American-Eurasian J. Agric. & Environ. Sci., 8 (5): 508-513, 2010
ISSN 1818-6769

Breed effect upon Carcass characteristics and Meat Quality of *Pelibuey* and *Polypay* x *Rambouillet* lambs

[1]G. Peraza-Mercado, [1]E. Jaramillo-López and [2]A.D. Alarcón-Rojo

[1]Instituto de Ciencias Biomédicas de la Universidad Autónoma de Ciudad Juárez,
Anillo Envolvente del Pronaf y Estocolmo s/n, C.P. 32300, A.P.1595-D,
Ciudad Juárez, Chihuahua, México
[2]Facultad de Zootecnia de la Universidad Autónoma de Chihuahua.
Km. 1.5 de la carretera Chihuahua-Cuauhtémoc. Chihuahua, Chihuahua, México

Abstract: Ten male *Pelibuey* lambs (P) and 11 male *Polypay x Rambouillet* lambs (PR) were used to evaluate the breed effect upon the carcass characteristics, commercial cuts and meat quality such as water holding capacity (WHC), drip loss, shear force, collagen content and color. Lambs were fed a diet containing 3 mega-calories of metabolizable energy and 18% of crude protein, according to NRC for lambs. They were sacrificed when reaching six months of age. Carcass traits, dorsal fat and commercial cuts were analyzed according to the Fisher and Boer method. *Longissimus dorsi* samples from the right side carcass of lambs were submitted to proximate analysis applying AOAC Methods. Racial groups did not present significant differences (P>0.01) over the proximate composition of *Longissimus dorsi* muscle. On the other hand all carcasses traits and commercial cuts presented significant differences (P<0.01) throughout breeds as assumed, excepting width of buttock and chest depth. As for meat quality analysis, there were no significant differences (P>0.01), expect on the color parameter concerning yellowness b*, PR presented a higher index 16.46 versus 12.97 from P, indicating a marked contrast of red orange meat color. Therefore, breed and conformation have a pronounced effect over carcass traits and commercial cuts, due to the fact that wool lambs are sturdier than hair lambs, but does not affect chemical composition.

Key words: Carcass · Lamb · *Pelibuey* · *Polypay* x *Rambouillet*

INTRODUCTION

The term “meat quality” inherently includes the properties of meat suitability, processing and meat storage. The main physicochemical attributes are sanitary hygiene, nutritional value, flavor, texture, water-holding capacity, color, composition and lipid content, oxidative stability and uniformity. In order to assure this quality, the environmental aspects are also considered as well as the animal development. Therefore, the term becomes a manifold of complex variables, influenced by multiple factors including the place where the meat is produced, as handling systems, breeding, genotype, feeding, pre-slaughter manipulation, stunning, slaughter method, cooling and storage conditions [1].

Ovine offer multiple advantages over other species, like great adaptability to variable environmental conditions and different nutritional regimes, high reproductive potential, smaller susceptibility to contract infectious diseases, as well as a low cost of initial investment, construction and maintenance of the farms, which facilitate their raising in young developing countries, putting it within the reach of the rural population and farmers. There are ovine breeds that have been put under selection during years, reaching better levels of meat production. Nevertheless, efforts have been made to improve the productivity of the flocks and the carcasses conformation due to the crossbreeding of species, as *Polypay x Rambouillet* ovines adapted to the northern region of Mexico.

Corresponding Author: G. Peraza-Mercado, Instituto de Ciencias Biomédicas de la Universidad Autónoma de Ciudad Juárez, Anillo Tel: +52 656 6881894; Fax +52 656 6881894,
Email address: gperaza@uacj.mx (G. Peraza-Mercado)

Crossbreeding of ovine contribute to the production of uniform animals with desirable and enhanced characteristics and a good habitat adaptation [2]. Besides, other changes take place among increased carcass characteristics, such as greater growth speed and a better yield when sacrificed [3].

