Iranian Journal of Science & Technology, Transaction A, Vol. 29, No. A1
Printed in The Islamic Republic of Iran, 2005

EFFECT OF EPHEDRINE ON CARCASS CHARACTERISTICS OF FAT-TAILED SHEEP *

M. J. ZAMIRI** AND A. KARIMI

Department of Animal Science, College of Agriculture
Shiraz University, Shiraz, I. R. of Iran
zamiri@shirazu.ac.ir

Abstract – The effect of daily oral administration of ephedrine (0, 1, 2, 4 or 8 mg kg^{-1} $W^{0.75}$) on carcass characteristics of forty-four 2 yr old crossbred (Mehraban x Ghezel) fat-tailed ewes was studied. The ewes were fed a fattening ration, and received ephedrine by using a drenching gun for either 50 or 70 days. There was a significant interaction ($P<0.05$) between the dose and duration of the ephedrine treatment for crude protein and ether extract (crude fat) of the carcass meat (dry matter basis), leg meat and *Longissimus dorsi* area at the 12th rib. On day 70, ephedrine at a dose of 8 mg kg^{-1} $W^{0.75}$, resulted in an increase of 21.5% in crude protein, and a decrease of 16% in ether extract contents of the carcass meat (dry matter basis) as compared with the control group ($P<0.05$). After 70 days, all doses of ephedrine significantly increased the cross sectional area of the *Longissimus dorsi* muscle, as compared with the control ewes. The weight of leg meat as a percentage of slaughter weight was significantly increased on day 70 at 8 mg kg^{-1} $W^{0.75}$. The data showed that ephedrine increased the protein, and decreased the fat content of the meat in crossbred fat-tailed ewe; a daily oral dose of 8 mg kg^{-1} $W^{0.75}$, administered for 70 days, was effective in changing carcass chemical composition.

Keywords – Beta-agonists, ephedrine, carcass characteristics, fat-tailed sheep

1. INTRODUCTION

Beta-adrenergic receptor (β-AR) agonists can alter the carcass characteristics of a number of meat producing animals [1, 2]. Large responses have been observed in carcass characteristics with a net result of increased lean and less fat. Zamiri and Izadifard [3] studied the effect of metaproterenol on carcass characteristics of 18 month old rams of two Iranian fat-tailed sheep (Ghezel and Mehraban). Metaproterenol affected body composition in a manner which was dependent on breed, dose and period of treatment. Unlike most published results in thin-tailed sheep [e.g., 4-7], carcass chemical protein, as well as fat, were increased by metaproterenol, but Zare Shahneh et al. [8] reported that subcutaneous injection of metaproterenol (7 and 14 μg kg^{-1} $W^{0.75}$) significantly reduced the fat and increased the protein content of carcasses of 10-month-old Varamini fat-tailed ewes. However, it is felt that there is a need for screening more β-AR agonists for possible use in Iranian fat-tailed sheep. The present study investigated the effects of ephedrine on carcass characteristics of Iranian fat-tailed sheep. Ephedrine is structurally similar to epinephrine and norepinephrine and is a non-selective beta-adrenergic agonist that releases norepinephrine at nerve endings. It is resistant to monoamine oxidase

*Received by the editor October 21, 2002 and in final revised form December 26, 2004
**Corresponding author

and has a half-life of 3 to 6 h [9]. Oskbjerk and Sorensen [10] reported that ephedrine was effective in reducing fat and increasing protein deposition in finishing pigs.

2. MATERIALS AND METHODS

This experiment was carried out at the Animal Research Station, College of Agriculture, Shiraz University, 15 km north of Shiraz, Iran. Two-year-old fat-tailed cross-bred (Ghezel x Mehraban) ewes (n=44) were randomly allotted to five treatment groups (n=8 to 10 ewes per group) and were drenched daily with ephedrine at 0, 1, 2, 4, or 8 mg kg^{-1} metabolic live body weight ($W^{0.75}$) for either 50 or 70 days; the treatments are designated as E0, E1, E2, E4, and E8, respectively. Ephedrine in the form of 25 mg ephedrine hydrochloride tablets were purchased from Daroupakhsh Pharmaceutical Company, and dissolved in drinking water before use. The control ewes (Treatment E0) were drenched with an equivalent volume of drinking water.

