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In vitro and *in situ* evaluation of feed lot rations with different levels of complete ear of the corn (*Zea mays*) in lambs

J SALINAS-CHAVIRA[1], M MUÑOZ-DE-ALBA[2], O D MONTAÑEZ-VALDEZ[3] and O MARTINEZ-ZAPIEN[4]

Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Tamaulipas, México

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ABSTRACT

The study was conducted to evaluate the nutritive value of the complete ear of the corn *(Zea mays)* and diets with 0, 15 and 30% whole ear of the corn (WEC) by two stage *in vitro* technique and nylon bag techniques, respectively using Pelibuey lambs. For *in situ* evaluation, diets had equal CP (14% DM basis) and metabolizable energy (ME, 11.0 MJ/kg DM) content. Three non-castrated Pelibuey male lambs fitted with permanent rumen cannula were utilized in a 3 × 3 Latin square design. Each experimental period consisted of 10 d of adaptation followed by sampling in *in situ* evaluation. Corn grain had higher IVDMD than cob and husk, which was similar between them. Bags containing the 6 g substrate were incubated in the rumen in pairs for 4, 8, 12, 24 and 48 h. The washing loss and potential degradation was similar among the treatments. WEC level did not influence the degradation rate or the effective degradation at passage rate (k) of 0.01, however at passage rate of 0.05, it was higher in T2 than T1 and T3 and at 0.10 T2 was higher than T1, and T3 was similar to T2 and T1. It was concluded that high concentrate diets with WEC had high DM degradability. The incorporation of whole ear of the corn (grain, cob and husk) in diets for feedlot lambs may reduce cost of production.

Key words: Digestibility, DM Degradability, Ear corn, Feedlot diets

Corn (*Zea mays*) is one of the main crops grown in Mexico as food and feed crop for man and animals, respectively. Corn crop yields high amount of biomass. Masoero *et al.* (2006) reported that at physiological maturity, stalk represented 38.06, leaf 9.17, cob 8.68, husk 5.99 and grain 38.34% DM. The CP, NDF and ADF values for stover were 4.54, 73.49, and 47.54; for leaves 7.32, 61.40, and 36.94; for cob 3.02, 76.05, and 37.68% of DM. *In vitro* DM and NDF digestibility for stover was 52.25 and 35.0; for leaves 69.19 and 49.81; for cobs 53.95 and 39.45 (% DM basis), respectively. However, *in vitro* OM disappearance and concentration of total volatile fatty acids decreased with the increase in maturity (Tang *et al*. 2009). These data considered only corn stover and complete plants of corn. However, data focusing on complete ear of the corn produced for grain are limited. Martinez *et al.* (2008) reported that the principal component of maize ear is the grain (88%) and consequently, the chemical composition of maize ear may be similar to corn, except for its higher fiber content.

In Mexico, sheep production is mainly on grazing which is low input and marginal output system. To improve productive performance, lambs are fed high concentrate diets, where hair lambs may have daily weight gain of up to 200 g (Salinas *et al.* 2006, Salinas-Chavira *et al.* 2010). Conversly, high cost of intensive feeding system make it less profitable. To reduce production costs of feedlot lambs it is required to develop different feeding alternatives. Whole ear of the corn comprises husks, grains and cob. Using only grains in animal feeding, the other ear of the corn component is wasted. It is hypothesized in the present study that the energy contained in all structural components of the ear corn may be used in intensive lamb production. Hence, it is important to generate information to know the nutritive value of total mixed rations for fattening lambs containing different levels of ear corn in substitution of sorghum grain, because this grain is used in finishing rations of lambs.

MATERIALS AND METHODS

In vitro *dry matter digestibility of the components of the ear of the corn:* Ten ears of the corn selected at random were dried at 65°C for 72 h. The weight of grain, husk and cobs for each corn ear was recorded. Individual samples were ground and stored in glass jars for further analysis. The *in vitro* dry matter digestibility was determined according to the 2 stages procedure of Tilley and Terry (1963) method

Present address:[1,2,4] ([1]e mail: jsalinasc@hotmail.com), Km 5.5 Carretera Cd. Victoria-Cd. Mante, Ciudad Victoria, Tamaulipas. C P. 87000 Mexico. Tel. (834) 3121061.

[3] Centro Universitario del Sur de la Universidad de Guadalajara (CUSUR-UDG), México.

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Table 1. Ingredient composition of experimental rations for *in situ* evaluation (dry matter basis,%)

Ingredient	Ration		
	T1	T2	T3
Urea	0.32	0.32	0.31
Sorghum grain, ground	58.81	38.00	21.10
Soybean meal	17.60	15.70	16.02
Sugar cane molasses	3.45	6.98	9.87
Mineral (premix)	2.00	2.00	2.00
Sorghum straw	10.00	7.00	6.00
Wheat, bran	4.90	13.00	13.90
Low ruminal bioutilization fat	2.92	2.00	0.80
Whole ear of the corn *	0.00	15.00	30.00

*Included husk, grain and cob.

with pepsin used in the second stage. The rumen liquor was obtained from a non-castrated Pelibuey lamb (20 kg live weigh) fixed with permanent rumen cannula. The lamb was housed in a metabolic pen of 2 m^2. Lamb had *ad lib.* water, and was fed at 9:00 and 16:00 h with a ration that contained 30% of whole ear of the corn. The animal was adapted to ration for 15 days, and after that the rumen liquor was collected for the *in vitro* determination.