Water holding capacity and drip loss are related according to Bond and Warner [4] due to the fact that water is normally held in the muscle in the myofibrils and a small portion is bound to proteins and in the intracellular space. Further more breakdown of the cytoskeleton located in the Z-disks have been implicated in reducing the force that gives place to water flow into the extracellular space causing drip loss from muscle.

The relationship between connective tissue and meat tenderness is also part of this integral study of meat quality, but according to Lepetit [5] there is a low correlation between tenderness and collagen solubility, but insoluble collagen is an important factor. The amino acid sequence of collagen is rich in proline and approximately 50% of proline side chains are hydroxylated post-translationally to form 4-hydroxyproline. Almost all studies have shown that the smaller the muscle fibers diameter or bundle size, the more tender the meat. The collagen fibers shrink when the hydrogen bonds in the collagen molecules are destroyed by heat above 60–65°C. Intramuscular connective tissue shrinkage squeezes out fluid released from heated myofibrils thus affecting their properties. The amount of collagen relates not only to the economic value of the raw material used but also to nutritional aspects since the low biological value of protein in connective tissue is due to the deficiencies in lysine, tryptophan and sulphur amino acids as stated by Messia *et al.* [6]. As meat is a composite material, meat tenderness has to be considered in terms of interactions between structures [7].

The objective of this paper was to examine the effect of breed on the carcass characteristics and meat quality of *Pelibuey* and *Polypay x Rambouillet* ovines.

MATERIALS AND METHODS

The project was developed in the Food Chemistry Laboratory of the Institute of Biomedical Sciences, with the collaboration of the Cattle Department, both of the Autonomous University of Ciudad Juarez.

Sample Obtention of *Longissimus dorsi* Muscle: Twenty-one lambs were used 10 *Pelibuey* (P) and 11 *Polypay x Rambouillet* (PR), distributed in individual pens.

Table 1: Chemical composition of feed

Chemical component	
Dry matter	89.66 %
Moisture	10.34 %
Protein	15.26 %
Fat	5.23 %
Ashes	5.01 %
Crude Fiber	14.31 %
Nitrogen-Free Extract (NFE)	60.19 %
Total Digestible Nutrients (TDN)	83.37 %
Digestible energy (DE kcal/kg)	3675.59
Metabolizable energy (ME kcal/kg)	3013.67

*Results reported as dry matter

The lambs were weaned sixty days after birth, with a fifteen day adaptation period. The feed consumed was weighed twice a day every twelve hours. The feed supplied increased when the rejection was higher then 5% of the offered portion. The diet contained 50.60% flaked corn, 41.60% alfalfa hay, 7.26% cottonseed meal, 0.013% ammonium sulfate and 0.44% pre-mixture of minerals. The chemical composition of the feed is presented in Table 1. When the lambs reached six months of age, they were sacrificed, previously with a twelve hour empty stomach. The sacrifice was by decollation, without previous stunning.

Fisher and Boer [8] standard method of sheep carcass evaluation was applied. After sacrifice, the full digestive system, lungs, heart, liver, spleen, trachea, skin, legs and head were weighed. Once the evisceration was concluded, the carcass was weighed warm and cold after cooled off at 4°C during twenty-four hours.

The cold carcass was divided longitudinally in two equal parts, on the left side the most important cuts were evaluated as rear lower leg, rear upper leg, lower back, abdomen, ribs, shoulder and front leg as described later on. On the right side carcass, a cut was made on the back between the tenth and eleventh thoracic vertebra and the fourth and fifth lumbar vertebra, to obtain the *Longissimus dorsi* muscle, on which the chemical analyses were performed.

