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Digestibility of a diet with hydroponic maize (*Zea mays* L.) green fodder and its effect on lamb growth

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ABSTRACT

Objective: Determine the apparent digestibility (AD) of diets with hydroponic maize green fodder (HMGF) (*Zea mays* L.) and evaluate its effect on dry matter (DM) intake and daily weight gain (DWG) in lambs.

Design/methodology/approach: Two experiments were carried out with four inclusion levels of HMGF (0, 20, 40, 60% of DM) in the diet. A total of 16 sheep was used to determine the AD of the diet. Growth testing was carried out in 20 male lambs. Both studies employed a completely randomized design.

Results: The AD of DM and crude protein was higher in diets with 40 and 60% of HMGF ($P \leq 0.05$; $P \leq 0.01$). Lambs fed diets with 0 and 20% of HMGF showed higher DWG ($P \leq 0.05$). Sheep fed diets with 60% of HMGF showed lower DM intake ($P \leq 0.05$).

Study limitations/implications: Although there are currently several methods to supplement sheep during drought periods, few are fully adapted to what the producers need. Hydroponic maize green fodder is a valuable alternative for the rapid and constant production of high nutritional value fodder.

Findings/conclusions: The hydroponic maize green fodder has high digestibility, and thus, it can be used as an excellent source of fodder in the diet of lambs, obtaining adequate weight gains with rations that include up to 40% in the ration in substitution of commercial feed.

Keywords: Hydroponic forage, feeding, digestibility, lambs.

INTRODUCTION

Forage production in the tropical dry is extremely seasonal; the highest volume and quality are obtained during the rainy season (Muñoz *et al*., 2016; Merlo *et al*., 2017), resulting in grazing animals gaining weight during the rainy season and losing it during winter and spring, when forage and nutrient availability decrease (Castro *et al*., 2017; Coleman *et al*., 2018). Therefore, it is important to look for technologies that can provide fodder to animals when they need it and reduce the environmental impact caused by large artificially modified areas. Hydroponic maize green fodder

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(HMGF) represents a valuable alternative for the rapid and constant green fodder production with high nutritional value in extensive livestock farming areas with long drought periods (Morales, 1987). HMGF is cultivated in small areas (greenhouse); therefore, it represents less phytosanitary problems and can be produced throughout the year (FAO, 2002; Müller *et al*., 2005). Hydroponic fodders are highly palatable to livestock and provide optimal protein and energetic levels, vitamins, and minerals, with higher digestibility than fresh pastures (FAO, 2002). The information regarding the use of HMGF in sheep is limited. Some authors suggest substituting between 50 and 70% of the feed ration (Herrera *et al*., 2007); however, high levels of HMGF in the diet could compromise feed efficiency and the productive behavior of animals. This study determined the apparent digestibility (AD) of diets with HMGF and evaluated its effect on dry matter (DM) intake and the daily weight gain (DWG) of lambs.

MATERIALS AND METHODS

The study was carried out in Chiná, Campeche, Mexico (19° 44′ N and 90° 26′ W) at an altitude of 15 masl with tropical savanna climate (AW), based on the Köppen classification modified by García (1973), with 1200 mm of annual precipitation distributed between June and November (Duch, 2002).

Diet apparent digestibility determination

We used a total of 16 Pelibuey male adults with an average live weight ± standard deviation (SD) of 35.2 kg ± 3.4 kg. Sheep were housed in individual metabolic cages made of wood and provided with feeding and drinking troughs and feces and urine collectors. Animals received four treatments consisting of different inclusion levels of HMGF (0, 20, 40, and 60% of DM) in their diet, composed of commercial feed with 15% of crude protein (Table 1). Each treatment had four replicates, each of which consisted of one animal housed in a metabolic cage. Before testing, animals were internally dewormed with ivermectin and subjected to a 14 d-adaptation period to diets and cages. Animals were first fed with the commercial feed in the mornings and then with HMGF at noon. Measurements were performed during a 7-day period in which we recorded the total amount of feces produced per day and the feed and HMGF intake by daily weighing the offered and rejected quantities. Once the total production of feces was determined, feces (10%) and offered and rejected feed and HMGF samples were collected daily to obtain composed samples at the end of the measuring period. Samples were preserved at −20 °C until further processing. We determined the content of dry matter (DM), crude protein (CP), organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) based on the procedures described by the AOAC (2016). We used a completely randomized statistical design (Montgomery, 2004). Results were analyzed with a repeated measures model and using the Proc Mixed procedure of the SAS statistical software (SAS Inst. Inc., 2003).

Table 1. Ingredients and composition of the commercial diet (% of DM).