In situ *dry matter digestibility of rations with ear of the corn:* Three 6-month-old non-castrated Pelibuey ram lambs (25 kg initial weight), fitted with permanent ruminal cannula (40 mm in diameter) were used in a 3 × 3 Latin square design to evaluate DM degradability of high concentrate diets containing 3 levels of whole ear of the corn (WEC). Before the trial, lambs were treated for both internal and external parasites (ivermectin), and injected with a vitamin ADE preparation. Lambs were housed in individual well-ventilated draft-free pens and fed *ad lib.* 3 dietary treatments based on soybean meal and sorghum grain (Table 1) in 2 equal meals at 9:00 and 16:00 h. Treatments were 0% WEC (T1); 15% WEC (T2); and 30% WEC (T3). Crude protein was determined according to AOAC (2007). Whole ear of corn had 6.8% CP on DM basis. All diets were formulated to fulfill growing lamb requirements according to NRC (2007) and contained 14% CP and 11.0 MJ/kg DM. Ration formulations was on DM basis; however, feed mixing and feeding of animals were on as such basis, which were estimated on the DM of ingredients in ration. Water was made available permanently throughout the experiment.

During the Latin square design experiment an adaptation period of 10 days was followed prior to the incubation of bags in the rumen. For rumen incubation, nylon bags of 5 × 10 cm and 53-µm mesh were used. Bags were incubated in duplicates with 6 g in each bag of the diet offered to lambs. Feed samples were ground in a No. 4 Wiley mill equipped with a 2.0 mm retaining screen. Bags with feed-sample were tied to a 20 cm nylon cord with a metal weight at the end to ensure that samples were immersed in the ventral sac of rumen. Bags were incubated for 4, 8, 12, 24 and 48 h. Then bags were removed, washed with tap water at low pressure until clear water came out of the bag, and then were dried in an air-forced oven at 60°C for 48 h to a constant weight.

The *in situ* dry matter degradability for samples on each incubation time was calculated by the weight lost of samples in bags before and after ruminal incubation, in accordance with the Ørskov and McDonald (1979) model, which was modified by McDonald (1981):

$$P = a + b\,(1 - e^{-c*t})$$

where P, degradation of DM (%); c, fractional degradation rate (h^{-1}); a + b, potential degradability (%);t, time (h).

Ruminal turnover constants (k) at 1, 5, and 10%/h^{-1} were used to calculate effective degradation (ED; Ørskov and McDonald 1979).

$$EDDM = a + (b \times c)/(c+k)$$

where, EDDM, effective degradation of dry matter; a, soluble fraction; b, degradable fraction; c, fractional degradation rate (h^{-1}); k, rumen outflow rate.

Rumen DM degradability of the sorghum grain and whole ear of corn was determined in one lamb selected at random, and using the same procedure that was described.

Data from the *in vitro* dry matter digestibility were analyzed as one-way analysis of variance considering 3 treatments (components of ear of corn: grain, cob or husk) with 10 repetitions. Data from *in situ* dry matter degradability were analyzed by 3 × 3 Latin square model. Turkey's test was used for mean comparison if significant differences among treatments were found. GLM procedures of SAS (2007) were used.

RESULTS AND DISCUSSION

For the different components of the ear of the corn, grain had higher ($P<0.05$) IVDMD than cob or husk, which were similar between them ($P>0.05$). IVDMD (% DM) was 93.28±3.47, 55.39±1.86, and 51.19±3.15 for grain, cob and husk, respectively. Méndez *et al.* (1995) also reported that intestinal starch digestibility has inverse relation to ruminal digestibility, and total tract starch digestibility in cereals is higher than 90%. The greater digestibility of the grain compared with cob or husk can be related to chemical composition (Salinas *et al.* 2003). The vegetative parts are mainly formed by carbohydrates of structure, located in cell wall which is of low digestibility, while the grain is formed mainly by starch located in cell contents, and are highly digestible by animals. Weaver *et al.* (1978) in corn observed that all plant parts except grain increased in cell wall (CW) percentage with maturity. The CW is composed primarily of hemicellulose, cellulose, and lignin; not only does the CW percentage increases with maturation; nevertheless, also the digestibility of the CW decreases.