The ration consisted of (DM basis) alfalfa hay (55%), corn grains (24.5%) and barley grains (20.5%). The calculated composition of the ration (DM basis) was 2.48 Mcal metabolizable energy kg^{-1}, 15.6% crude protein, 0.85% calcium, and 0.30% phosphorus. The ewes were group-fed, and feed, salt licks and water were freely available. The ewes were slaughtered after 50 or 70 days of receiving ephedrine. Feed and water were removed for 12 h before slaughter. Skin, several internal organs (heart, kidneys, liver, lung, stomach, and spleen) and cavity fats (pericardial, perinephric, pelvic, and gastrointestinal) were weighed. Hot and cold (after 24 h) carcass weights were also determined. The fat-tail was dissected, and the right side of the carcass was divided into conventional cuts including the leg, shoulder, back, breast, neck and flap [11]. Physically separated fat, bone and lean meat of each of the cuts were weighed. Dissected fat (excluding the tail) and lean from the right side of the carcass were thoroughly minced, mixed, and a sample was frozen at -20° C for analysis of dry matter (DM), crude protein, ether extract and ash [12]. Subcutaneous fat depth (SCFD) was measured with calipers between the 12th and 13th ribs; measurements were taken at four points and their mean was used as SCFD. The greatest width and depth of the cross section of *Longissimus dorsi* (LD) muscle at the 12th rib were measured by calipers. An LD cross-sectional area was traced on a paper, and its area was determined by using a planimeter. The means for the width, depth and LD area of the right and left cross-sections were used in the analysis of variance.

Data were analyzed by using the GLM procedure of the Statistical Analysis System [13] for a 5 (ephedrine dose) by 2 (treatment duration) design with interaction. Body weight, cold carcass weight, (or cut weight) was included as the covariate where appropriate. Means were compared by using the Student-Newmann-Kuhl test. Percentage data were transformed into arcsine √X before analysis, but actual percentages are reported in the paper.

3. RESULTS

There was a significant interaction between dose and duration of the ephedrine treatment for several carcass measurements (Table 1). Other carcass characteristics were not affected by the ephedrine treatment (Table 2). Measurements taken on bodily organs, individual fat depots, and various cuts were not affected by the treatment (data not shown).

Table 2. Carcass measurements of 2 year old crossbred fat-tailed ewes that were not affected (P>0.05) by ephedrine treatment (mean±SD)

	DOSE OF EPHEDRINE (MG KG^{-1} $W^{0.75}$)				
	E0 (n=8)	E1 (n=9)	E2 (n=9)	E4 (n=10)	E8 (n=8)
Slaughter weight (kg)	64.94 ±7.31	60.56 ±6.82	62.33 ±7.35	63.45 ±5.10	60.31 ±6.79
Hot carcass weight (kg)	33.84 ±4.65	31.85 ±3.49	32.62 ±3.63	32.89 ±2.96	31.37 ±3.37
Dressing percentage	52.00 ±2.01	52.63 ±1.45	52.40 ±1.59	51.82 ±1.56	52.08 ±1.98
Cold carcass weight (kg)	33.11 ±4.65	31.85 ±3.49	32.62 ±3.63	32.89 ±2.96	31.37 ±3.37
Tail weight (kg)	4.93 ±1.28	4.34 ±1.02	4.55 ±1.08	4.71 ±0.63	4.51 ±0.92
Dissected fat and tail weight (kg)	11.83 ±3.18	10.66 ±2.45	10.78 ±2.46	10.91 ±1.73	10.57 ±2.06
Total lean (without breast and flap) (kg)	14.28 ±1.82	13.88 ±1.47	14.31 ±1.01	14.50 ±1.40	13.78 ±1.43
Total bone (kg)	4.42 ±0.57	4.15 ±0.40	4.36 ±0.53	4.39 ±0.54	4.11 ±0.48
LD depth (cm)	3.05 ±0.52	3.11 ±0.36	3.27 ±0.40	3.20 ±0.31	3.17 ±0.29
Subcutaneous fat depth (cm)	1.14 ±0.13	1.09 ±0.40	1.06 ±0.32	0.96 ±0.28	1.05 ±0.14
Meat dry matter (%)	44.70 ±5.22	44.96 ±3.68	43.32 ±2.25	45.17 ±3.11	43.90 ±2.61
Ash % in meat dry matter	2.15 ±0.66	1.81 ±0.72	1.79 ±0.63	1.67 ±0.45	2.16 ±0.83

