https://doi.org/10.22319/rmcp.v11i3.5149

Article

Supplementation with zilpaterol hydrochloride in lambs finished with a diet formulated without forage fiber

Ricardo Vicente-Pérez [a]

Ulises Macías-Cruz [b]*

Ramón Andrade Mancilla [a]

Rogelio Vicente [a]

Enrique O. García [a]

Ricardo Martínez [a]

Leonel Avendaño-Reyes [b]

Oziel D. Montañez [c]

[a] Universidad de Guadalajara, Departamento de Producción Agrícola-CUCSUR, Autlán de Navarro. Jalisco, México.

[b] Universidad Autónoma de Baja California, Instituto de Ciencias Agrícolas, Valle de Mexicali, Baja California, México.

c Universidad de Guadalajara, Departamento de Ciencias de la Naturaleza-CUSUR, Ciudad Guzmán. Jalisco, México.

* Corresponding author: ulisesmacias1988@hotmail.com

Abstract:

A total of 24 hair male lambs were distributed under a completely randomized block design in two treatments to evaluate the effects of supplementing zilpaterol hydrochloride (ZH. 0 *vs*. 10 mg/d/animal) in a finishing diet with non-forage fiber source on productive performance, carcass characteristics, primary cut yields and non-carcass component weights. A feedlot test was conducted during 30 d, and subsequently half the animals under each treatment (n= 6) were slaughtered. Supplementation with ZH did not affect the weight gain, but it improved ($P \leq 0.02$) feed efficiency, carcass weight and yield, and *Longissimus dorsi* muscle area, as well as leg and whole loin yields. Both KPH and mesenteric fat diminished ($P \leq 0.05$) due to ZH. The rest of percentages of non-carcass components remained unaffected by ZH. It can be concluded that dietary supplementation of generic ZH improved the muscle mass deposition by decreasing the internal fat deposition, favoring the feed efficiency of male lambs fattened with diet formulated without forage fiber.

Key words: Hair sheep, Fattening of lambs, Adrenergic agonist, Grofactor®.

Received: 14/11/2018

Accepted: 1/07/2019

Introduction

The Mexican ovine inventory grew by 20 % in the last decade; this generated a meat production of 62,939 t for 2018 and a considerable reduction in the importations of this product(1). The production of lamb meat has proven, for the last few decades, to be a niche of opportunity in the Mexican market and, in general, across the world, as the demand remains unmet and the kilogram of meat has a competitive price(2). In this sense, the search for strategies to improve the production of lamb meat is today a pressing need.

The β2 adrenergic agonist (β2-AA) zilpaterol hydrochloride (ZH) is an effective growth promoter to improve productive performance and carcass characteristics with economic importance when administered 4 to 5 wk before slaughtering to feedlot-finished lambs(3-6), but not to lambs finished at pasture(7). This β2-AA acts as a growth promoter because it redistributes energetic substrate from the fatty tissue and of certain organs toward building muscle mass (hypertrophy)(4,8,9). Notably, the effectiveness of ZH as a growth promoter in fattening lambs has been proven by offering diets formulated with both grains and forage in order to favor the correct functioning of the rumen. However, the diets for fattening lambs are being formulated today with non-forage fibers, given that forage is scarce in certain regions and at certain seasons of the year, and also because it sometimes has a high cost(10).

Sawdust and the agro-industrial wastes are two sources of alternate fiber that do not cause digestive problems in lambs when used to substitute 100 % of the forage fraction in the fattening diet(11,12). However, the effectiveness of ZH as a growth promoter in lambs fed with non-forage fiber has not been determined. Therefore, the objective of this study was to evaluate the effect of ZH on productive performance, carcass characteristics and primary cut yields in hair breed lambs finished in feedlot, using a mixed diet based on grains without forage fiber.

Material and methods

All the procedures involved in the management and slaughter of the animals were carried out according to the Mexican Official Norms of SAGARPA (NOM-051-ZOO-1995: Humanitarian care of animals during mobilization, and NOM-033-ZOO-1995: slaughter of domestic and wild animals). The study consisted of a 30-d feedlot test conducted at the “El Tilzapote” ranch, located in the town of Ayutita, Autlán de Navarro, Jalisco. Subsequently, half the lambs were slaughtered at a commercial slaughterhouse located in Tapalpa, Jalisco.

