as follow: $ME = DE \times 0.82$ (NRC 1985). Also, net energy for maintenance ($NEm = 1.37EM - 0.138EM^2 + 0.0105EM^3 - 1.12$) and gain ($NEg = 1.42EM - 0.174EM^2 + 0.0122EM^3 - 1.65$) were calculated using the formulas from NRC (1985).

2.2. Evaluation of feedlot performance

Individual BW was recorded before the morning feeding at days 1 and 31 of the experimental period. Body weights were reduced 4% to adjust for gastrointestinal fill. Also, both feed and water offered and refused were measured daily before the morning feeding. From data collected, average daily gain (ADG), total weight gain, dry matter intake (DMI), feed efficiency (ADG/DMI) and water intake were calculated for the overall period.

2.3. Evaluation of carcass and non-carcass traits

All lambs were slaughtered immediately after the 30-d feeding period in a commercial abattoir. Diet and water were withdrawn 12 h before the slaughter. The methodology utilized to evaluate carcass and non-carcass traits was the same as described by Macías-Cruz et al. (2010) and Avendaño-Reyes et al. (2011). After slaughter by exsanguination, lambs were bled, skinned and eviscerated to obtain weights of non-carcass components (i.e. blood, skin, head, foot, testicles, heart, liver, lungs, kidney, rumen, and small and large intestine), kidney–pelvic–heart fat (KPH), and hot carcass weight (HCW). After 24 h of cooling at 4°C, cold carcass weight (CCW), carcass length, thorax depth, leg length and perimeter, and carcass conformation (Smith et al. 2001; numerical scale from 1 = bad to 10 = excellent) were recorded. Each carcass was ribbed between the 12th and 13th rib to determine *longissimus* muscle (LM) area using a dot square grid of 64 mm^2, likewise fat thickness at approximately 5.0 cm from lateral to middle line with a vernier calliper. Additionally, the LM pH at 45 min and 24 h post-mortem was measured with a portable digital pH meter equipped with a puncture electrode (Hanna, Model HI 98140, USA).

Weights of all non-carcass components were expressed as percentages of the final BW, while KPH fat was expressed as a percentage of HCW. Cooling loss percentage was calculated by the difference between HCW and CCW as percentage of HCW, and dressing percentage was calculated as (HCW/final BW) × 100.

2.4. Evaluation of wholesale cut yields

Carcasses were split along the middle line and right sides were used to obtain the following wholesale cuts: neck, shoulder, square cut shoulder, rack, loin, breast and flank, and leg. The yield of each cut was calculated expressing its respective weight as percentage of the weight of the carcass half.

2.5. Statistical analysis

Feedlot performance, carcass traits, non-carcass components and wholesale cut yields were subjected to analysis of variance using the PROC GLM of SAS (SAS Inst. Inc., Cary, NC) under a randomized complete block design. Treatment means were compared through Tukey test considering significant differences at $P \leq .05$.

3. Results

Lambs fed ZH had greater ($P \leq .05$) final BW, ADG, total weight gain and DMI than control lambs. Water intake and feed efficiency were not affected ($P \geq .13$) by ZH (Table 2). ZH supplementation increased ($P \leq .05$) HCW, CCW, dressing percentage, LM area, carcass length and leg perimeter, but decreased ($P = .04$) KPH fat (Table 3). Other carcass characteristics were not affected ($P \geq .13$) by ZH supplementation. Additionally, there were no changes ($P \geq .25$) in wholesale cut yields by ZH effect (Table 4). The effects of ZH supplementation on non-carcass components expressed as percentage of the final BW are shown in Table 5. With exception of blood percentage which decreased ($P < .01$) with ZH supplementation, the rest of the non-carcass components were not affected ($P \geq .12$) by ZH.

4. Discussion

Increased efficiency of growth by preferentially stimulating skeletal muscle growth compared with adipose tissues is the mode of action of β_2-AA in finishing animals (Moody et al. 2000; Johnson and Chung 2007). In the present study, ZH supplementation increased growth rate and DMI without affecting feed efficiency of finishing ram lambs. Therefore, the increased weight gain is likely explained by the increased DMI observed. Also, changes in composition of tissue gain (more lean than fat tissue) by ZH supplementation may partly explain the increased weight gain, such redirection of energy to protein synthesis and hence to lean tissue growth as previously described Mersmann (1998). The smaller KPH values observed in the present study in the ZH-fed group make evident that ZH affected tissue composition towards greater protein synthesis and less lipid synthesis. Supplementation of ZH during the last 30–32 days before

Table 2. Productive performance of hair sheep male lambs supplemented with ZH.

Item	ZH[a] (mg/d/animal) 0	10	SEM	*P*-value
Initial weight (kg)	37.32	36.39	0.67	.37
Final weight (kg)	44.11	46.01	0.58	.02
Total gain (kg)	6.79	9.57	0.79	.05
Average daily gain (kg/d)	0.23	0.32	0.02	.04
Dry matter intake (kg/d)	1.33	1.61	0.05	<.01
Feed efficiency	0.17	0.20	0.02	.24
Water intake (L/d)	3.06	3.74	0.27	.13

[a]ZH supplementation: Lambs individually received a daily oral capsule that contained 0 or 10 mg of ZH before the morning feeding. Capsules were administered for 28 d followed by a 2-d withdrawal period.