Linear carcass measurements were made on the intact carcass, defining the terms on the overall skeletal size as: carcass length: from the caudal edge of the last sacral vertebra to the dorso-cranial edge of the atlas (1st cervical) vertebra; leg length: from the centre of the tuberosity on the proximal end of the tibia to the distal edge of the tarsus, also called Palsson´s "T"; chest depth: the greatest depth was measured in the horizontal plane on the hanging carcass; and the development of the hindquarter as: circumference of buttock: in a horizontal plane of the hanging carcass, passing through the proximal edges of the two patellae; width of buttock: the greatest width was measured in a horizontal plane on the hanging carcass. The degree of fatness was expressed as: thickness of subcutaneous fat: by making two incisions through the fat along lines extending 4 cm ventro-laterally from the dorsal midline at the last rib and, at the limit of that cut, extending 4 cm cranially, a flap of fat was raised allowing direct measurement of thickness at the intersection of the incisions; thickness of thoracic body wall: midway between the mid-dorsal and mid ventral lines, between $10/11^{th}$ ribs. This last parameter as well as side length was measured on the prepared right side.

The anatomical joints of the lamb carcass, also considered commercial cuts, were determined as distal pelvic limb (rear lower leg), proximal pelvic limb (rear upper leg), lumbar region with the sub-lumbar muscles at the caudal end (lower back), abdominal region (abdomen), neck and thorax (ribs), proximal thoracic limb (shoulder), distal thoracic limb (front leg).

Longissimus dorsi **Sample Preparation:** A portion of approximately 100g of *Longissimus dorsi* muscle was used, the portion was ground until obtaining a homogenous sample. The meat was stored hermetically in closed and labeled containers and frozen to -10°C until analyzed.

Proximate Analysis: The proximate analysis were determined using the AOAC techniques [9]. The percentage of protein was determined by the Kjeldahl method, moisture by means of dry furnace, fat was determined by the Soxhlet method and the ashes were determined by incineration.

Physicochemical Characteristics of *Longissimus dorsi* Muscle: *Color* was measured using a Minolta CM-2002 colorimeter, defining color as a set of three variables: L* brightness, a* redness, b* yellowness [10].

Water holding capacity was determined as Hamm [11] reported applying the determination by cook loss on 5 g sample, cooked for 20 min at 90°C.

Shear force was evaluated using a Chatillon LR 5K texture analyzer equipped with a Warner-Bratzler device. The samples were prepared individually placed in polyethylene bags in a water bath at 70°C for 15 min, dried with filter paper and cut with a half inch meat core sampler obtaining three replicates of 2-3 cm length and shear force determined [12].

Drip loss was determined as a percentage of weight loss after seven days storage at 4°C, the loss by dripping was expressed as the percentage of the weight of the initial portion [13, 14].

AOAC Method 990.26 [8] was used to quantify hydroxyproline (collagen) like a measurement of the collaginous material in meat. The collaginous connective tissue contains 12.5% of hydroxyproline (when nitrogen-protein factor 6.25 is used) or 14% (with factor 5.55). The samples were hydrolized in sulfuric acid at 105°C, leaked and diluted. The hydroxyproline was oxidized from t-chloramine to pirrol. A red-purplish color was developed after the addition of 4-dimethylamine benzaldehyde, which was measured photometrically at 560 nm.

Statistical Analysis: The statistical package SPSS version 11 was used to compare the data applying a multivariate design, using the live weight as covariable, class (wool or hair) as fixed factor and the carcass and physicochemical analysis data as dependent variables and a correlation coefficient (r = 0.99) to establish the differences between the breeds studied against meat quality and carcass characteristics.