Animals, housing and pre-experimental management

Twenty-four entire Katahdin male lambs with age of 4 mo and average body weight of 35.8 ± 5.3 kg were used in the feedlot test. Lambs were housed in individual pens and adapted to a basal diet formulated for a daily weight gain of 300 g (Table 1)(13) 15 d before the test. In addition, they were subjected to cutaneous deworming with 1 ml of ivermectine at 1%/25 kg of live weight. The amount of diet used during the experimental period was mixed in one time, and two samples were drawn from the various sacks in order to determine the following chemical compounds: dry matter, crude protein, ether extract, total fiber, acid and neutral detergent fibers, and ash(14,15). The total digestible nutrients and the different types of energy (digestible, metabolizable, net for maintenance and gain) were estimated using formulas(16,17).

Table 1: Ingredients and chemical composition of the experimental basal diet

Ingredients, as offered	**%**
Ground corn	57
Pine sawdust	20
Soybean meal	10
Wheat bran	8
Frying oil	2
Mineral pre-mixture	2
Urea	1
Chemical composition in a dry matter basis	%
Dry matter	94.2
Crude protein	14.4
Ether extract	11.2
Fiber	21.5
Ashes	11.2
Acid detergent fiber (ADF)	20.4
Neutral detergent fiber	30.6
Total digestible nutrients (TDN)	79.3
Energy from the diet in a dry matter basis	Mcal/kg
Digestible energy (DE)	3.5
Metabolizable energy (ME)	2.9
Net energy for maintenance (NEm)	1.9
Net energy for growth (NEg)	1.3

TDN = 102.56 – (%ADF X 1.140) (Alves *et al.*, [16]); DE = TDN x 0,044 (NRC [17]); ME = 0.82 x DE (NRC [17]); NME = 1.37 x ME – 0.14ME^2 + 0.01ME^3 – 1.12 (NRC [17]); NEg = 1.42 x ME – 0.17ME^2 + 0.012ME^3 – 1.65 (NCR [17]).

Treatments and experimental feeding

On the first day of the test, the lambs were weighed, and pairs of similar weight (blocking factor) were formed in order to assign them randomly within each block to one of the two dietary treatments (n=12): 1) basal diet without ZH (control) and 2) basal diet with 10 mg of generic ZH/d/head (Grofactor®, Virbac México, Guadalajara, México). The daily dose of ZH was estimated based on the amount of commercial product (208 mg) and was placed in a gel capsule to be administered orally to each animal treated with ZH before the morning feeding. In the control group, a gel capsule with 208 mg of soybean meal was administered daily to each sheep as a placebo. The dose of ZH was determined by the recommendations of previous studies[(18,19)]. The ZH was offered during 28 d, followed by a 48 h withdrawal period before slaughter.

The daily amount of feed per pen was estimated for a rejection of approximately 10 % and was offered once, at 0700 h, immediately after administering the treatment capsules. Water was available *ad libitum*, and the health status of the animals was examined every day through direct observation.

Productive performance

The productive performance was assessed by registering the live weight at the beginning (d 1) and at the end (d 31), before the morning feeding. The amount of feed refused per pen was also registered. From this data, dry matter intake, total and daily weight gain, and feed efficiency were calculated for the overall period (d 1 to 30).

Carcass characteristics and primary cuts

For the assessment of the carcass traits, only half of the lambs of each treatment group (n= 6) were transported to the slaughterhouse, located 2 h away from the site of the feedlot test. Since the study was carried out in a private ranch, the producer determined that the heaviest lambs should be slaughtered. Accordingly, the lambs of blocks 7 to 12 were slaughtered using the exsanguination method. The individual live weight of the lambs was registered once more before the slaughter line. All bodies were eviscerated in order to register the hot carcass weight (HCW), as well as the weights of the head, blood, skin, heart, lungs, liver, kidneys, spleen, testicles, and feet. The weights of the mesenteric, omental, and kidney-pelvis-heart fat (KPH) were also registered. Subsequently, the carcasses remained at 4 ° C during 24 h, and the following variables were registered, according to the methodologies described by Avendaño-Reyes *et al*[18] and Macías Cruz *et al*[20]: cold carcass weight (CCW), *Longissimus dorsi* muscle area (LDM), and dorsal fat thickness. Other morphometric measurements of the carcass were the length of the carcass, leg and shoulder, and the circumference of the thorax, neck, leg and shoulder. Finally, the carcass was cut along the middle line, and the weight of the right half carcass was registered and later utilized to obtain the following primary cuts: neck, loin, ribs with flank, breast, leg, and shoulder.

