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Effect of different combinations of soybean-maize silage on its chemical composition, nutrient intake, degradability, and performance of Pelibuey lambs

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Abstract Sheep raising in the state of Guerrero, México, is a primary activity that is worth about US$3,251,931 annually. The objective of the present study was to evaluate the chemical composition, degradability, nutrient intake, and animal performance of Pelibuey lambs fed on different combinations of maize-soybean silages. Twenty-one combinations of maize silage (MS) and soybean silage (SS) were evaluated at day 45 post-ensiling; in each combination, MS was replaced by 5 % of SS. The 21 combinations were analysed for crude protein (CP) and chemical composition. In order to obtain a statistical criterion of potential treatments for the animal feeding test, a cluster analysis was performed based on the CP contents of all combinations at day 45 post-ensiling. From cluster analysis, four treatments were selected T1=100–0 % (MS/SS), T8=65–35 %, T12=45–55 %, and T16=25–75 %. Results indicated that cluster analysis was useful for identifying the potential treatments for animal feeding based on the crude protein content. The dry matter (DM), organic matter (OM), and acid detergent lignin (ADL) contents did not declined significantly ($P>0.05$) during the fermentation of silages but CP content decreased from day 0 to 45 post-ensiling. The treatment with the highest estimated microbial crude protein synthesis was T8 and it showed the highest metabolizable energy intake, high feed efficiency with a forage-concentrate ratio of 84:16.

Keywords Protein · Soybean · Silage · *In sacco* degradability · Weight gain · Pelibuey lambs

Introduction

The majority of farmers in Latin America are small-scale mixed farming systems that produce on small plots of land (Flores-Sanchez et al. 2011). The dry tropical area of Guerrero, México, is constituted by a mountainous zone with brush resources mainly appropriate for raising goats and hair sheep (Martínez Rojero et al. 2005), sheep raising grew from 500, 000 in 2004 to 1,013,000 tons in 2013; this is a primary activity that is worth about US$3,251,931.

As in many other farming systems, feeding costs may range from 52 to 70 % of total costs; of which commercial concentrates that supply protein to the diet may represent up to 90 % of direct expenditures (Espinoza-Ortega et al. 2007). The aim of improving farm-grown forage production is a common goal of farming systems all over the world; therefore, on-farm availability of forages with high protein content could be a strategy to increase profitability and sustainability of ruminant production systems and for this reason, soybean is a preferred crop mainly cultivated for grain; however, it can be conserved as silage and the quality of soybean silages has been examined in several studies (Vargas-Bello-Pérez et al. 2008; Touno et al. 2014; Spanghero et al. 2015). However, until now, there is no significant research that investigates the optimum combination of maize and soybean silages in the diets used for growing

Pelibuey lambs. Therefore, the objective of the present study was to evaluate the chemical composition, degradability, nutrient intake, and animal performance of Pelibuey lambs fed with a combination of maize-soybean silages.

Materials and methods

Location, climatic conditions, and sowing of crops

The study was carried out in the state of Guerrero located at 18° 15′ 59.1 North and 99° 38′ 48.5 West, at an altitude of 620 m, the type of climate is warm (Aw_0), with a mean annual temperature of 22.5 °C and mean annual rainfall of 1136 mm mainly during summer season. The maize and soybean crops were sown in a clay-like texture soil, with pH 7.1, electric conductivity of 0.23 dS/m and organic matter of 1.7 % (Barrios et al. 2014).

The variety VS-535 was used for maize crop and the variety SalCer (ID 2976) was used for soybean crop (Table 1). The fertilizer applications were 160:55:60 kg/ha and 75:75:100 kg/ha (nitrogen, phosphorous, potash), respectively.

Fermentation of silages

The maize crop was harvested as soon as the grain begun to dent (dimple) at the tip (pasty stage); at this point, the crop had hard dough, early dent stage. The soybean crop was harvested in the R6 stage (Fehr et al. 1971); their dry matter content at harvest (D0) is presented in Table 2. The harvest of the two crops was carried out with a silage machine T-MSM-HM SWISSMEX, the forage was chopped to a theoretical length of 25 mm and then it was compressed and stored in clear polyethylene bags (80×120 cm and 114.3-μm thickness) of 20 kg, this amount of forage was considered as 100 % in the combinations.

Combinations for silages and mini silos

Twenty-one combinations of maize silage (MS) and soybean silage (SS) were prepared, in each combination, MS was replaced by 5 % of SS. The combinations were placed in mini-silos, they were sealed on the same day and stored in the same room conditions up to 45 days. The mini-silos were sampled at D0 and D45, four repetitions were prepared for each combination. These combination where analysed for dry matter (DM), organic matter (OM), and crude protein (CP) as described in AOAC (1990); the neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) as described by Van Soest et al. (1991). Four samples of about 500 g fresh matter were collected from the mini-silos and analysed in duplicate.