RESULTS AND DISCUSSION

Carcass Evaluation: Live weight was used as covariable when analyzing the data due to the fact that the animals were sacrificed at six months of age and not at a particular weight, therefore being significant ($P<0.01$) among class (wool or hair) and the intercept (Live weight x Class). As far as the carcass main components and commercial cuts (Table 2 and Table 3), all traits were significant ($P<0.01$) as was assumed due to the bigger complexion of the *Polypay x Rambouillet* compared to the rustic and leaner *Pelibuey*. The only parameters that did not present significant difference were width of buttock and chest depth (Table 4). Stating that breed and conformation have an effect over the components, since wool specimen are more robust than those of hair. These results confirm those of Gutiérrez *et al.* [15] for *Pelibuey* males sacrificed at nine months of age on the following traits: hot carcass, cold carcass, carcass length and leg length; showing a slightly higher difference in fat thickness of the lambs analyzed in this research. The fact that hair lambs present less subcutaneous fat than wool lambs was also verified, as discussed by Jiménez [16] when evaluating *Pelibuey*, *Blackbelly*, *Rambouillet* and *Suffolk* breeds. As for anatomical joints, similar results were obtained by Jaramillo *et al.* [17] studying *Pelibuey* and *Polypay x Rambouillet*, only presenting higher weights on lower

Table 2: Slaugther performances of *Polypay x Rambouillet* and *Pelibuey* lambs carcasses (mean ± SE) (kg)

Traits	*Polypay x Rambouillet*	*Pelibuey*
Live weight	38.318 ± 5.69^a	30.620 ± 3.35^b
Hot carcass weight	18.290 ± 3.00^a	15.088 ± 1.84^b
Cold carcass weight	18.232 ± 3.00^a	15.041 ± 1.83^b
Blood	2.324 ± 0.38^a	1.915 ± 0.27^b
Skin	3.400 ± 0.66^a	2.503± 0.39^b
Head	1.751 ± 0.21^a	1.570 ± 0.19^b
Feet	0.815 ± 0.11^a	0.616 ± 0.01^b
Heart	0.221± 0.00^a	0.157 ± 0.00^b
Lungs-Trachea	0.670 ± 0.10^a	0.516 ± 0.01^b
Liver	0.861 ± 0.14^a	0.697± 0.15^b
Spleen	0.009 ± 0.00^a	0.006 ± 0.00^b
Bladder	0.003 ± 0.00^a	0.002 ± 0.00^b
Penis	0.006 ± 0.00^a	0.004 ± 0.00^b
Testis	0.369 ± 0.10^a	0.339 ± 0.01^b
Full Rumen	4.723 ± 0.75^a	3.462 ± 0.36^b
Full small intestine	1.326 ± 0.27^a	1.316 ± 0.23^b
Full large intestine	1.165 ± 0.15^a	0.985 ± 0.13^b
Mesenteric fat	0.428 ± 0.19^a	0.535 ± 0.22^b

$^{a-b}$ Different letters in the same row indicate statistical difference (P<0.01)

Table 3: Anatomical joints of lamb carcass (mean ± SE) (kg)

Traits	Polypay x Rambouillet	Pelibuey
Rear lower leg	0.843 ± 0.14^a	0.707 ± 0.01^b
Rear upper leg	4.884 ± 0.83^a	3.902 ± 0.44^b
Lower back	1.294 ± 0.28^a	1.011 ± 0.17^b
Abdomen	1.330 ± 0.24^a	1.174 ± 0.26^b
Ribs	6.385 ± 0.14^a	5.335 ± 0.79^b
Shoulder	2.715 ± 0.48^a	2.300 ± 0.28^b
Front leg	0.598 ± 0.01^a	0.472 ± 0.01^b

$^{a-b}$ Different letters in the same row indicate statistical difference (P<0.01)

Table 4: Measurements of the intact carcass (cm) according to Fisher and Boer (1994)

Traits	*Polypay x Rambouillet*	*Pelibuey*
Exterior Carcass length	70.36 ± 4.38^a	66.70 ± 5.22^b
Side carcass length	74.00 ± 4.29^a	66.30 ± 4.99^b
Leg length	25.00 ± 2.64^a	24.60 ± 1.57^b
Circumference of buttock	66.09 ± 4.72^a	60.00 ± 4.32^b
Width of buttock	25.55 ± 2.87^a	26.20 ± 6.32^a
Chest depth	26.45 ± 1.63^a	27.30 ± 3.68^a
Thickness of subcutaneous fat	0.855 ± 0.14^a	0.510 ± 0.17^b
Thickness of thoracic body wall	0.436 ± 0.19^a	0.240 ± 0.15^b