The live weight at slaughter was adjusted to 96 % because the content of the gastrointestinal tract was considered to be 4 %. With exception of KPH fat, the weights of all non-carcass components were expressed as a percentage of the adjusted live weight at slaughter. The KPH fat was expressed as a percentage of the HCW. The carcass yield was estimated by expressing the HCW as a percentage of the live weight at slaughter. The carcass loss due to cooling was also estimated by expressing the difference between HCW and CCW as a percentage of the HCW. The yield of each primary cut was calculated by expressing the respective weight of each cut as a percentage of the half-carcass weight.

Statistical analysis

The statistical analysis consisted of a variance analysis under a completely randomized block design, using the GLM procedure of the SAS software[21]. The means were compared with a Tukey test at $\alpha = 0.05$. Trends were not considered, given the low number of repetitions for slaughter-related variables.

Results

In the productive performance test, only feed efficiency was affected (P<0.01) by supplementation with ZH, having increased by 9.4 % due to the AA-β2 (Table 2). The feed intake tended to diminish (P=0.08) as a result of supplementation with ZH. As for the carcass traits (Table 3), supplementation with ZH increased (P≤0.02) HCW, CCW, carcass yield and LDM area by 7.5, 7.3, 5.7, and 10.2 %, respectively, while decreasing (P=0.05) the percentage of KPH fat. The rest of the of the carcass characteristics were similar (P≥0.17) between treatments. As for the non-carcass component weights expressed as a percentage of the adjusted live weight at slaughter, the mesenteric fat diminished (P<0.01) by 23.2 % due to the inclusion of ZH in the diet (Table 4). The rest of weights of the non-carcass components did not vary (P≥0.08) with ZH supplementation. Finally, ZH increased (P≤0.04) by 5.1 % the loin and leg yield, but reduced (P=0.03) by 8.1 % the yield of rib with flank (Table 5). The rest of primary cuts had similar (P≥0.18) yields between treatments.

Table 2: Productive performance of male lambs supplemented with generic zilpaterol hydrochloride during the feedlot finishing phase

Variables	Zilpaterol hydrochloride (mg/head/day) 0	10	SE	*P*- values
Live weight, kg				
Initial	35.7	35.8	0.2	0.83
Intermediate	41.5	41.2	0.3	0.49
Final	46.0	46.4	0.2	0.23
Total weight gain, kg	10.3	10.6	0.2	0.29
Daily weight gain, g/d	343.0	354.3	7.1	0.29
Feed intake, kg/d	1.7	1.5	0.1	0.08
Feed eficiency, g/kg	204.6	223.9	4.4	<0.01

SE= standard error.

Table 3: Characteristics and morphometric measures of the carcass in male lambs supplemented with generic zilpaterol hydrochloride during the feedlot finishing phase

Variables	Zilpaterol hydrochloride (mg/head/day) 0	10	SE	*P*- values
Hot carcass weight, kg	22.7	24.4	0.2	<0.01
Cold carcass weight, kg	21.9	23.5	0.2	<0.01
Carcass yield, %	49.1	51.9	0.4	<0.01
Weight loss by cooling, %	3.3	3.5	0.2	0.52
LDM area, cm^2	17.6	19.4	0.2	0.02
Dorsal fat thickness, cm	0.3	0.2	0.1	0.33
KPH fat, %	4.6	3.3	0.4	0.05
Carcass length, cm	63.2	63.3	0.6	0.92
Thorax circumference, cm	74.5	75.2	0.5	0.36
Neck circumference, cm	40.1	39.8	1.0	0.87
Leg length, cm	52.0	52.3	0.8	0.77
Leg circumference, cm	43.5	45.7	1.0	0.19
Shoulder length, cm	41.7	41.0	0.8	0.59
Shoulder circumference, cm	33.1	34.6	0.7	0.17

SE= standard error; LDM= *Longissimus dorsi* muscle; KPH fat= The sum of the fats accumulated in the kidneys, the pelvis, and the heart.

Table 4: Weights of the non-carcass components expressed as a percentage of the adjusted weight at slaughter in hair male lambs supplemented with generic zilpaterol hydrochloride during the feedlot finishing phase (%)

Variables	Zilpaterol hydrochloride (mg/head/day) 0	10	SE	*P*- values
Head	3.27	3.33	0.04	0.38
Blood	4.14	3.93	0.12	0.26
Skin	10.0	9.92	0.41	0.89
Heart	0.48	0.48	0.02	0.57
Lung	1.73	1.74	0.12	0.96
Liver	2.23	1.69	0.17	0.08
Kidney	0.31	0.28	0.02	0.48
Spleen	0.24	0.18	0.02	0.08
Mesenteric	0.99	0.76	0.03	<0.01
Omental	2.45	2.54	0.15	0.72
Testicles	0.89	0.86	0.04	0.74
Feet	2.22	2.29	0.06	0.46

SE= standard error.

