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RESEARCH ARTICLE

Influence of corn forage type and flaxseed on the productive parameters, meat quality and sensory analysis in Pelibuey lambs

Diana Tamara Ramírez[1], José Reyes Galaviz-Rodriguez[2], Xochitl Gabriela Montalvo-Aguilar[2], Patricia Villalobos-Peñalosa[2], Pablo Cortés-Roldán[2], Luz Marina Hernández-Calva[2]*

[1]College of Agriculture. California State University, Chico. 400 West First Street. Chico, CA 95929, USA, [2]Facultad de Agrobiología. Medicina Veterinaria y Zootecnia. Universidad Autónoma de Tlaxcala. Ex-Hacienda de Xalpatlahuaya. Huamantla, 90513, Tlaxcala. México

ABSTRACT

The effect of corn straw (CS) or silage (CL), combined with flaxseed (Fx) on meat quality production and sensory analysis of Pelibuey lambs were evaluated. Sixty-four Pelibuey lambs were divided to each of the following treatments: T1) Corn Straw (CS: 16.3%) without flaxseed (Fx) in the diet, T2) CS plus 6% of Fx, T3) Corn silage (CL: 15%) without Fx and T4) CL plus 6% of Fx. Dry matter intake improved by 9.2% with CL vs. CS. The feed conversion improved with the use of CL in 1-14d ($P \leq 0.02$) and 14-28d (0.05) in 11.7% and 10.4%, respectively. Coordinate b was increased by 38% ($P = 0.01$) in the animals fed with CS. Thus results show that Fx did not influence the physical-chemical and sensory variables of the meat. CL favorably changed the feed intake, flavor and juiciness of the meat, as in the fattening of lambs.

Keywords: Corn straw; Corn silage; Flaxseed; Lambs, Meat

INTRODUCTION

The increase per capita of meat consumption worldwide has cause developing countries to increase their production rate to 2% (FAO 2013). At the same time, there was also an increase in the demand of better meat quality. Consumers request more juiciness, tenderness, less cholesterol content and saturated fatty acids on the everyday meat. (Della Malva et al., 2016). In production systems, lamb (*ovis aries*) grazing improves the content of α-linolenic acid in meat, compared to feeding lambs with high grain diets (French et al., 2000). However, in some regions of the world, grazing is difficult due to problems of land tenure or disorganization for the use of communal lands. In some regions of developing countries, the grain produced by farmers is not adequately paid for; consequently, they choose to include them in the diets of their animals destined for meat production.

Specifically, in the central highlands of Mexico, corral intensive feedings of lambs have increased. The butchers demand animals with a minimum weight of 40 kg, young and well formed so that the carcass yields at least 50% and with little fat, with a good sensory quality of the meat for consumers satisfaction. Some work done in cattle, indicates that corn silage has improved the performance of animals and improved the sensory acceptability of meat (Hernández-Calva et al., 2011). In the case of lambs, data on some supplements with forages and oils included in the feeding ration have been shown beneficial. But, data on the use of flaxseed and forage type is scarce. In Mexico as in other countries, corn forage is highly available as silage or hay. The objective of the present study was to evaluate silage and corn straw, as one of the main available forages, combined with flaxseed on the productive characteristics of the lambs, carcass yield and sensory quality of the meat.

MATERIAL AND METHODS

Animals and distribution

Sixty-four male Pelibuey lambs of 7 months old were selected. These were housed in the experimental farm

***Corresponding autor:**
Luz Marina Hernandez-Calva, Facultad de Agrobiología. Medicina Veterinaria y Zootecnia. Universidad Autónoma de Tlaxcala. Ex-Hacienda de Xalpatlahuaya. Huamantla, Tlaxcala. México. C.P. 90513 México. **E-mail:** marinahc@yahoo.com