Ingredients	%
Ground sorghum	46.87
Canola	11.00
Wheat bran	13.00
Soybean hulls	14.00
Cane molasses	5.00
Soybean meal	3.85
Calcium carbonate	2.80
Nutritional additives	0.84
Common table salt	0.80
Urea	0.80
Sodium bicarbonate	0.40
Ammonium sulfate	0.15
Trace minerals	0.43
ADE vitamins	0.06
	100.00
Chemical composition	
Dry matter (%)	88.84
Crude protein (%)	15.48
EM (Mcal/kg of DM)[a]	2.74

[a] Estimated based on NRC (1985).

Lambs growth evaluation

A total of 20 weaned Pelibuey male lambs were used with an average live weight ± SD of 20 ± 2.18 kg. These lambs were randomly assigned (Montgomery, 2004) to the four HMGF treatments (0, 20, 40, and 60% of DM) used in the digestibility testing. Animals were fed a basal diet composed of a commercial feed with 15% crude protein (Table 2). Each treatment had five replicates; each replicate consisted of an animal housed in a feedlot provided with feeding and drinking troughs, concrete floor, and shade. Before testing, lambs were internally dewormed with ivermectin and vaccinated against pneumonic pasteurellosis. Additionally, animals were subjected to a 14 d-adaptation period to diets and cages. Animals were first fed with the commercial feed in the mornings and then with HMGF at noon. Feed daily intake was determined by weighing the offered and rejected amounts of each of the ration ingredients. Animals were weighed before fasting for 16 h, then every 14 days, and finally at the end of the measuring period, which lasted 84 d. We determined the daily weight gain (DWG) and the total weight gain of lambs. DWG results were analyzed using a repeated measures model. The remaining variables were analyzed with a linear model for fixed effects, which considered the effect of the level of inclusion of HMGF in the diet, using the Proc Mixed and Proc GLM procedures of the statistical software SAS (SAS, 2003).

Table 2. Chemical composition of hydroponic maize green fodder.

Component	% Dry basis
Moisture	76.97
Dry matter	23.03
Organic matter	96.2
Crude protein	18.30
Minerals	3.80
Phosphorus	0.44
Calcium	1.20
Neutral detergent fiber	36.92
Acid detergent fiber	15.05

Analyses performed in the Water-Soil-Plant laboratory of ITA Conkal, Mexico.

RESULTS AND DISCUSSION

Table two shows the results for the chemical composition of the HMGF. We observe high moisture, CP, and phosphorus (P) contents, the latter being of greater relevance because they represent approximately double the value reported for other tropical fodders (González *et al*., 2011; Merlo *et al*., 2017; Cuervo *et al*., 2019). These results are of great importance if we consider that the highest contribution of nutrients from the HMGF remains constant all the time and is not subject to a decrease in its content, as happens in traditional fodder (Muñoz *et al*., 2016; Castro *et al*., 2017). It is also worth noting the low concentrations of fiber fractions (NDF and ADF), which indicate that HMGF may be a high-quality fodder. High-quality fodders have high amounts of crude protein, between 12 and 20%, and low fiber levels, approximately 28 to 60% (Linn & Martin, 1991). It is worth mentioning that the contents of CP, NDF, and ADF of HMGF were within the mentioned ranges, highlighting the low proportion of the ADF fraction (15%). Similar values were reported for CP, fiber, and ashes by Naik *et al*. (2014).

Regarding the apparent digestibility of the different diet components (Table 3), we observed higher DM and CP digestibility in the diets with 40 and 60% of HMGF ($P \leq 0.05$; $P \leq 0.01$). Other authors (Herrera *et al*., 2007) observed a 56% DM digestibility in sheep fed diets with 100% HMGF, below what we found in this study. Similar values were observed by Acosta *et al*. (2016) in goats fed HMGF with DM and CP digestibilities of 77 to 90%. The increase in ruminal function in lambs is probably due to the quality of the HMGF; HMGF inclusion, along with sorghum and canola grains, constitutes a good complement for more efficient use of the diet components. In ruminants, the highest digestive efficiency occurs at higher rumen retention times (Hart & Glimp, 1991). On the contrary, digestibility decreases in diets with high concentrate content due to its lower retention time in the digestive tract of animals (Moore *et al*., 1999; Krämer *et al*., 2013).

There were no significant differences between treatments regarding the apparent digestibility of OM, NDF, and ADF ($P > 0.05$). Naik *et al*. (2016) report a 60% digestibility for HMGF crude fiber; however, this component does not consider the insoluble lignin portion (Van Soest *et al*., 1991). The digestibility values for the NDF of HMGF are higher than those reported for other conventional fodders (Naranjo & Cuartas, 2011; Coblentz *et al*., 2019). The higher apparent digestibility for the NDF of HMGF may be due to the ease of hydrolysis of this fiber, which stimulates its rapid disappearance in the rumen (Allen & Oba, 1996), and to the structure and composition of the cellular wall (Ramírez *et al*., 2002; Valenciaga, 2004). Furthermore, it is important to consider that the HMGF is composed mainly of tender leaves (12 to 14 days of age), making it more digestible.

