Proportions of Concentrate and Corn Silage Rehydrated Ground Grain at Different Storage Times for Better Use of Starch by Lambs

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Abstract

The objective of this study was to evaluate the nutritional and bioeconomic potential of corn silage, rehydrated ground grain corn silage (RCGS), at different storage times associated with proportions of concentrates for better starch utilization by sheep. Forty Dorper-Santa Inês crossbred sheep were used, with an average body weight of 24 kg ± 3.9 kg, and an average age of 60 days. The sheep were confined for 63 days and distributed entirely at random with eight sets of repetitions and five experimental diets: Diet 1: ground corn dry; Diet 2: proportion of 850 g / kg of concentrate + rehydrated ground grain corn silage (RCGS) stored for 45 days; Diet 3: proportion of 650 g / kg of concentrate + RCGS stored for 90 days; Diet 4: RCGS stored for 45 days + 650 g/kg concentrate; Diet 5: RCGS stocked with 90 + 850 g/kg concentrate. As roughage, silage corn whole plant. Starch intake was higher (P<0.05) with the dry ground corn diet, however, digestibility was lower (P<0.05) for most nutrients compared to the RCGS diet. A smaller amount of starch was found in the feces of animals that received the RCGS diet. RCGS stored for 45 days and the diet with 650 g/kg of concentrate generates greater net income, increases nutrient intake, it is an alternative during the fluctuation of corn prices.

Highlights

1. The rehydrated ground grain corn silage (RCGS) contributed to a greater effective degradability of dry matter

2. There is better use of starch and reduction of starch in feces, in the diet with rehydrated ground corn silage

3. RCGS is an alternative to take advantage of corn price fluctuations

4. RCGS stored for 45 days reduces the cost of the diet and contributes to a better economic return.

Introduction

Corn grain is used globally in animal feed and consists mostly of starch, which serves as the main energy source for confined ruminants. However, proteins surrounding starch granulescan hinder the attack of rumen microorganisms, thenthe processing of corn through rehydration and ensiling can contribute to better use of starch.

Ensiling rehydrated corn grain involves adding water to ground maize kernels until reaching 35% moisture level to be ensiled (Ferraretto et al., 2018).Starch digestibility depends on the organizational structure of starch granules and how it reacts with prolamin, the protein encapsulating starch granules. During the ensiling process, protein subunits attached to starch granules undergo proteolysis, explaining the better digestibility of starch when animals are fed corn with high moisture content as opposed to dried corn grain (Ferraretto et al., 2013).

The storage time of rehydrated corn silage can favor the breakdown of the protein barrier and facilitate the access of ruminal microorganisms to starch.

It is also important to highlight that providing high starch diets increases the risk of metabolic disorders such as acidosis (caetse and Fotzel, 2006). Therefore, the use of different proportions of concentrates in association with dry (hay) or wet (silage) forages are important for ruminal health and better use of corn starch.

The efficiency in starch degradability is due to corn processing, and access of microorganisms to starch granules. reino et al. (2019) found an increase in feed efficiency in finishing beef cattle due to the input of metabolizable energy and increased use of this energy by the animal.

However, most of these studies focused on in vitro and in situ research, and when in vivo, bovines are used, consequently, starch digestibility results in sheep are not observed, as well as the effects on performance.

The aim of this study was to evaluate the nutritional and bioeconomic potential of ground and rehydrated corn grain silages at different storage times associated with proportions of concentrates on the productive parameters of finishing sheep.

Materials And Methods

Ethical standards for animal experimentation

The study was conducted at the Research Laboratory for Ruminant Nutrition and Feeding (LaPNAR) and the Laboratory of Animal Nutrition in the Department of Agricultural and Environmental Sciences at the State University of Santa Cruz (UESC) in the municipality of Ilhéus, Bahia, Brazil.

Animals, facilities, and experimental diets

Forty castrated male sheep of Dorper-Santa Inês crossbreed, with an average body weight (BW) of 24 kg ± 3.9kg and the average age of 90 days, were used. The animals were identified, de-wormed, and confined in a barn laid out withcovered, slatted floor stalls, equipped with individual feeding and watering troughs. The lambs were confined for 63 days, of which 15 days were assigned for adaptation and diets and 48 days were for the experimental period.