Table 3. Carcass characteristics of hair sheep male lambs supplemented with ZH.

Item	ZH[a] (mg/d/animal) 0	10	SEM	*P*-value
Hot carcass weight (kg)	20.34	22.63	0.32	<.01
Cold carcass weight (kg)	19.00	22.23	0.32	<.01
Dressing (%)	46.18	49.37	0.88	.05
Cooling loss (%)	2.62	1.77	0.34	.13
Conformation[b] (units)	7.21	7.71	0.38	.58
LM[c] area (cm^2)	15.48	17.69	0.51	.02
pH of LM				
45 min	6.13	6.16	0.09	.82
24 h	5.48	5.55	0.07	.17
Fat thickness (cm)	0.28	0.24	0.04	.48
KPH fat (%)	5.65	4.17	0.27	.04
Carcass length (cm)	60.57	63.93	0.88	.03
Thorax depth (cm)	19.64	20.40	0.39	.35
Leg length (cm)	38.93	39.00	0.36	.89
Leg perimeter (cm)	44.01	47.60	0.76	.01

[a]ZH supplementation: Lambs individually received a daily oral capsule that contained 0 or 10 mg of ZH before the morning feeding. Capsules were administered for 28 d followed by a 2-d withdrawal period.
[b]Conformation was evaluated using a numerical scale from 1 = bad to 10 = excellent (Smith et al., 2001).
[c]LM = *Longissimus* muscle.

Table 4. Wholesale cuts from carcass of hair sheep male lambs supplemented with ZH.

Item (%)[b]	ZH[a] (mg/d/animal) 0	10	SEM	*P*-value
Neck	6.73	7.02	0.16	.25
Shoulder	18.44	18.04	0.24	.29
Square cut shoulder	9.41	9.69	0.34	.59
Rack	10.40	10.78	0.39	.52
Loin	8.03	8.18	0.22	.70
Breast and flank	16.92	16.15	0.47	.29
Leg	30.17	30.67	0.35	.35

[a]ZH supplementation: Lambs individually received a daily oral capsule that contained 0 or 10 mg of ZH before the morning feeding. Capsules were administered for 28 d followed by a 2-d withdrawal period.
[b]Expressed as % of the half carcass weight.

Table 5. Percentage of non-carcass components in hair sheep male lambs supplemented with ZH.

Item (%)[b]	ZH[a] (mg/d/animal) 0	10	SEM	*P*-value
Head	4.74	4.49	0.12	.20
Blood	4.09	3.32	0.15	<.01
Skin	8.25	7.03	0.54	.16
Heart	0.50	0.37	0.05	.12
Lung	1.33	1.25	0.08	.47
Liver	2.02	2.04	0.12	.92
Kidney	0.28	0.25	0.02	.12
Rumen	2.48	2.56	0.10	.62
Small intestines	1.25	1.09	0.13	.43
Large intestines	2.96	2.57	0.19	.15
Testicles	1.78	1.67	0.09	.41
Foot	2.41	2.24	0.10	.23

[a]ZH supplementation: Lambs individually received a daily oral capsule that contained 0 or 10 mg of ZH before the morning feeding. Capsules were administered for 28 d followed by a 2-d withdrawal period.
[b]Expressed as % of the final BW.

slaughter has shown to consistently improve growth and feed efficiency in beef cattle (Avendaño-Reyes et al. 2006; Lean et al. 2014); however, it has been inconsistent in finishing lambs. Some studies have reported no effects (Macias-Cruz et al. 2010; Dávila-Ramírez et al. 2015), improvements of growth rate and feed efficiency without affecting DMI (Estrada-Angulo et al. 2008; Mondragón et al. 2010; Avendaño-Reyes et al. 2011) or increased growth rate, and feed efficiency and decreased DMI (López-Carlos et al. 2011, 2012) in sheep after 30–34 d consuming feedlot diets supplemented with ZH. Improvement in growth rate has been the most consistent and DMI the least consistent effect of ZH on sheep. Contrary to the increased DMI observed in the present study, previous experiments have shown that ZH supplementation to finishing sheep have decreased DMI (López-Carlos et al. 2011, 2012), or no effect on DMI (Estrada-Angulo et al. 2008; Mondragón et al. 2010; Avendaño-Reyes et al. 2011). Although the reasons for inconsistencies of effects of ZH supplementation on DMI of finishing sheep are not certain, the responses have been associated to factors such as climatic conditions (Macías-Cruz et al. 2013), initial BW (Aguilera-Soto et al. 2008) and dose of ZH (López-Carlos et al. 2011).