There was a significant (P<0.05) effect of ephedrine on LD width (Table 1). Ephedrine at 8 mg kg^{-1} $W^{0.75}$ resulted in a significant increase in LD width as compared with the control ewes (6.04 vs. 5.39 cm). LD width of other ephedrine groups was not significantly different from the control group. On day 50, the LD area was significantly smaller in E4 as compared with the control group; however, on day 70, LD areas for all ephedrine groups were significantly greater than the value for the control sheep.

On day 50, ether extract as a percentage of meat dry matter (EEDM%) in E4 ewes was increased in comparison with the control ewes. On day 70, EEDM% for all ephedrine groups were smaller than for the control sheep, but only the difference between the control and the E8 group was significant. On day 50, crude protein as a percentage of meat dry matter (CPDM%) was not significantly affected by the ephedrine treatment; however, on day 70, CPDM% was lowest for E0, intermediate for E1, E2, and E4, and highest for E8 ewes.

On day 50, breast weight as a percentage of cold carcass weight was lowest for E2 ewes, but on day 70, it was lowest for the E8 group (Table 1). This trend was similar to that of EEDM% on day 50. This was probably due to an increase in breast fat; breast fat was not dissected because it is difficult to precisely remove fat from the breast and flap. Although the leg meat on day 70 was increased in the E2 group, leg meat as a percentage of slaughter weight was greatest in the E8 group. On day 50, these measurements were not affected by the ephedrine treatment (Table 1).

4. DISCUSSION

Studies on the effect of beta-adrenergic receptor (β-AR) agonists on Iranian fat-tailed sheep are very few [3, 8]. Carcass weight and dressing percentage (DP) were not significantly affected by the ephedrine treatment in the present experiment. However, Zamiri and Izadifard [3] reported that subcutaneous injection of metaproterenol (5 μg kg^{-1} $W^{0.75}$) to 18 month old Mehraban and Ghezel rams resulted in an increase in the cold carcass weight and DP when fat-tailed weight was excluded from the carcass weight; similar results were reported by Zare Shahneh et al. [8] for 10 month old Varamini ewes. Baker et al. [4] found increased DP in lambs that had been fed clenbuterol, but Hamby et al. [14] reported no changes in DP with this compound. Cimaterol increased the carcass weight and DP in lambs [6, 15] and rabbits [16], but had no effect in pigs [17]. $L_{664,986}$ did not affect the lamb carcass weight [18]. Salbutamol increased the carcass weight in pigs [19, 20], but it did not affect the carcass weight in guinea pigs ([21].

Although metaproterenol was effective in reducing the fat-tail weight and total dissected fat from the carcass of 18 month old Ghezel and Mehraban rams [3], ephedrine did not have a significant effect on these measurements in 2 year old crossbred ewes of these breeds in the present experiment. According to Zare Shahneh et al. [8], metaproterenol significantly decreased the cavity fat and fat-tail weight in Varamini ewes. The effect of β-AR agonists on several fat depots in thin-tailed sheep have also been inconsistent [4, 6, 14, 15, 18, 22].