The experimental design was entirely random, with eight sets of repetitions and five experimental diets (Table 1).The experimental diets were: Diet 1: dry ground corn + 850 g/kg of concentrate; Diet 2: ratio of 850 g/kg concentrate + RCGS (Rehydrated ground grain corn silage 45 d; Diet 3: ratio of 650 g/kg concentrate + RCGS 90 d; Diet 4: RCGS stored for 45 days + 650 g/kg concentrate; Diet 5: RCGS stored for 90 days + 850 g/kg concentrate. The experimental diets consisted of whole plant corn silage as roughage, and the concentrate based on soybean meal, urea, mineral premix, limestone, in addition to RCGS or dry ground corn (Table 1).

Maize kernels were ground in a mill with a 2.0 mm diameter sieve to make RCGS. Water was subsequently added to guarantee moisture levels close to 40 %. A ratio of 100 kg of corn grain per 40 liters of water was used, mixed homogeneously, then transferred and compacted into 200-liter-capacity drums where it was sealed and stored. The silages were produced before the experimental period so they could be opened after 45 and 90 days of storage.

Intake, apparent digestibility of nutrients, and DM degradability *in situ*

Diets were provided twice a day (8:00am and 3:00pm), allowing approximately 200 g/kg of DM leftover for voluntary ingestion.Voluntary diet intakeswere calculated as the difference between quantity offered and feed leftover by each animal.

Feces was collected directly from the rectal ampoules of animals during the experimental period. These samples were identified, frozen, and later submitted for laboratory analysis.Dietary component digestibility was estimated using the internal indigestible neutral detergent fiber (iNDF) indicator. Diet, leftovers, and feces samples were incubated *in situ* for 288 hours (Reis et al.,2017). The coefficient of digestibility (CD) of each nutrient was calculated in the following manner:

$$CD = (\text{nutrient intake} - \text{excreted}) / \text{intake} * 100$$

To estimate degradability*in situ*, 3 Dorper-Santa Inês crossbred sheep were used, which were fistulated and given permanent rumen cannula. The following feeds were analyzed: dried corn grain and RCGS with two storage times (45 and 90 days). The incubation times were 0, 3, 6, 12, 24, 48, and 72 hours (Fortaleza et al., 2009).To estimate the kinetic parameters of MS, the model proposed by Orskov and McDonald (1979):

$$DP = a + b (1 - e - c.t)$$

where DP is the potential ruminal degradability of feeds, “a” is the soluble fraction; “b”, potentially degradable insoluble fraction; “c”, degradation rate of the potentially degradable insoluble fraction; and “t” the incubation time in hours. To estimate the effective degradability (DE), the mathematical model was used:

$$DE = a + [(b * c)/(c + K)];$$

where k is the estimated solid passage rate in rumen, assuming values between 2.5 and 8%/hr(ARC, 1984).

Performance

Lambs were weighed at the beginning of the study period and every 24 days for a total of two weight measurements to determine their total weight gain. Average daily gain (GMD) was determined by dividing the total weight gain by the number of days in the experimental period. Feed efficiency was calculated by dividing the GMD by the CMS of the animals.

Laboratory analysis

Feed, leftovers, and feces were pre-dried, and ground through 1 mm sieve, and analyzed for determination of dry matter, mineral matter, crude protein and ether extract according to methodologies proven by AOAC (2000), by methods 920.15, 932.05, 976.05 and 920.39, respectively.

The analysis of neutral detergent fiber (NDF) was according to Mertens (2002). NDF correction for nitrogenous compounds and neutral and acid detergent insoluble nitrogen (NDIN) compound estimates were carried out according to Licitra, et al. (1996).Lignin was determined using the method proposed by Van Soestand Wine (1967).Non-fiber carbohydrate (NFC) content, expressed as % in DM, was calculated according to Hall (2003), in which:

$$NFC = 100 - [(CP - CPurea + urea) + NDFap + EE + MM]$$

whereCPurea is crude protein in urea, and NDFap is neutral detergent fiber corrected for ash and protein.TDN content in the diet composition table was estimated using the following formulas:

$aDCP = 0.7845 \times \% CP - 0.97$ (Detmann et al., 2006a);

$adEE = 0.8596 \times \% EE - 0.21$ (Detmann et al., 2006b);

$adNDFap = 0.67 \times \{(NDFap - L) \times (1 - (L / NDFap) ^\wedge 0.85)\}$(Detmann, et al., 2007);

and$adNFC = 0.9507 \times \% NFC - 5.72$ (Detmann et al., 2006c).