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of Tlaxcala, Mexico (AEC 016). Subsequently, they were dewormed with Ivermectin (Ivomec®, Bovines / Sheep Merial Laboratory Mexico) and vaccinated against clostridial diseases (Ultrabac7®, Schering-Plow Veterinary, Mexico). Adaptation to a diet with more than 50% grain was performed for 15 days (base diet in the experiment). The treatments used were as follows: T1) Corn Straw (CS: 16.3%) without flaxseed (Fx) in the diet, T2) CS plus 6% of Fx, T3) Corn silage (CL: 15%) without Fx and T4) CL plus 6% of Fx. All diets formulated on an iso-protein basis (15.6%) and the composition of experimental diets is shown in Tables 1-5. The lambs were weighed and in each treatment they were assigned by homogeneous weight around 25kg, in 16 pens (four animals/pen), with repetitions of four pens per treatment. Each pen has an area of 2m^2, with shade, concrete floor, wooden chip bed, feeding trough and drinking fountain.

Table 1: Composition of experimental diets with corn forage type and flaxseed level

Treatments	T1	T2	T3	T4
	Corn straw		Corn silage	
Ingredients, %	Fx-0	Fx-6	Fx-0	Fx-6
Corn, grain	31.47	25.47	32.97	26.77
Wheat, grain	28.0	28.0	28.0	28.0
Cane molasses	12.8	12.6	12.8	12.8
Flaxseed (Fx)		6.0	0	6.0
Corn Straw	16.3	16.3	0	10.5
Corn silage			15.0	15.0
Limestone	1.03	1.03	1.03	1.03
Urea	1.0	1.2	0.8	1.0
Trace minerals[a]	0.4	0.4	0.4	0.4
Nutrimental composition (basis dry matter)				
ME, Mcal/kg	2.6	2.6	2.7	2.8
NE_g, Mcal/kg	1.1	1.1	1.2	1.2
Protein, %	15.5	15.6	15.6	15.6
NDF	26.1	25.0	22.6	21.3
Calcium, %	0.6	0.60	0.6	0.6
Phosphorus, %	0.26	0.26	0.3	0.3

[a] Trace mineral salt content: $CoSO_4$, 0.068 %; $CuSO_4$, 1.04 %; $FeSO_4$, 3.57 %; ZnO, 1.24 %; $MnSO_4$, 1.07 %; KI, 0.052 % and NaCl, 92.96 %

Productive variables

The feed samples were obtained homogeneously and dried in a forced air oven at a temperature of 100ºC for 48h. (AOAC, 1990) Subsequently, the samples were mixed and at the end of the fattening a representative sample was obtained for the laboratory analysis. Dry matter intake (DMI) and average daily weight (ADG) were measured every 14 days. ADG of the animals was recorded during the fattening time from 7 to 9 am, using a digital scale with an accuracy of ± 10 g, obtaining the average of three readings. ADG was obtained by the difference in final and initial weight divided between the days of each experimental period. Feed efficiency (FE) was estimated with DMI / ADG.

Slaughtering

Prior to slaughtering, the lambs were subjected to a 12h fasting period. The procedure consisted of desensitizing each animal with a hidden pistol gun, then they were bled with a cut in the jugular. The variables recorded were slaughter weight, hot carcass weight and chilled carcass weight. Commercial performance was calculated. The weight readings were made with the same scale mentioned above. The eviscerated carcass was identified with a numbered bracelet, later they were introduced to a cold room at 4ºC. After 48h, they were dissected and cut transversely with a saw. The separation of the neck was made in the cut from the 1st to the 5th thoracic vertebra, the back was obtained with a cut from the 1st lumbar vertebra to the 1st sacral vertebra, thus obtaining two cuts per carcass.

During the cutting of the carcass, the loin (*Longissimus lumborum*) was obtained. The samples were vacuum packed, identified with labels and kept in refrigeration at 4ºC until the physical-chemical and sensorial analyses were performed.