In agreement with previous reports (López-Carlos et al., 2010; Ríos-Rincón et al., 2010; Dávila-Ramírez et al. 2014), ZH supplementation in ram lambs improved carcass weights, dressing percentages and LM area, as well as reduced KPH fat deposition. These results can be attributed to the inhibitory effect of ZH on the proteolysis and lipogenesis, which in turn promotes increased protein synthesis by redirecting energy towards this process (Domínguez-Vara et al. 2013). Thus, ZH in lambs increases the formation of lean meat and, hence, the carcass weight and yield, as well as LM area at the same time that internal fat deposition decreases. Consistent with the present study, most studies in sheep have reported a lack of ZH effects on energy repartition away from subcutaneous fat (Estrada-Angulo et al. 2008; Macias-Cruz et al. 2010; Ríos-Rincón et al. 2010; Dávila-Ramírez et al. 2014, 2015).

Although the use of ZH in cattle has been associated with low muscle pH post-mortem (Avendaño-Reyes et al. 2006; Strydom et al. 2009; Hope-Jones et al. 2010), results in sheep are limited and inconsistent (López-Carlos et al. 2010; Mondragón et al. 2010; Dávila-Ramírez et al. 2014). A pH below 6.0 45 min post-mortem is associated with low water retention capacity and tenderness, and a pH greater than 6.0 24 h post-mortem is associated with dark, firm and dry (DFD) meat (Martínez-Cerezo et al. 2005). In the present study, LM pH at 45 min and 24 h post-mortem was not affected by ZH supplementation, and mean values were within the normal range expected. Consequently, this suggests that ZH supplementation did not cause problems of water retention capacity, tenderness, or DFD meat in sheep.

On the other hand, no effect of ZH on some wholesale cut yield was observed in the present study, which is in agreement with other studies where ZH supplementation was evaluated in ram (Macías-Cruz et al. 2016) and ewe lambs (Dávila-Ramírez et al. 2015) during a 34-d feeding period. However, our results also differ slightly from those previously reported by Dávila-Ramirez et al. (2014), who found greater leg yield but lower plain loin yield with no effect on other cuts (i.e. forequarter, hindquarter, neck, ribs, loin, shoulder and sirloin) by effect of ZH in heat-stressed ram lambs. Also, Macías-Cruz et al. (2010) observed greater yield of ribs, hindquarter and legs, but lower yield of forequarter, neck and shoulder in ewe lambs fed ZH during a warm season. It should be mentioned that there is no precise explanation for our results obtained, as previous studies in beef cattle have reported that ZH improved the development of type II muscle fibre, and consequently, muscle growth (Mersmann 1998; Walker et al. 2010). Based on the above, we expected a greater yield of some wholesale cuts, mainly in those cuts with high amount of type II muscle fibre (i.e. legs, loin, shoulder). Indeed, it is very possible that the low number of animal used affected the test power, situation that did not allow to detect differences between treatments in the wholesale cut yields. However, the improvement of carcass yield with ZH supplementation has been documented in other studies (López-Carlos et al. 2010; Ríos-Rincón et al. 2010); consequently more research is required but using a larger sample size per treatment to elucidate the effect of ZH on cut yields.

The redirection of nutrients from visceral organs for muscle formation is an action mechanism used by β_2-AA to act as growth promoter in beef cattle (Montgomery et al. 2009). However, given our results of non-carcass components, we observed very little effect of ZH on the organs weights of sheep (Ríos-Rincón et al. 2010; Dávila-Ramírez et al. 2014). It is possible that the transformation of mass from visceral organ to carcass tissues is a secondary mechanism used by the ZH molecule to improve muscle protein synthesis and weight gain in finishing lambs. Although, visceral tissues such as liver and gut represent only 6–10% of the body (Burrin et al. 1992), and is estimated that they consumed between 40% and 50% of net energy for maintenance (Webster 1981). Those tissues are very active in protein synthesis, and hence the contribution of these tissues to whole-body energy expenditure is substantial. Therefore, effects on size or weight of viscera tissue impact growth efficiency of the animal. Because ZH did not alter the organ and viscera weights but whether HCW, improvements in carcass composition most likely are not explained by redirection of energy from non-carcass components in hair sheep. Moreover, Reeds and Mersmann (1991) state that from all beta receptors, β_1-AA receptors are more abundant in smooth muscle; thus the lack of effect of ZH on the weights of non-carcass components was related to the possible low level of β_2-AA receptors in smooth muscle, a tissue associated with several internal organs in the body.

5. Conclusion

Overall results showed that ZH supplementation to Dorper × Pelibuey male lambs during the finishing phase was beneficial to improve growth traits, nevertheless, feed efficiency was not improved. Also, the addition of ZH to the finishing diet had a positive effect on some carcass traits of economic importance to the sheep meat industry such as carcass weight, dressing percentage and LM area. However, these improvements due to ZH were not reflected on wholesale cut yields of hair sheep male lambs finished in feedlot.

Disclosure statement

No potential conflict of interest was reported by the authors.

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