In sacco study

Data of *in sacco* organic matter degradability (Ørskov and McDonald 1979) were fitted to the equation $D=a+b(1\text{-}\exp^{(-ct)})$; where a is the soluble fraction, b is the potentially rumen degradable fraction, c is the degradation rate (/h) and t is time (h). From *in sacco* degradability of OM, effective rumen degradability (ERD) was then calculated according to the equation ERD = a + $(bc)/(c + k)$; where k is the ruminal outflow rate (7 %) a, b and c parameters as described in the above equation; the outflow rate (k) was calculated following the equation $k = -0.024 + 0.179\ (1-\exp^{(-0.278\times L)})$ where L is the level of feeding calculated as 1.7 at maintenance level of feeding (AFRC 1993). Three Pelibuey lambs of 35 kg body weight (BW) and cannulated in rumen were used for *in sacco* studies, fed ad libitum with a diet based on alfalfa hay, maize stover, commercial compound (blend of milled grains; soybean meal; grain by products; vitamins A, D3, and E; mineral premix; and molasses). The in vitro digestibility of OM was determined according to Tilley and Terry (1963) and the metabolizable energy (ME) contents of silages as described in AFRC (1993).

Estimation of fermentable metabolizable energy and microbial crude protein synthesis

The estimated fermentable metabolizable energy (eFME) content of the treatments for animal feeding was a mean value obtained from AFRC (1993) for 29 maze silages and then multiplied by the ME content of treatments (eFME= 0.80*MEI). The estimated microbial crude protein synthesis (eMCPS) was estimated with the equation eMCPS (g/MJ FME)$=7+6(1-\exp^{(-0.35\times L)})$; where L = level of feeding (AFRC 1993).

Determination of the best combination of silages for animal feeding

In order to obtain a statistical criterion of possible MS/SS combinations for the animal feeding test, a cluster analysis was performed based on the similarities of CP contents of all 21 combinations at day 45, due to SS was used for improving the CP in the diet, therefore, four clusters were obtained from the analysis (Fig. 1). Cluster 1 grouped the combinations T1 to T7 (102 to 109 g/kg OM), cluster 2=T8 to T11 (110 to 121 g/kg OM), cluster 3=T12 to T15 (122 to 138 g/kg OM), and cluster 4=T16 to T21 (139 to 157 g/kg OM); from these clusters, T1=MS/SS 100–0 % was selected as control (102 g/kg OM) because is commonly used in diets for growing lambs and then, the first combination of clusters 2, 3, and 4 were used as treatments (T8=65–35 %, T12=45–55 %, T16=25–75 %), based on their similarity within clusters.

Animal experimentation

Twenty growing and complete male Pelibuey lambs, 7 months old, averaging 30.3 (±1.7)kg BW, were randomly assigned to one of the four treatments (T1=MS/SS 100–0 %, T8=65–35 %, T12=45–55 % and T16=25–75 %) supplemented with 0.273 g OM/day of a commercial compound, the forage-concentrate ratio was 84:16. Lambs were confined individually in corrals of 1.5 m^2, total daily OM (Table 1) was offered once during the day (at 0800 hours) with water and mineral rocks available at all time.

The experiment of animal feeding consisted of an adaptation period of 21 days and a 7-day recording period; therefore, the lambs were weighed at days 1, 21, and 28 before being offered their first meal. Animals were dewormed (dose rate of 0.2 mg ivermectin/kg BW) at the beginning of the study and the animals were placed in individual corrals where the four treatments (Table 1) were simultaneously offered. The feed intake was recorded daily during the recording period by weighing the feed offered and refused, feed refusals were weighed prior to the morning feeding (0800 hours).

Statistical analysis

The chemical composition during fermentation of silages was analysed using the analysis of variance of a complete randomize block design and the general linear model (GLM) was; $Y_{ij} = \mu + T_i + B_j + E_{ij}$. Where Y_{ij} is the response variable; μ is the general mean; T_i is the effect due to treatment (i=T1, T8, T12, T16); B_j is the day post-ensiling (j=0, 45); and E_{ij} is the error term. The feed and nutrient intake, and daily weight gain (DWG) variables were analysed using the analysis of variance of a randomize design with orthogonal contrasts to determine linear and quadratic effects of treatments (Steel and Torrie 1980). The GLM procedure implemented in Minitab (2003) V.14 was used.

Results

Table 2 presents the chemical composition of treatments during the fermentation period of silages from day 0 to 45. There were no significant loses in DM, OM, and ADL contents from day 0 to 45 in all treatments; however CP, NDF, and ADF decreased during the fermentation period (P<0.05). As expected, there were significant (P<0.05) differences among treatments with respect to CP content; the more SS in the mixture, the more CP content in the combination; however, T12 and T16 had the highest CP loses during the fermentation period of silages (30 and 19 g/kg OM, respectively) relative to T1 and T8 (5 and 11 g/kg OM; respectively).