$^{a-b}$ Different letters in the same row indicate statistical difference (P<0.01)

Table 5: Proximate composition percentages of *Longissimus dorsi* muscle (mean ± SE) (% Wet basis) (AOAC, 2000)

Traits	*Polypay x Rambouillet*	*Pelibuey*
Moisture	78.883 ± 0.52^a	73.264 ± 0.62^a
Ashes	1.565 ± 0.64^a	1.401 ± 0.74^a
Crude fat	4.564 ± 0.34^a	4.524 ± 0.71^a
Crude Protein	14.066 ± 0.13^a	16.375 ± 0.76^a

$^{a-b}$ Different letters in the same row indicate statistical difference (P<0.01)

back and front leg, but lower weight of ribs. On the other hand Rubio *et al.* [18] obtained for *Pelibuey* lambs, higher results of subcutaneous fat but lower weights in carcass length, chest depth and buttock width.

***Longissimus dorsi* Analysis:** Although differences in conformation between the two breeds exist, the study of proximate composition of *L. dorsi* did not report difference (P>0.01) among them, reason to believe that the breed does not have any effect over these parameters at such young age (Table 5). This confirms the previous results obtained by Peraza-Mercado *et al.* [19] when analyzing diet effect over these same breeds, also not presenting difference (P>0.01) over chemical composition of *L. dorsi* from animals fed corn diet, such as moisture content 73.70% and 74.07% (PR and P, respectively), ashes 1.33% and 1.44%, crude fat 4.57% and 3.22% and crude protein 14.56% and 16.99%, which are very similar to the results obtained in the present research.

Physicochemical Characteristics of *Longissimus dorsi* Muscle: Finally, the meat quality analysis of *L. dorsi* muscle (Table 6) offered a low resistance to the cut, 2.51 kgf and 2.33 kgf (PR and P, respectively) compared to 3.34 kgf of second cross lambs reported by Bond and Warner [4] and 3.16 kgf on Manchego Spanish breed lambs studied by Vergara and Gallego [12] which are statistically different. This could be consistent with the foundings of Vergara *et al.* [10] indicating that shear force and tenderness are not affected by weight and that hardness can remain stable or even decrease as slaughter age increases due to the infiltration of fat, which was not

Table 6: Physicochemical characteristics of *Longissimus dorsi* muscle of *Polypay x Rambouillet* and *Pelibuey* lambs

Traits	*Time post-slaughter*	*Polypay x Rambouillet*	*Pelibuey*
Shearforce (kgf)	7 days	2.515 ± 0.29^a	2.334 ± 0.17^a
WHC (%)	1 day	85.94 ± 0.04^a	85.95 ± 0.08^a
Drip loss (%)	7 days	1.37 ± 0.04^a	1.28 ± 0.08^a
Collagen(g/100g meat)	7 days	0.073 ± 0.02^a	0.101 ± 0.06^a
Color L*(brightness)			
a* (redness)			
b*(yellowness)	7 days	38.350 ± 3.02^a	40.339± 2.93^a
		13.875 ± 2.66^a	12.913± 1.45^a
		16.465 ± 2.94^a	12.978± 1.22^b

$^{a-b}$ Different letters in the same row indicate statistical difference (P<0.01) significant for PR and P. Although recent studies by Toohey *et al.* [20] on crossbred lambs were analogous 2.549 kgf at 5 days post-slaughter.

In addition low collagen contents (g/100g meat) were obtained, 0.073 g (PR) and 0.101 g (P), compared to Messia *et al.* [6] that analyzed meat products whose values varied from 0.13 to 0.38 g. These results are very similar to the one obtained for *Longissimus lumborium* by Tschirhart *et al.* [21] 0.026 mg and 2.61 kgf (SF), reaffirming the fact that this parameter has direct effect over shear force, which indicates a good degree of tenderness. However, Maoiorano *et al.* [22] acquired a higher amount of intramuscular collagen as of 0.239 g.