Table 5: Primary cut yields in hair male lambs supplemented with generic zilpaterol hydrochloride during the feedlot finishing phase

Variables*	Zilpaterol hydrochloride (mg/head/day) 0	10	SE	*P*- values
Neck, %	9.20	8.70	0.40	0.42
Loin, %	19.20	20.17	0.26	0.04
Rib with flank, %	16.84	15.47	0.33	0.03
Breast, %	5.56	5.07	0.22	0.18
Leg, %	29.12	30.60	0.29	0.01
Shoulder, %	20.08	19.98	0.55	0.90

*All cut weights were expressed as percentages of the half-carcass weight.
SE= standard error.

Discussion

Supplementation with ZH was not effective to improve growth, but increased feed efficiency of lambs finished with diets without forage fiber. These results differ partially from those found in previous studies[5,22,23] where greater feed efficiency, weight gain and final weight by supplementing this β2-AA the last 30 d before slaughter. However, there are several studies that point out the absence of the effect of supplementation with ZH in the daily weight gain and final weight of the lambs[7,24,25]. The control lambs exhibited lower feed efficiency because the diet had a low amount of effective fiber, as the sawdust was ground. This may have increased the gastrointestinal passage rate and decreased the degradation rate of ruminal microorganisms[26], increasing the feed intake and reducing the feed efficiency. The better feed efficiency observed in ZH-fed lambs was due to the fact that β2-AA improved the digestibility of the diet because it increased the ruminal bacterial population and reduced the motility of the gastrointestinal tract[27]. Thus, the lambs treated with ZH tended to reduce their daily feed intake without affecting growth rate.

Although the growth of the lambs did not improve with generic ZH supplementation, the muscle deposition increased significantly by including this β2-AA as part of the diet. So, in line with previous studies[23,28,29], ZH increased HCW, CCW, carcass yield and LDM area in our male lambs. These results were attributed to the fact that ZH promoted a redirection of energetic substrates to increase the protein synthesis while reducing the muscle proteolysis[8]. Both processes led to a muscular hypertrophy in the lambs treated with ZH. Unexpectedly, results of the present study showed that the origin of the energetic substrate utilized to form muscle in lambs supplemented with ZH was mainly the adipose tissue, and not from organ, viscera, heat, feet or testicles. This finding agrees with other researches on lambs where ZH of the Zilmax® company was utilized[6,18,28], but not in those that used Grofactor® ZH[22,23], like the present study. The Grofactor® ZH[22,23] promotes the deposition of muscle mass in fattening lambs because it uses energetic substrates resulting from a better distribution of dietary energy, as well as those produced by certain organs, viscera or head, but not from fatty tissue. No explanation was found for the way in which the ZH acted in the present study, although there is evidence that this type of ZH removes fatty tissue and promotes muscle deposition[9]. Nevertheless, the results suggest that the type of fiber used in the finishing diet of fattening lambs may modify the mechanisms of action of this β2-AA. Research is required at the level of ruminal metabolism and kinetics in order to elucidate how the type of dietary fiber modifies the mechanism of action of the ZH.

The morphometric measures of the carcass were not affected by generic ZH, even when at least a greater length and circumference of the legs were expected, considering that certain studies have reported that the greatest muscular development promoted by this β2-AA is physically evident in this region of the body(4,20). In hair lambs finished with different dosages of generic ZH(22), a quadratic increase was observed for carcass length, thorax depth and leg perimeter as the ZH dose increased from 0 to 0.20 mg/kg of live weight. An increase in the leg perimeter in both male(24,28) and female(19) lambs was also found, without any effect on other morphometric measurements as a result of supplementation with patent ZH.

According to the literature, the results of the effect of patent or generic ZH in primary cut yields are inconsistent. In the present research, generic ZH improved the leg and loin yields, in partial agreement with the findings of other studies in which only the leg yield increased as a result of supplementation with generic ZH in fattening lambs(22,23). Other studies found no changes in the primary cut yields due to supplementation with patent ZH in lambs finished in feedlot(7,28). Results of the present study were attributed to the fact that. both legs and loin have high amount of type II muscle fibers, in which there is a great number of β2-adrenergic receptors(8,18). In this receptors are bonded the β2-AA offered exogenously in the diet to cause its biological effects

Conclusions and implications

It was concluded that ZH supplementation in fattening male lambs enhances feed efficiency, carcass weight and yield, LDM area, without affecting the live weight gain, when they are fed diets formulated with non-forage fiber. In addition, supplementation with ZH improves the loin and leg yields. Finally, supplementation with ZH is a recommendable nutritional strategy for increasing the carcass weight gain and the yield of economically important primary cuts in lambs finished with diets formulated without forage fiber.