Weights of internal organs were not affected by ephedrine in the present experiment, but subcutaneous injection of metaproterenol. Metaproterenol (10 μg kg^{-1} $W^{0.75}$) resulted in a 45% decrease in the heart weight of the Mehraban rams [3]. Zare Shahneh et al. [8] also did not find any significant changes in the weight of the heart, kidneys, and liver when Varamini ewes were subcutaneously injected with metaproterenol. Cimaterol implants decreased the heart weight of lambs, but had no significant effect on the kidney and liver weights [6]. Cimaterol feeding did not affect the lamb heart weight [15]. Effects of β-AR agonists on the weights of internal organs in other species have also been variable [16, 17, 20, 21, 23].

Subcutaneous fat depth (SCFD) was not significantly affected by ephedrine in the present experiment. Subcutaneous injection of metaproterenol decreased SCFD in Mehraban [3] rams and Varimini ewes [8], but not in Ghezel rams. Studies with several BAA in thin-tailed sheep found decreases in SCFD [4, 6, 15, 24). The LD area was significantly increased in the present study; an effect similar to the effect of metaproterenol in Varamini ewes [8]. However, Zamiri and Izadifard [3] did not find any significant effect of metaproterenol on this measurement in fat-tailed rams of Mehraban and Ghezel breeds. Both ephedrine (present work) and metaproterenol [3] increased the LD width in Iranian sheep. β-AR agonists also increased the LD area in thin-tailed sheep [4, 18, 22].

Ephedrine was effective in increasing the leg meat and leg meat as a percentage of live weight, but the effect was dose- and time- dependent (Table 1). The treatment decreased the relative weight of the breast cut, which is not a prime cut. Metaproterenol increased the weight of flap meat in fat-tailed rams [3] and Zareh Shahneh et al. [8] found that metaproterenol increased weights of several cuts in carcasses of Varamini ewes. Cimaterol feeding of Dorset wether lambs for 12 weeks increased the weights of leg, loin, rack and shoulder, but no effects were noted when it was fed for 7 weeks [22]. In a study by Kim et al. [15], cimaterol feeding for 8 weeks increased the weights of prime cuts in crossbred Suffolk x Rambouillet wether lambs. Carcasses of lambs fed $L_{644,969}$ exceeded the control

carcasses in boneless retail cut yields, but were similar in bone-in cut yields [18]. β-AR agonists have also increased the weight of several muscles [15, 22, 24, 25].

Feeding of ephedrine at 8 mg kg^{-1} $W^{0.75}$ for 70 days increased CPDM% by 27% and decreased EEDM% by 14% relative to the control group; but ash%, and dry matter% in meat were not significantly affected by ephedrine treatment. Metaproterenol had no significant effect on moisture, ash and protein percentages, but increased both the total amount of protein and fat in the carcass meat of fat-tailed rams [3]; there was a tendency (P=0.065) for metaproterenol to increase the fat percentage. Zare Shahneh et al. [8], using metaproterenol, found an increase of 21% points in protein and a similar decrease in the fat content of meat samples from the 10th to 12th ribs of Varamini ewes. Baker et al. [4] found increases in moisture and protein content, and a decrease in fat percentage in lambs fed clenbuterol. Thornton et al. [7] also showed that clenbuterol reduced fat content and increased protein content of meat in sheep. Cimaterol feeding of lambs did not affect percentages of moisture, ash, fat or protein in the carcass [15]; however, cimaterol implants reduced fat and increased moisture and protein contents [6].

Although β-AR agonists have a considerable effect on carcass composition, there are species differences in the magnitude of their effects. There are several reasons for such differences: some species have been intensively selected for growth rate; a particular β-AR agonist may not be as effective in one species as in another; beta-adrenergic receptors in target tissues may be rapidly inactivated, or a particular species may have a limited number of these receptors on its tissues, thus, reducing the response to β-AR agonists [2, 26]. Several beta-adrenergic receptors have been identified in animal species, including α_1, α_2, β_1, β_2, and β_3. The β-receptor subtypes show differential desensitization; and β_3 is generally less responsive than the other two subtypes [27-29]. The β-receptor subtype populations may change with the stage of differentiation of a cell or with the hormonal milieu provided to the cell. The proportion of these subtypes present on skeletal and adipose tissues in a particular species may suggest the response of the cell to a particular agonist [26].