Water holding capacity 85.94 and 85.95% (PR and P, respectively) was high compared to light weight Manchego Spanish breed lambs, 75.53% [10]. On the other hand on a second study Vergara and Gallego [12] obtained a similar value 85.81%. Therefore, the tendency to release more water as in the second study could suggest their initial juiciness could be greater than in PR and P; although, this parameter remains constant with increasing weight.

The color parameter was statistically significant ($P<0.01$) only for parameter b* (yellowness), a higher value for wool lambs was observed (L* a* b*) 38.99, 13.53 and 16.17 and for hair lambs 39.62, 13.69 and 13.29, producing a red orange hued meat compared to the lambs studied by Bond and Warner [4] that also present a significant difference ($P<0.01$) on parameter b* but on the contrary produced a much redder meat at 7 days post-slaughter, (L* a* b*) 35.81, 17.82 and 7.0. This agrees with the data presented by Vergara and Gallego [12] (L* a* b*) 46.44, 17.35 and 7.15 at 8 days post-slaughter obtaining a much brighter red. Tschirhart *et al.* [21] presented similar values for *L. lumborium* (L* a* b*) 42.7, 14.7 and 3.8. But color obtained by Toohey *et al.* [20] at 5 days post-slaughter was less red (L* a* b*) 39.4, 6.11 and 9.03, significantly different in parameter a* and b*.

CONCLUSIONS

There was a significant ($P<0.01$) breed and conformational effect over carcass traits and commercial cuts, even over intact carcass measurements according to Fisher and Boer [8], except buttock width and chest depth. On the contrary, results showed that a significant difference ($P>0.01$) did not exist between the chemical components of the meat from both breeds.

According to physicochemical characteristics of the meat, there were no significant results ($P>0.01$) besides parameter yellowness b* for color differing between breeds and being higher for PR representing a remarked red orange hue compared to the orange hue from P. Regarding texture, both meats presented low shear force, a good content of collagen, a high water holding capacity and a low drip loss which confirms an overall good degree of tenderness.

Therefore, if a higher carcass yield is required *Polypay x Rambouillet* could be used due to their robust complexion but sacrificed at an early age to preserve the meat tenderness characteristic. However, if leaner carcasses are required as known from hair lambs, then *Pelibuey* should be used compensating the carcass yield.

According to the results, it is highly recommended to evaluate pH of the meats studied in order to have a better understanding of the physicochemical characteristics and how they interact, as well as sex effect over meat quality.

ACKNOWLEDGEMENTS

This work has been made possible by financial help from Promep/SEP/SES (Programa de Mejora del Profesorado, Secretaría de Educación Pública, Subsecretaría de Educación Superior, México).

REFERENCES

1. Aberle, E.D., J.C. Forrest, D.E. Gerrard and E.W. Mills, 2001. Principles of Meat Science. Forth Edition. Kendall-Hunt Publishing Company. Dubuque, Iowa. pp: 354.
2. López, P.M.G., L.M.S. Rubio and S.E.M. Valdés, 1999. Efecto del cruzamiento, sexo y dieta en la composición química de la carne de ovinos Pelibuey con Rambouillet y Suffolk. Vet. Méx. J., (31): 11-18.
3. Gracey, J.E., 1989. Higiene de la carne. 8ª Edición, Ed. Interamericana Mc Graw Hill.
4. Bond, J.J. and R.D. Warner, 2007. Ion distribution and protein proteolysis affect water holding capacity of *Longissimus thoracis* and *lumborum* in meat of lamb subjected to antemortem exercise. Meat Sci., 75: 406-414.
5. Lepetit, J., 2008. Collagen contribution to meat toughness: Theoretical approach. Meat Sci., 80: 960-967.