Table 2: Influence of corn forage type and flaxseed level on growth performance response of feedlot Pelibuey lambs

	T1	T2	T3	T4	SEM[1)]	*P* =		
	Corn Straw		Corn silage			Forage (Fo)	Flaxseed (Fx)	Fo x Fx
	Fx-0	Fx-6	Fx-0	Fx-6				
Initial weight, kg	25.03	25.59	25.83	25.53	1.13			
Average daily gain (ADG), kg/d								
1-14	0.215	0.221	0.231	0.241	0.09	0.09	0.18	0.11
14-28	0.237	0.242	0.238	0.241	0.07	0.19	0.24	0.10
28-42	0.232	0.233	0.235	0.239	0.06	0.31	0.36	0.42
Dry matter intake (DMI), kg/d								
1 -14	1.14	1.18	1.12	1.11	0.05	0.41	0.21	0.45
14-28	1.24	1.28	1.11	1.15	0.04	0.31	0.13	0.29
28-42	1.23	1.24	1.13	1.16	0.06	0.04	0.04	0.37
Feed efficiency: DMI/ADG								
1-14	5.32	5.40	4.85	4.62	2.4	0.02	0.19	0.35
14-28	5.24	5.33	4.68	4.79	1.9	0.05	0.31	0.43
28- 42	5.16	5.28	4.89	4.82	1.5	0.24	0.34	0.51

[1)]Standard error of the means.

Table 3: Influence of corn forage type and flaxseed (Fx) level on carcass characteristics of feedlot Pelibuey lambs

	T1	T2	T3	T4	SEM1)	*P* =		
	Corn Straw		Corn silage			Forage (Fo)	Flaxseed (Fx)	Fo x Fx
	Fx-0	Fx-6	Fx-0	Fx-6				
Carcass hot weight, kg	21.08	21.02	21.49	21.52	1.02	0.11	0.23	0.65
Carcass cold weight, kg	20.9	20.6	21.44	22.68	1.01	0.04	0.45	0.56
Commercial dressing, %	52.7	52.12	53.61	53.63	1.61	0.02	0.39	0.14
Fat thickness over, mm	0.81	0.90	0.92	1.06	.01	0.03	0.04	0.07

1)Standard error of the means

Table 4: Influence of corn forage type and flaxseed level on physicochemical characteristics of Pelibuey lamb meat

	T1	T2	T3	T4	SEM1)	*P* =		
	Corn straw		Corn silage			Forage (Fo)	Flaxseed (Fx)	Fo x Fx
	Fx-0	Fx-6	Fx-0	Fx-6				
Luminosity L	34.02	36.57	36.94	36.96	3.22	0.11	0.25	0.78
Intensity a	9.82	9.54	8.91	9.35	1.26	0.54	0.45	0.38
Brilliance b	0.42	0.55	0.34	0.36	0.01	0.01	0.64	0.71
Meat hardness	17.9584	19.3340	19.3171	18.3754	113.23	0.34	0.23	0.56
pH	5.85	5.72	5.53	5.72	0.33	0.78	0.65	0.51
Water retention capacity	38.18	40.20	43.21	37.16	6.42	0.46	0.34	0.14
Peroxide index	5.51	5.35	5.12	4.91	0.37	0.15	0.35	0.81
Emulsion capacity	75.41	76.91	92.7	89.21	0.6	0.02	0.07	0.35

1)Standard error of the means

Table 5: Influence of corn forage type and flaxseed level on sensorial analysis of Pelibuey lamb meat

	T1	T2	T3	T4	SEM1)	*P* =		
	Corn straw		Corn silage			Forage (Fo)	Flaxseed (Fx)	Fo x Fx
	Fx-0	Fx-6	Fx-0	Fx-6				
General quality	8.11	7.73	8.72	9.21	2.11	0.03	0.76	0.65
Flavor	7.23	7.91	8.01	8.23	2.52	0.04	0.67	0.29
Lamb odor intensity	9.35	9.12	7.11	7.42	2.13	0.02	0.34	0.56
Color	8.33	8.12	8.45	8.96	2.15	0.45	0.27	0.76
Juiciness	7.52	7.12	9.48	9.61	2.31	0.02	0.47	0.37
Softness	9.41	9.92	9.51	9.44	2.82	0.54	0.21	0.56

1)Standard error of the means

Chemical analysis and instrumental measurement

Chemical analysis: The feed samples consumed by the animals were analyzed in Dry Matter (DM), ash, total nitrogen (by the Kjeldahl method) (AOAC 1990) and Neutral Detergent Fiber (NDF) (Weizhong and Udén 1998).