The most frequently observed effect of the orally administered β-AR agonists is an increase in the muscle mass; this could be due to increased protein synthesis, decreased protein degradation, or a combination of both [26, 30]. The fat reducing effect of β-AR agonists could be due to stimulation of adipocyte triacylglycerol degradation and an inhibition of fatty acid and triacylglycerol synthesis, although the response of adipose tissue has not been as persistent as that of the skeletal muscles. Other mechanisms of action of β-AR agonists include increased blood flow to certain regions of the body. Increased blood flow to muscles may provide more nutrients for protein synthesis. On the other hand, increased blood flow to adipose tissues might be envisioned to carry non-esterified fatty acids away from the tissue to enhance lipolysis. The Modulation of circulating concentrations of hormones could be another mechanism. Systemic effects of β-AR agonists have been found in some species. Acute and chronic increases in plasma non-esterified fatty acids were reported in steers [31] and pigs [32] with clenbuterol, and in lambs with cimaterol [15, 33]. Blood glucose decreased in pigs treated with salbutamol [20], and chronically increased in steers with clenbuterol [31]. However, Ricks et al. [34] did not find any changes in glucose concentration of steers fed clenbuterol. Salbutamol also increased serum levels of lipase, triacylglycerols, cholesterol and glucose in guinea pigs [21]. Any of these mechanisms, or more likely, some of their combinations could be operative in a given species administered a given β-AR agonists, at a particular age, with a specific genetic background, under a designated husbandry condition, and fed a particular diet.

Treatment with β-AR agonists results in tougher meat production, due to increases in the amount of connective tissue in the muscle. There is also a decrease in the activity of proteolytic enzymes that

prevent tissue breakdown after slaughter. The formation of bonds between collagen molecules is another factor that makes the meat tougher [35]. We did not measure the toughness of meat in the present experiment, but Oksbjerg and Sorensen [36] reported that ephedrine caused a change in the proportion of fiber types and increased the toughness of meat in the pig.

The results of the present experiment are in general agreement with the effects of β-AR agonists in sheep [2, 26]. The data also indicate that ephedrine, a non-selective β-AR agonist, is an effective compound for increasing protein and decreasing the fat content of the carcass of fat-tailed sheep. Concern has been raised as to the tissue contamination by some compounds such as clenbuterol, however, it is likely that safe and effective β-AR agonists could be developed for use in animal production [37].

Acknowledgements- We sincerely acknowledge the cooperation of the director and staff of the Animal Research Station during the conduct of this experiment.