6. Messia, M.C., T. Di Falco, G. Panfili and E. Marconi, 2008. Rapid determination of collagen in meat-based foods by microwave hydrolysis of proteins and HPAEC–PAD analysis of 4-hydroxyproline. Meat Sci., 80: 401-409.
7. Brooks, J.C. and J.W. Savell, 2004. Perimysium thickness as an indicator of beef tenderness. Meat Sci., 67: 329-334.
8. Fisher, A.V. and H. de Boer, 1994. The EAAP standard method of sheep carcass assessment. Carcass measurements and dissection procedures Report of the EAAP Working Group on Carcass Evaluation, in cooperation with the CIHEAM Instituto Agronómico Mediterráneo of Zaragoza and the CEC Directorate General for Agriculture in Brussels. Livestock Production Sci., 38: 149-159.
9. Association of Official Analytical Chemist, AOAC., 2000. Methods of Analysis of Association of Official Analytical Chemists. 20 th Edition Washington. D.C. pp: 5-10, 20-29, 69-79.
10. Vergara, H., A. Molina and L. Gallego, 1999. Influence of sex and slaugther weight on carcass and meat quality in light and medium weight lambs produced in intensive systems. Meat Sci., 52: 221-226.
11. Hamm, R., 1986. En: P.J. Bechtel (Ed.) Muscle as Food. Food Science and Technology. A Series of Monographs (1986). New York: Academics Press, pp: 135-189.
12. Vergara, H. And L. Gallego, 2000. Effect of electrical stunning on meat quality of lamb. Meat Sci., 56: 345-349.
13. Stoier, S., M.D. Aaslyng, E.V. Olsen and P. Henckel, 2001. The effect of stress during lairage and stunning on muscle metabolism and drip loss in Danish pork. Meat Sci., 59: 127-131.
14. Vergara, H., L. Gallego, A. García and T. Landete-Castillejos, 2003. Conservation of *Cervus elaphus* meat in modified atmospheres. Meat Sci., 65: 779-783.
15. Gutiérrez, J., M.S. Rubio and R.D. Méndez, 2005. Effects of crossbreeding Mexican *Pelibuey* sheep with *Rambouillet* and *Suffolk* on carcass traits. Meat Sci., 70: 1-5.
16. Jiménez, B.G., 2002. Thesis: Evaluación de la canal en corderos de engorda de diferentes razas de ovinos de pelo y cruzas. Universidad Autónoma del Estado de México.
17. Jaramillo, L.E., H.F. Molinar, M.J.A. Leos and A.M.C. Hinojosa, 2008. Efecto de la dieta en corderos de lana y pelo sobre la ganancia diaria de peso, consumo de alimentos, conversión alimenticia y características de la canal. Ciencia en la Frontera, 6: 133-141
18. Rubio, M.S., N. Torres, J. Gutierrez and R.D. Mendez, 2004. Composition and sensory evaluation of lamb carcasses used for the traditional Mexican lamb dish, "barbacoa". Meat Sci., 67(2): 359-364.
19. Peraza-Mercado, G., E. Jaramillo-López and A.D. Alarcón-Rojo, 2006. Diet effect upon chemical composition of *Pelibuey* and *Polypay x Rambouillet* meat. American-Eurasian J. Scientific Res., 1(1): 8-11.
20. Toohey, E.S., D.L. Hopkins, D.F. Stanley and S.G. Nielsen, 2008. The impact of new generation pre-dressing medium-voltage electrical stimulation on tenderness and colour stability in lamb meat. Meat Sci., 79: 683-691.
21. Tschirhart-Hoelscher, T.E., B.E. Baird, D.A. King, D.R. McKenna and J.W. Savell, 2006. Physical, chemical and histological characteristics of 18 lamb muscles. Meat Sci., 73: 48-54.
22. Maiorano, G., C. Cavone, R.J. McCormick, A. Ciarlariello, M. Gambacorta and A. Manchisi, 2007. The effect of dietary energy and vitamin E administration on performance and intramuscular collagen properties of lambs. Meat Sci., 76: 182-188.