Meat colour: Piece of meat were cuts of 2.5 cm and Chroma meter (Hunter Lab, Chromameter CR-410, Konica Minolta Sensing, Inc. Japan) was used to determine the colour and chromatic values were reported as L*, a*, b*, and shades (tan-1b/an angle and magnitude ((a2 + b2)1/2) g).

Meat hardness: Pieces of meat were cut perpendicular to the direction of the muscle fibers, and boiled in distilled water at 80°C by 20 min. Subsequently, cuts of 2.5 cm thickness were made. Shear force values were determined on meat cuts of 2.5 cm thickness using a Warner-Bratzler shear in a TA-XT2 texture analyser (Texture Technologies Corp., Scarsdale, NY), at 5mm test speed and 5mm/g backing speed, being applied 0.981 N force (Ishihara et al. 2013).

pH: Meat samples were placed in a 200 mL beaker, 100 mL of distilled water was added and ground in a blender for 1 min. The potentiometer was standardized with a phosphate buffer solution

Water retention capacity (WRC): Ten grams of sample were deposited in the 30 mL centrifuge tube in duplicates. To each tube 16 mL of 0.6 M NaCl solution was added and stirred for one min. The tubes were placed in an ice bath for 30 min, with continuous agitation (Goga et al., 2012).

Peroxide index: It is defined as the amount of peroxides in the sample that cause the oxidation of potassium iodide (expressed in milli equivalent of active oxygen per kg of fat). Five grams of fatty tissue were added in 30 mL of a mixture of acetic acid and chloroform (3:2). The calculation was reported in mL of thiofulfate per gram of meat, using the following equation: Index of peroxide (IP) = (((mL thiosulfate x N (0.01)) x 1000) / g sample).

Emulsion capacity: Meat homogenate (32.5 mL) plus 75 ml of sunflower oil, and 97.5 ml 0.45 M NaCl solution were deposited in the blender (Oster M6798) jar. At 6000 rpm, 100 mL oil was added at a rate of 0.5 mL/sec. After the oil had been added, the emulsion was stirred for an additional 5 sec. The electrical conductivity during the emulsification was recorded by a microprocessor and the total of the added oil before and after emulsification was recorded as emulsion capacity (Kurt and Ceylan, 2018).

Sensorial analysis

The QDA method (Quantitative Descriptive Analysis) was used on the meat samples (ISO 13299.2 2003). Samples were placed on a grill for roasting on a stove, exposing the meat to medium heat (120°C) for five min per side, repeating the operation sometimes for 15 min. Subsequently were presented to the panelists in the form of cubes, (approximately 1.5 cm^3) to be evaluated on a structured scale of 1 to 15 cm. The collaboration of 30 panelists (30 x 4 treatments = 120 meat samples) previously trained in sensory analysis (students of the 9th and 10th grade of the degree of Veterinary Medicine). The panel members were seated in individual stands in a room with controlled temperature and light, receiving a set of four samples (one per treatment) served in randomized order. Water and crackers were used to cleanse palate to remove residual flavors, between samples and at the beginning of the session. The attributes evaluated to the meat were: 1) general quality, 2) flavor, 3) juiciness, 4) odor and 5) softness. The panelists were asked to mark their horizontal perception of each variable (value of zero, as lousy) on a horizontal line of 15 cm long. Distances were measured and each variable was reported in centimeters at the distance from the zero point (Guerrero et al., 2002).

Statistical analysis

The following statistical model included effects of forage type (Fo: corn straw and corn silage), flaxseed level (Fx: cero and 6%) and (Fo x Fx) was used:

$$Y_{ijk} = \mu + Fo_i + Fx_j + Fo_i\, Fx_j + e_{ijk}$$

Where:

Y_{ijk} = variable of response of the productive performance, carcass and meat quality.

μ = average population.

Fo_i = effect of the forage type.

Fx_j = effect of the flaxseed level block.

$Fo_i\, Fx_j$ = effect of the interaction of random groups, feed types and fixed terms.

e_{ijk} = experimental error.