REFERENCES

1. Hanrahan, J. P. (1987). *Beta-agonists and Their Effects on Animal Growth and Carcass Quality*. Elsevier Applied Science, London, England.
2. Wellenreiter, R. H. (1991). Beta-adrenergic agonists for poultry. *Crit. Rev. Poult. Biol., 3*, 229-237.
3. Zamiri, M. J. & Izadifard, J. (1995). Effects of metaproterenol, a beta-adrenergic agonist, on feedlot performance and body composition of two fat-tailed breeds of sheep. *Small Rumin. Res., 18*, 263-271.
4. Baker, P. K., Dalrymple, R. H., Ingle, D. L. & Ricks, C. A. (1984). Use of a beta-adrenergic agonist to alter muscle and fat deposition in lambs. *J. Anim. Sci., 59*, 1256-1261.
5. Convey, E. M., Ricks, E., Yang, Y. T., McElligott, M. A. & Olson, G. (1987). Effects of the beta-adrenergic agonist $L_{644,\ 969}$ on growth performance, carcass merit and meat quality. In: *Reciprocal Meat Conference Proceedings,* p. 47 Chicago, National Livestock, and Meat Board.
6. Fennessy, P. F., McEwan, J. C., Lord, E. A., Gareer, G. J., Bain, W. E., Johnstone, P. D., Knowler, M. A., Dalrymple, R. H. & Ingle, D. A. (1990). Effect of cimaterol implants on lamb growth and carcass characteristics. *N. Z. J. Agric. Res., 33*, 413-427.
7. Thornton, R. F., Tume, R. K., Payne, G., Larsen, T. W., Johnson, G. W. & Hohenhaus, M. A. (1985). The effect of the beta2-adrenergic agonist, clenbuterol, on lipid metabolism and carcass composition of sheep. *Proc. N.Z. Soc. Anim. Prod., 45*, 97.
8. Zare Shahneh, A., Mataji, R., Zamiri, M. J. & Moradi Shahre-Babak, M. (2001). Effects of beta-adrenergic agonist metaproterenol on carcass characteristics of Varamini ewes. *J. Sci. & Technol. Agric. & Nat. Resour., 5*, 157-166 (In Farsi with English Abstract).
9. Adams, H. R. (1995). *Adrenergic agonists and antagonists, In: Veterinary Pharmacology and Therapeutics*, Adams, H. R. (Ed.), 7th ed., Iowa State University Press, Ames.
10. Oksbjerg, N. & Sorensen, M. T. (1995). Separate and combined effects of ephedrine and caffeine on protein and lipid deposition in finishing pigs. *Anim. Sci., 60*, 299-305.
11. Farid, A. (1989). Direct maternal and heterosis effects for slaughter and carcass characteristics in three breeds of fat-tailed sheep. *Livest. Prod. Sci., 23*, 137-162.
12. Official Methods of Analysis (1975). *Association of Official Analytical Chemists*. Washington, D.C.
13. SAS, (1996). *SAS System for Windows, Release 6.12*. SAS Inst. Inc. Cary. N. C., USA.