The NDF and ADF contents declined significantly (P<0.01) in the treatments as the proportion of SS increased in the combinations, the NDF content of T8 and T16 dropped markedly from day 0 to 45 (62 and 50 g/kg OM, respectively). Contrary to cell wall content, the ME presented significant (P<0.001) differences among treatments; the more SS in the mixture, the more ME content in the combination, in which T16 had the highest content at day 45 (Table 2).

Figure 2a shows the data of *in sacco* degradability fitted to the exponential model up to 48 h and Fig. 2b shows the degradation rate profiles of cell wall components which involves a fully degradable primary cell wall fraction, a slowly degradable cell wall fraction, and fraction that is effectively resistant to fermentation during the normal time that the substrate remains in the rumen.

It was observed that OM degradability decreased as the SS proportion decreased in the treatments, note that T16 is the one with the highest OM degradability during the whole incubation period (Fig. 2a). In terms of degradation rate, the maximum degradation of non-structural carbohydrates might be represented by the peak at 8 h observed in T12 and T16, the degradation of insoluble fraction but potentially degradable might be represented by the soft peak observed between 16 and 24 h in T1 and T8 (Fig. 2b); it is important to note that T16 and T12 did not present slowly degradable cell wall fractions.

Table 3 shows the feed intake, nutrient intake, and Pelibuey performance. There were significant (P<0.05) differences among treatments in all variables and a significant (P<0.05) quadratic effect was observed in CPI, MEI, and DWG.

Discussion

Chemical composition and degradability of the treatments

Although fermentation parameters of silages such as pH, ammonia, and organic acids were not measured for assessing the silage quality, it can be assumed that our silages were of good quality since the OM intakes were in the range of 0.9 to 1.36 kg OM/day, which were similar to the intakes reported by Przemysław et al. (2015) and Rezaei et al. (2014) for legumes and grass silages; the ME and CP contents of MS and SS at day 45 post-ensiling were similar to those reported by Rezaei et al. (2014) and (Tobía et al. 2007, 2008) and the OM degradability observed in T8 was lower than degradability reported by Lima et al. (2011) for a diet in which sorghum silage and soybean silage were mixed in a proportion of 60/40, the difference might be due to NDF content in T8 which was higher (54 g/kg OM).

Intake and animal performance

The OMI measured in this study in T12 and T16 was 0.900 to 1.16 g/day; however, T8 showed the highest DGW that could be explained by the fact that this treatment showed significant differences ($P<0.05$) in feed intake. Therefore, the highest MEI and the eFME allowed to estimate the eMCPS which was the highest among treatments. According to the AFRC (1993), the energy supplied to rumen microbes yield the energy substrate adenosine triphosphate necessary as a fuel to drive the rumen microbes' synthetic process and according to this, the energy supply is normally the first limiting factor on microbial protein synthesis and although CPI in T16 was the highest (Table 3), the OMI, the eFME, and eMCPS were significantly lower than T8.

According to Vargas-Bello-Pérez et al. (2008), feeding forage as SS reduced the intake in dairy cows, which could be attributed to greater NDF contents of SS. In our study, we observed that T16 had more NDF content (0.63 %) relative to NDF content in T8, leading to a reduction of 0.2 kg OMI/day.

In a similar study carried out by Lima et al. (2011), they obtained average DWG of 95 g/day with a diet based on a mixture of sorghum and soybean silages (60:40) which is similar to DWG obtained in T1 and T12. On the other hand, in the experiment carried out by Salinas-Chavira et al. (2013), the effect of high concentrate diets and substitution of sorghum stover by sugarcane tops silage were tested in feedlot lambs, they obtained average daily gains of 168 and 165 g/day when sugarcane top silage was included in 5 and 10 % (respectively) in the diet or they obtained 6 and 3 g more with respect to their control diet. In another study, the effect of ensiling a totally mixed potato hash ration and a totally mixed maize ration were tested (Nkosi and Meeske 2010); they found that lambs fed with these totally mixed rations had 190 and 162 g/day of average DWG, respectively. In these two experiments, higher daily gains were obtained relative to the results obtained in T1, T12, and T16 of our study (about 72 g/day lower and relative to the study carried out by Salinas-Chavira et al. (2013); nonetheless, T8 had superior DWG than those obtained in the study carried out by Nkosi and Meeske (2010).

The DM, OM, and ADL contents did not changed significantly during the fermentation period but CP content decreased from day 0 to 45 post-ensiling. The treatment with the highest CP content, organic matter degradability, and degradation rate was T16; however, when all treatments were evaluated for animal performance, T8 showed the highest OMI, MEI, eMCPS, and a superior feed efficiency with a forage-concentrate ratio of 84:16.

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Conflict of interest The authors declare that they have no competing interests.

Compliance with ethical standards The study was carried out in accordance with the guidelines of the Research Ethics Committee of the CEP-CSAEGRO and the EU Directive 2010/63/EU for animal experiments.

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