Acknowledgments

The authors wish to thank Ramón Andrade Mancilla, VMD, for the facilities provided at his ranch “El Tilzapote”. They also express their gratitude for financial support provided to the first author by the South Coast University Center of the Universidad de Guadalajara, within the framework of the P3e 2018 project, No. 239754, on pertinent research in agropecuarias agriculture sciences and related to the same for the regional development”.

Literature cited:

1. SIAP. Estadísticas de la producción de ovinos del Servicio de Información Agroalimentario y Pesquera, SAGARPA. 2018. Disponible en: http://infosiap.siap.gob.mx/repoAvance_siap_gb/pecResumen.jsp. Consultado 1 Mar, 2019.

2. Muñoz-Osorio GA, Aguilar-Caballero AJ, Sarmiento-Franco LA, Wurzinger M, Cámara-Sarmiento R. Technologies and strategies for improve hair lamb fattening systems in a tropical region: A review. Rev Ecosist Rec Agropecu 2016;3(8):267-277.

3. Lopez-Carlos MA, Ramirez RG, Aguilera-Soto JI, Plascencia A, Rodriguez H, Arechiga CF, *et al*. Effect of two beta adrenergic agonists and feeding duration on feedlot performance and carcass characteristics of finishing lambs. Livest Sci 2011;138(1-3):251-258.

4. Aguilar López EY, González Ronquillo M, Salem AZM, Partida de la Peña JAP. Use of zilpaterol hydrochloride in sheep feeding. In: Salem AZM, editor. Nutritional strategies of animal feed additives. Nova Science Publishers; 2013:115-117.

5. Macías-Cruz U, Álvarez-Valenzuela FD, Soto-Navarro SA, Águila-Tepato E, Avendaño-Reyes L. Effect of zilpaterol hydrochloride on feedlot performance, nutrient intake, and digestibility in hair-breed sheep. J Anim Sci 2013;91(4):1844-1849.

6. Ortiz Rodea A, Amezcua Barbosa M, Partida de la Peña JA, González Ronquillo M. Effect of zilpaterol hydrochloride on animal performance and carcass characteristics in sheep: A meta-analysis. J Appl Anim Res 2016;44(1):104-112.

7. Macías-Cruz U, Avendaño-Reyes L, Vicente-Pérez R, Álvarez-Valenzuela FD, Correa-Calderón A, González-Ríos H, *et al*. Growth and carcass characteristics of lambs finished with zilpaterol hydrochloride in grazing alfalfa | Crecimiento y características de la canal de corderos finalizados con clorhidrato de zilpaterol en pastoreo de alfalfa. Rev Mex Cien Pecu 2016;7(2):243-252.

8. Mersmann HJ. Overview of the effects of beta-adrenergic receptor agonists on animal growth including mechanisms of action. J Anim Sci 1998;76(1):160-172.

9. Avendaño-Reyes L, Meraz-Murillo FJ, Pérez-Linares C, Figueroa-Saavedra F, Correa A, Álvarez-Valenzuela FD, *et al.* Evaluation of the efficacy of Grofactor, a beta-adrenergic agonist based on zilpaterol hydrochloride, using feedlot finishing bulls. J Anim Sci 2016;94(7):2954-2961.

10. Iñiguez-Covarrubias G, Díaz-Teres R, Sanjuan-Dueñas R, Anzaldo-Hernández J, Rowell RM. Utilization of by-products from the tequila industry. Part 2: potential value of Agave tequilana Weber azul leaves. Bioresour Technol 2001;77(2):101-108.

11. Guerra-Medina CE, Cobos-Peralta MA, Montañez-Valdez OD, Pérez-Sato M. Uso de aserrín de pino (*Pinnus patula*) como fuente de fibra en dietas para borregos en cebo. Trop Subtrop Agroecosys 2010;12(3):667-673.

12. Guerra-Medina CE, Montañez-Valdez OD, Ley-de Coss A, Reyes-Gutiérrez JA, Gómez-Peña JE, Martínez-Tinajero JJ, *et al*. Fuentes alternas de fibra en dietas integrales para ovinos en engorda intensiva. Quehacer Cient Chiapas 2015;10(1):3-8.