14. Hamby, P. L., Stoufer, J. R. & Smith, S. B. (1986). Muscle metabolism and real-time ultrasound measurement of muscle and subcutaneous adipose tissue growth in lambs fed diets containing a beta-agonist. *J. Anim. Sci., 63*, 1410-1417.
15. Kim, Y. S., Lee, Y. B. & Dalrymple, R. H. (1987). Effect of the repartitioning agent cimaterol on growth, carcass and skeletal muscle characteristics in lambs. *J. Anim. Sci., 65*, 1392-1399.
16. Forsberg, N. E., Ilian, M. A., Ali-Bar, A., Cheeke, P. R. & Wehr, N. B. (1989). Effects of cimaterol on rabbit growth and myofibrillar protein degradation and on calcium-dependent proteinase and calpastatin activities in skeletal muscle. *J. Anim. Sci., 67*, 313-3321.
17. Jones, R. W., Easter, R. A., McKeith, F. K., Dalrymple, R. H., Maddock, H. M. and Bechtel, P. J. (1985). Effect of the beta-adrenergic agonist cimaterol (CL263, 780) on the growth and carcass characteristics of finishing swine. *J. Anim. Sci., 61*, 905-913.
18. Shackelford, S. D., Edwards, J. W., Smarr, E. K. & Savell, J. W. (1992). Retail cut yeilds of Rambouillet wether lambs fed the beta-adrenergic agonist $L_{644,969.}$ *J. Anim. Sci., 70*, 161-168.
19. Cole, D. J. A., Wood, J. D. & Kilpatrick, M. J. (1987). Effects of the beta-agonist GAH/034 on growth, carcass quality and meat quality in pigs, In: Hanrahan, J. P. (ed.), *Beta-agonists and Their Effects on Animal Growth and Carcass Quality*. London, England, Elsevier Applied Science.
20. Warriss, P. D., Kestin, S. C., Rolph, T. P. & Brown, S. N. (1990). The effect of the beta-adrenergic agonist salbutamol on meat quality in pigs. *J. Anim. Sci., 68*, 128-136.
21. Zamiri, M. J. & Ehsani, K. (1995). Salbutamol affects body composition of the guinea pig. *Iran. Agric. Res., 14*, 1-18.
22. Beermann, D. H., Hogue, D. E., Fishell, V. K., Dalrymple, R. H. & Ricks, C. A. (1986). Effects of cimaterol and fishmeal on performance, carcass characteristics and skeletal muscle growth in lambs. *J. Anim. Sci., 62*, 370-380.
23. Moloney, A. P., Allen, P., Ross, D. B., Olson, G. & Convey, E. M. (1990). Growth, feed efficiency and carcass composition of finishing Friesian steers fed the beta-adrenergic agonist $L_{644, 969.}$ *J. Anim. Sci., 68*, 1269-1277.
24. Wang, S. Y. & Beermann, D. H. (1988). Reduced calcium-dependent proteinase activity in cimaterol-induced muscle hypertrophy in lambs. *J. Anim. Sci., 66*, 2545-2550.
25. Claeys, M. C., Mulvaney, D. R., McCarthy, F. D., Gore, M. T., Marple, D. N., & Sartin, J. L. (1989). Skeletal muscle protein synthesis and growth hormone secretion in young lambs treated with clenbuterol. *J. Anim. Sci., 67*, 2245-2254.
26. Mersmann, H. J. (1998). Overview of the effects of β-adrenergic receptor agonists on animal growth including mechanisms of action. *J. Anim. Sci., 76*, 160-172.
27. Lafontan, M. (1994). Differential recruitment and differential regulation by physiological amines of fat cell β-1, β-2 and β-3 adrenergic receptors expressed in native fat cell and in transfected cell lines. *Cell. Signaling, 6*, 363-392.
28. Langin, D., Tavernier, G. & Lafontan, M. (1995). Regulation of β-3 adrenoceptor expression in white fat cells. *Fundam. Clin. Pharmacol., 9*, 97-106.
29. Marullo, S., Nantel, F., Strosberg, A. D. & Bouvier, M. (1995). Variability in the regulation of β-3 adrenoceptor subtypes. *Biochem. Soc. Trans., 23*, 126-129.
30. Yang, Y. T. & McElligot, M. A. (1989). Multiple actions of β-adrenergic agonists on skeletal muscle and adipose tissue. *Biochem. J., 261*, 1-10.
31. Eismann, J. H., Huntington, G.B. & Ferrell, C. L. (1988). Effects of dietary clenbuterol on metabolism of the hindquarters in steers. *J. Anim. Sci., 66*, 342-353.

32. Mersmann, H. J. (1987). Influence of infused beta-adrenergic agonists on porcine blood metabolites and catecholamines. *J. Anim. Sci., 67*, 2633-2645.
33. Beermann, D. H., Hogue, D. E., Fishell, V. K., Dalrymple, R. H., Ricks, C. A. & Scanes, C. G. (1987). Cimaterol-induced muscle hypertrophy and altered endocrine status in lambs. *J. Anim. Sci., 65*, 1514-1524.
34. Ricks, C. A., Dalrymple, R. H., Baker, P. K. & Ingle, D. L. (1984). Use of a beta-adrenergic agonist to alter fat and muscle deposition in steers. *J. Anim. Sci., 59*, 1247-1255.
35. Chesworth, J. M., Stauchberry, T. & Scaife, J. R. (1998*). An Introduction to Agricultural Chemistry.* London, Chapman and Hall.
36. Oksbjerg, N. & Sorensen, M. T. (1996). Effects of ephedrine and caffeine on chemical composition and histochemistry of muscle in pigs. *Acta Agric. Scand. Section A, Anim. Sci., 46*, 125-128.
37. Smith, D. J. (1998). The pharmacokinetics, metabolism, and tissue residues of β-adrenergic agonists in livestock. *J. Anim. Sci., 76*, 173-194.