The study had four groups of lambs selected randomly, housed in four pens per group: 1) fed with corn straw (CS) and cero percent of flaxseed (Fx-0), 2) fed with corn straw (CS) with 6% of flaxseed (Fx-6), 3) fed with corn silage (CL) and cero percent of flaxseed (Fx-0), and 4) fed with corn silage (CL) and six percent of flaxseed (Fx-6). The effect of the interaction (Fo_i x Fx_j) was given in all variables. All data are shown with means and standard error means. Significance was declared at P<0.05, and trends were declared at P<0.1. The data collected in this study were subjected to analysis of variance and comparison of averages through contrast, using SAS 9.1 software (SAS Institute Inc., Cary, NC, USA).

RESULTS

Productive parameters and carcass characteristics

Table 2 shows the values of the ADG, DM intake and FE of Pelibuey lambs with the different treatments. During the first period of fattening (1-14d) there was a tendency to improve (5.9%, $P \leq 0.09$) the weight with CL. DMI during the whole fattening period improved by 9.2% with CL *vs*. CS. The FE improved with the use of CL in the periods of 1-14d ($P \leq$ 0.02) and 14-28d (0.05) in 11.7 and 10.4% respectively.

Table 3 shows the variables analyzed on carcass characteristics. The CL improved the weight of the chilled canal, the commercial yield and the cover fat in 6.8% (*P*=0.04), 2.3% (*P*=0.02) and 11.5% (*P*=0.03), respectively. There was a trend of statistical interaction between the type of forage and Fx in the cover fat (*P*=0.07). CL in the diets during the first 14 days of fattening tended to improve the weight gain and feed intake during the whole fattening phase.

Meat quality

Table 4 shows the physical-chemical values of the meat of lambs evaluated in different treatments. The L coordinate (luminosity) did not show significant differences (*P*>0.05) between the treatments, while the coordinate *b*, (index of yellow to blue: brightness) was increased by 38% (*P*=0.01) in the animals fed with CS (CS: 0.70 vs. CL: 0.97). The emulsion capacity increased 19% (*P*=0.02) with the CL (CS: 76.16 vs. CL: 90.95). The hardness expressed as resistance to the cut (orientates to the quality of the meat: hardness) and the values of WRC (expressed in mL of 0.6 M NaCl retained in 100 g of meat) did not show significant differences between the treatments. Post-mortem pH meat did not change between treatments. The diet did not affect the cutting force or the loss of water. The average pH in the meat was 5.7.

Sensorial analysis of meat

Table 5 shows the values of the sensory analysis in the meat of the lambs evaluated. The attributes evaluated to the meat were: 1) General quality. The CL improved the quality in general by 13% (*P*=0.03, CS: 7.92 *vs.* CL: 8.96). 2). Flavor. The taste was increased by 7 (*P*=0.04: CS: 7.57 *vs.* CL: 8.12). 3) Juiciness increased 30% (*P*=0.02: CS: 7.32 *vs.* CL: 9.54). 4) Odor. The smell of lamb decreased by 12% (*P*=0.02: CS: 9.23 *vs.* CL: 7.26%). 5) Softness. The treatments with CS had 2% more toughness than CL (*P*= 0.56: CS: 9.67 *vs.* CL: 9.48).

DISCUSSION

Weight gain and feed intake improvement with CL in the diets, was expected, since CL offers better palatability to the diet consumed (Lee et al., 2009, Minchin et al., 2009, He et al., 2012). The Fx in the diet showed no response in growth performance in this study, other authors observed that Fx processed in different ways, increased the weight of the growing heifer carcass (Maddock et al., 2006). The inclusion of CL increased the energy density of the diet and decreased the NDF content (Table 1), improving the weight and yield of the carcass (Hernández-Calva et al*.,* 2011) and the content of cover fat (Galli, 2008). Other research also cites Fx in the diet increased the fat deposition in growing steers (Drouillard et al*.,* 2002, Aharoni et al., 2004, Kim et al*.,* 2009) and heifers (Maddock et al*.,* 2006).