13. NRC. Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids; 2007.

14. AOAC. Official Methods of Analysis . 15th ed. Association of Official Analytical Chemists. Arlington, VA, USA. 1990.

15. Van Soest PJ, Robertson JB, Lewis BA. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 1991;74(10):223-232.

16. Alves AR, Beelen PMG, de Medeiros AN, Neto SG, Beelen RN. Consumo e digestibilidade do feno de sabiá por caprinos e ovinos suplementados com polietilenoglicol. Rev Caatinga 2011;24(2):152-157.

17. NRC. Nutrient requirements of sheep. 6th ed. Washington, DC, USA: National Academy Press; 1985.

18. Avendaño-Reyes L, Macías-Cruz U, Álvarez-Valenzuela FD, Águila-Tepato E, Torrentera-Olivera NG, Soto-Navarro SA. Effects of zilpaterol hydrochloride on growth performance, carcass characteristics, and wholesale cut yield of hair-breed ewe lambs consuming feedlot diets under moderate environmental conditions. J Anim Sci 2011;89(12):4188-4194.

19. Dávila-Ramírez JL, Macías-Cruz U, Torrentera-Olivera NG, González-Ríos H, Peña-Ramos EA, Soto-Navarro SA, *et al.* Feedlot performance and carcass traits of hairbreed ewe lambs in response to zilpaterol hydrochloride and soybean oil supplementation. J Anim Sci 2015;93(6):3189-3196.

20. Macías-Cruz U, Álvarez-Valenzuela FD, Torrentera-Olivera NG, Velázquez-Morales JV, Correa-Calderón, Robinson PH, *et al.* Effect of zilpaterol hydrochloride on feedlot performance and carcass characteristics of ewe lambs during heat-stress conditions. Anim Prod Sci 2010;50(10):983.

21. SAS institute. SAS/STAT: User's Guide Statistics Released. 2004.

22. Avendaño-Reyes L, Torrentera-Olivera NG, Correa-Calderón A, López-Rincón G, Soto-Navarro SA, Rojo-Rubio R, *et al.* Daily optimal level of a generic beta-agonist based on zilpaterol hydrochloride for feedlot hair lambs. Small Ruminant Res 2018;165:48-53.

23. Rivera-Villegas A, Estrada-Angulo A, Castro-Pérez BI, Urías-Estrada JD, Ríos-Rincón FG, Rodríguez-Cordero D, *et al.* Comparative evaluation of supplemental zilpaterol hydrochloride sources on growth performance, dietary energetics and carcass characteristics of finishing lambs. Asian-Australas J Anim Sci 2018;00(00):1-8.

24. Dávila-Ramírez JL, Macías-Cruz U, Torrentera-Olivera NG, González-Ríos H, Soto-Navarro SA, Rojo-Rubio R, *et al.* Effects of zilpaterol hydrochloride and soybean oil supplementation on feedlot performance and carcass characteristics of hair-breed ram lambs under heat stress conditions. J Anim Sci 2014;92(3):1184-1192.

25. Estrada-Angulo A, Barreras-Serrano A, Contreras G, Obregon JF, Robles-Estrada JC, Plascencia A, *et al.* Influence of level of zilpaterol chlorhydrate supplementation on growth performance and carcass characteristics of feedlot lambs. Small Ruminant Res 2008;80(1-3):107-110.

25. Salinas-Chavira J, Arzola C, García-Castillo RF, Briseño DA. Approaches to the level and quality of forage in feedlot diets for lambs. J Dairy Vet Anim Res 2017;5(3):96-97.

27. McIntyre AS, Thompson DG. Review article: Adrenergic control of motor and secretory function in the gastrointestinal tract. Aliment Pharmacol Ther 1992:6:125-142.

28. Rojo-Rubio R, Avendaño-Reyes L, Albarrán B, Vázquez JF, Soto-Navarro SA, Guerra JE, *et al*. Zilpaterol hydrochloride improves growth performance and carcass traits without affecting wholesale cut yields of hair sheep finished in feedlot. J Appl Anim Res 2018;46(1):375-379.

29. López-Carlos MA, Ramírez RG, Aguilera-Soto JI, Aréchiga CF, Méndez-Llorente F, Rodríguez H, *et al.* Effect of ractopamine hydrochloride and zilpaterol hydrochloride on growth, diet digestibility, intake and carcass characteristics of feedlot lambs. Livest Sci 2010;131(1):23-30.