Table 3. Apparent digestibility of the diet of lambs fed with different inclusion levels of hydroponic maize green fodder (HMGF).

Component	Inclusion level of HMGF (% of DM)				P value	SEM
	0	20	40	60		
Dry matter	89.74b	90.17ab	91.38a	90.98ab	0.022	0.23
Organic matter	87.15	90.32	88.40	89.62	0.820	5.90
Crude protein	75.58b	79.13ab	81.04a	80.04a	0.010	0.69
Neutral detergent fiber	79.6	78.61	82.63	90.40	0.589	3.20
Acid detergent fiber	71.00	72.22	69.20	76.09	0.237	1.62

Different letters in the same row indicate statistical difference ($P<0.05$; $P<0.01$). SEM = standard error of the mean

Table 4 shows the results obtained for lamb growth. Animals fed diets with 60% HMGF had a lower total DM intake (22%) than animals fed with 0% of HMGF (P≤0.01). Herrera *et al*. (2007) report DM intake of 564 g (per animal per day) in sheep that received HMGF (19% dry basis) in their cutting grass diet. This intake is below that observed in this study (1000 g per animal per day, on average) with the diets that included HMGF. The higher intake observed in the concentrate-based ration (0% of HMGF) can be explained by the fact that diets with high grain content have a shorter retention time in the digestive tract of animals (Hart & Glimp, 1991; Moore *et al*., 1999), which increases the intake level. There were no significant differences in the total DM intake between treatments with different inclusion levels of HMGF (P>0.05). The DM intake values fall within the ranges established for growing hair sheep (Solís *et al*., 1991; Huerta, 2001).

Lambs treated with 0 and 20% of HMGF showed more significant daily weight gain and total weight than those that received 60% of HMGF (P≤0.01). There were no significant differences between the animals that consumed 20 and 40% of HMGF (P>0.05). Due to their weight gain, lambs fed with 0, 20, and 40% of HMGF consequently had a greater weight at the end of the experiment (P≤0.01). Other authors (Morales, 1987) reported daily weight gains of 240 g in lambs fed with concentrate *ad libitum* and 300 g of dry matter of HMGF. These results are similar to those obtained in the present study with the animals fed with 0 and 20% of HMGF. This author concludes that the inclusion of HMGF allowed to improve the assimilation of the concentrate and decrease the fattening time of animals. Herrera *et al*. (2007), observed higher DWG in sheep supplemented with wheat middling compared to those fed with HMGF (41 *vs* 12 g/animal/day), in which the HMGF represented 19% (dry basis) of the cutting grass diet. The low DWG reported by these authors could be explained by the fact that they did not use a concentrated feed in the rations.

Although lambs fed with 60% of HMGF registered the lowest DWG, the values obtained are much higher than those observed in other studies with animals fed on fodder and supplemented with protein, which report DWG of 50 to 80 g/animal (Gonzalez *et al*., 2011; Holguin *et al*., 2018). The above can be attributed to the higher nutritional content and digestibility of the HMGF, which was reflected in the productive behavior of the animals.

CONCLUSIONS

Hydroponic maize green fodder (HMGF) has a high amount of crude protein and digestibility. By including up to 40% in the diet, substituting the commercial feed, it is possible to obtain adequate weight gains. Therefore, HMGF can be considered as an excellent source of fodder and a viable alternative for feeding lambs.

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Table 4. Dry matter intake and weight gain of lambs fed with different inclusion levels of hydroponic maize green fodder (HMGF).

Variable	Inclusion level of HMGF (% of DM)				P value	SEM
	0	20	40	60		
Feed intake (kg of DM/animal/day)	1.120a	0.968ab	0.865b	0.568c	0.0001	0.05
HMGF intake (kg of DM/animal/day)	0.00	0.122a	0.225b	0.312b	0.0001	0.03
DM total intake (kg/animal/day)	1.125a	1.095ab	1.060ab	0.875b	0.0253	0.03
Final weight (kg)	39.00a	38.60a	35.80a	28.13b	0.0006	3.04
Daily weight gain (g/animal)	255a	246ab	205bc	170c	0.0085	3.74
Total weight gain (kg)	17.56a	15.76a	14.54ab	9.13b	0.0098	2.09

Different letters in the same row indicate statistical difference (P≤0.05; P≤0.01). SEM = standard error of the mean.

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