A pH-hardness ratio is mentioned when the pH is greater than six (this study obtained 5.7) associated with softness (Purchas 1990). The pH also has an important influence on the WRC, since it determines the electrical charges of the proteins and therefore the capacity of these to retain the water (Offer and Knight 1988). A similar study carried out in cows of waste was observed less loss of water with CL (Hernández-Calva et al*.,* 2011). The loss of water is influenced by race, age (Fiems et al*.,* 2003) and post mortem factors (Aalhus et al*.,* 2001). The color intensity of the meat decreased with CL, contrary to that observed in cows fed with CL (Hernandez-Calva et al*.,* 2011). Mainly the color differences are associated by the presence of fat and connective tissue (Merera et al*.,* 2010) to light scattering, and associated with the greater loss of water, where the bright red color of fresh meat depends on the amount of the oxy-hemoglobin in the tissue, the rate of oxygen diffusion and the partial pressure of oxygen on the surface of the meat (Beriain et al., 2009). Several authors mention that the susceptibility of meat to oxidation depends on several factors, although one of the most important is the content of polyunsaturated fatty acids in cell membranes (Mir et al., 2004, Realini et al., 2004, Daly et al., 2007). CL and mainly Fx contain more Polyunsaturated fatty acids, which increase the emulsification capacity of fats and give differences in the color of the meat (Gibb et al., 2004, LaBrune et al., 2008).

The inclusion of Fx in the diet of lambs improved the sensory analysis of the meat (Nassu et al., 2011, He et al., 2012) to increase the intensity of unpleasant taste due to the greater fatty acids oxidation (LaBrune et al., 2008) or to present strange flavors, due to the content of linoleic acid and α-linolenic acid in fat (He et al., 2012) or meat (Nassu et al., 2011). Studies in lambs, also mention that Fx in the diet increased the formation of some volatile compounds in cooked meat, although this response was less dramatic when the lambs were fed with fish oil (Elmore et al., 2000, Jaworska et al., 2016). According to this study, only 6% of Fx included in the diet did not induce changes in the sensory analysis, as reported by another study (Nguyen et al., 2017), but when the amount of 10% of Fx was used, the intensity of unpleasant taste increases (LaBrune et al., 2008); the cause is the high content of n-3 fatty acid contained in fx (Vatansever et al., 2000). It causes a decrease in preferences in the panelists who evaluate in sensory analysis of meat with a high content of unsaturated fatty acids (Dima et al., 2014) and increased in oxidation products (Yang et al., 2002). In this study, the values of general quality, flavor, odor and juiciness were increased with the use of CL. It is evident that the nutritional quality of the supplemented forage influences several parameters of the sensory analysis (DeBrito et al., 2016) as it happened in this study. Other minimum factors that also influence are the chopping process and the homogenization of the meat prepared for the sensory analysis; the causes are variations in the degrees of alteration in the cellular structure, that facilitates the interactions between pro-oxidants and unsaturated fatty acids and the formation of free radicals that can propagate oxidation. Therefore, subtle differences in the meat preparation properties can give differences in meats with CS or CL in the diet.

CONCLUSIONS

The use of Fx did not influence the physical-chemical and sensory variables of the meat. However, CL favorably influenced the feed intake, some carcass characteristics, the flavor and juiciness of the meat. In the case of the "lamb odor" variable, it was lower and was considered a good attribute for the Latins consumer. Perhaps in other countries as Asia or Europe it is the opposite, the greater intensity in odor is considered an attribute. The results generated from the study, consider encouraging the use of CL in the fattening of lambs, since it presented better attributes in the improvement of the carcass and Pelibuey lamb meat.

Authors contributions

Diana Tamara Ramirez participated in the feeding of animals and carried out each of the quality tests of pelibuey sheep meat. Jose Reyes Galaviz-Rodríguez analyzed the behavioral test of the animals according to the diet. Xochitl Gabriela Montalvo-Aguilar analyzed and collected the samples in the humanitarian death of Pelibuey sheep process. Patricia Villalobos-Peñalosa participated in data collection and statistical analysis. Pablo Cortes-Roldan performed sensory analysis and coordinated the panelists of pelibuey sheep. Luz Marina Hernandez-Calva performed data analysis was in charge of the overall direction and planning, writing, and interpretation of the manuscript and interpretation of results.

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