The *in vitro* dry matter digestibility for the components of the ear of the corn observed in our study is in agreement with Rasby *et al.* (2008). Weaver *et al.* (1978) reported values

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of 96.6, 52.3 and 80.7%, for grain, cob and husk (the value for husk is not equal. It is higher by, 29.51% units accordingly substantiate the statement) respectively in mature plants of corn; the high *in vitro* digestibility of husk could be related to maturity stage of corn that they used. In similar results, Gutierrez-Ornelas and Klopfenstein (1991) found *in vitro* dry matter digestibility of 98.6 and 68.4% for grain and husk respectively, without considering grain, husk had greater IVDMD than other parts of corn plant. In contrast, Tang *et al.* (2006) observed higher digestion in the husk than cob using the gas production technique. However, digestion in cob was higher than the other fractions of the plant. Morphological fractions of maize stovers differed in their volume of gas production in a decreasing order: husk > cob > leaf sheath > stem > leaf blade (Tang *et al.* 2008). The rapid gas production in the early stage of fermentation recorded for husk and cob indicated higher contents of rapidly fermentable soluble components in these fractions. Tang *et al.* (2008) confirmed that husk and cob are well digested by ruminants. Corn grain is collected only after physiological maturity of plant; by that time, vegetative parts are high in cell wall content and low in digestibility. Lignin interferes with cellulose and hemicellulose digestibility. Corn residues represent one of the greater hemicelluloses contents. Hence, cob and husk are rich in OM with acceptable value of *in vitro* digestibility, and because of that, their feeding in ruminants may represent a way for converting their energy content into useful products for man (NAP 1983).

Results of ruminal dry matter degradability of diets with whole ear of the corn are shown in Table 2. Rapidly soluble fraction (a), degradable (b) and potentially degradable (a+b) fractions were similar (P>0.05) among the treatments. At low ruminal turnover (1%/h), effective degradability was similar between diets (P>0.05). However, at higher ruminal turnover (5 and 10%/h), diets with ear of the corn are more degraded in rumen than diet without earn of the corn.

The diets used in the present study included high percentage of concentrate (90% DM). Hence, ruminal turnover could be from medium to high, which caused differences in effective degradability of experimental rations. These differences in the present trial are due to the different ingredient composition of diets. Diets with ear of the corn (T2 and T3) were more digested than diet without ear of the corn. Rumen degradability is not only related to ear of the corn, also diet composition could influence rumen function. In the present study, T2 and T3 contained not only whole ear of the corn, but also had higher levels of sugar cane molasses and wheat bran which are of rapidly degraded in the rumen causing that these diets to degrade more in the rumen during the first hours of incubation. This is in agreement with others (Linares-Caballero *et al*. 2003, Rosales *et al*. 2005) who found that ruminal degradation of diets are influenced by sugarcane molasses and wheat bran in feed lot ram lambs.

Table 2. *In situ* kinetics of the experimental diets with different levels of ear of the corn in ram lambs

Parameter	Ration			SEM
	T1	T2	T3	
Soluble fraction (a)	38.0	43.5	42.8	1.4
Degradable fraction (b)	56.5	34.7	44	3.5
Potential degradability (a+b)	94.5	78.2	87.0	4.4
Rate constant (c)	2.4	4.9	2.7	0.6
Effective degradability of DM modeled at fractional passage rate (h^{-1}) of:				
0.01	77.7	72.3	73.8	1.6
0.05	56.1[b]	60.7[a]	57.4[b]	0.3
0.10	48.8[b]	54.9[a]	51.7[ab]	0.5

[a, b]Values bearing different superscripts in a row differ significantly (P<0.05); SEM, standard error of the mean.

In addition, grain type also may affect ruminal digestion rate. It was reported that sorghum grain has lower digestion rate in rumen than other grains (Herrera-Saldaña *et al*. 1990). In agreement with present research where the diet with higher sorghum grain (T1) had lower rumianl degradation than diets with whole ear of the corn (T2 and T3). *In situ* DM digestibility (%), respectively, for whole ear of the corn and sorghum grain at different incubation times were: 4 h (41.7 and 44.3); 8 h (48.4 and 49.2); 12 h (50.4 and 49.3); 24 h (58.4 and 58.0); 48 h (67.0 and 69.0). It shows that whole ear of the corn had small difference with sorghum grain for rumen digestibility, though whole earn of the corn contains grain plus husks and cob, and consequently more cell wall components.

In the current study, diet without ear of the corn had 10% of sorghum straw, while diet with 30% of ear of the corn had 6% of sorghum straw. On the other hand, whole ear of the corn was formed (DM) by 16.3±4.5% husks; 74.1±4.2% grain; 9.6±1.7% cob. On basis to this, ration with 30% of ear of the corn had 13.8% of forage, which includes 7.8% from husk plus cob in whole ear of corn, and 6% from sorghum straw. On similar basis, ration 2 with 15% of whole earn of the corn had 10.9% of forage (7% from sorghum straw plus 3.9% from husk and cob from whole ear of the corn). This information also contribute to explain why whole earn of the corn diets were not affected in ruminal dry matter degradability when compared with diet without ear of the corn. In addition, other ingredients of diet also could have influence the ruminal dry matter kinetics.

It is concluded from the present study that diets with whole ear of the corn were well digested in the rumen. The use of whole ear of the corn for feedlot lambs is an alternative for reducing production costs, because all structural components (husks, grains and cobs) are used by the animal for productive function.

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