Afterward, TDN was estimated using the equation below:

$$TDN = aDCP\% + (adEE\% \times 2.25) + adNDFap\% + adNFC\%,$$

Where, aDCP is apparently digestible crude protein; adEE, apparently digestible ether extract; adNDFap, apparently digestible neutral detergent fiber corrected for ash and protein; adNFC, apparently digestible non-fiber carbohydrates; and TDN: total digestible nutrients.

To calculate digestible and metabolized energy (DE and ME, respectively) of the diets, the following equations were used, according to NRC (2001):

$$DE\ (Mcal/kg) = (dNFC/100) \times 4.2 + (dNDF/100) \times 4.2 + (dCP/100) \times 5.6 + (dEE/100) \times 9.4 - 0.3;$$

$$ME\ (Mcal/kg) = [1.01 \times (DE) - 0.45] + 0.0046 \times (EE - 3),$$

Where: dNFC: digestible non-fiber carbohydrates; dNDFap: digestible neutral detergent fiber corrected for ash and protein; dCP: digestible crude protein; and dEE: digestible ether extract.

Starch quantification was performed using the Anthrone method (Dische, 1962).

Economic analyses of thediets

The economic evaluation took into account the feed offered to the animals without counting other costs in the system. The calculation was based on prices of the feed offered in the experiments in relation to the live weight of the lambs. The values for the economic analysis were $29.25 USD/kg live weight and the following prices, per kg of dry matter: $2.92USD forcorn silage, $5.18 USD forrehydrated corn grain silage, $3.12USD for corn grain, $8.70 USDfor soybean meal, $33.89 USDfor mineral supplement, $11.93 USDfor urea, $1.48USD for calcitic lime, and $23.43 USDfor sodium bicarbonate.

The economic value of each diet offered could be calculated with the cost data of each feed and its DM consumption during the experimental period using the following equations:

Daily diet cost (USD/animal/day) = Diet cost x DM consumption; weight gain cost (USD/kg) = feed conversion x diet cost; total feed cost (USD) = weigh gain cost x total weight gain; total revenue (USD) = total weight gain x animal cost price; total cost (%total revenue) = total feed cost x 100/ total revenue; net margin (USD) = Total revenue – total feed cost.

Statistical Analysis

The experiment design was completely randomized, with five experimental diets and eight sets of repetitions, considering each lamb as an experimental unit. Initial body weight was used as covariate and the statistical model adopted was:

$$Yij = \mu + \alpha i + \beta (Xij - X^{-}) + \varepsilon ij$$

whereYij = observed values of variable responses in relation to i experimental diet in repetition (lamb) j;

μ = the mean common to all observations;

αi = effect of experimental diet i;

β = coefficient of linear regression of covariate (X);

Xij = observed covariate value (initial body weight);

X^{-} = covariate mean (initial body weight);

ε = random error.

Initially, the obtained data was tested regarding error normality and variance homoscedasticity through the Shapiro-Wilk and Bartlett tests, respectively, to confirm basic suppositions for the analysis of variance. The results were then subjected to analysis of variance andwhen significant F values were found at 5% probability, the degrees of freedom of experimental goals were broken down using orthogonal contrast technique (C), as presented by BanzattoandKronka (2006). The contrasts were: contrast 1:comparison between RCGS and dried corn grain (control); contrast 2: comparing RCGS storage time (45 *vs*90 days), independently ofconcentrate proportion;and contrast 3: comparing diet concentrate proportion (850 *vs*650 g concentrate/kg DM), independently of storage time (Table 2).

Corn grain, RCGS stored for 45 days, and RCGS stored for 90 days were used to obtain dry matter *in situ* degradability results. The experimental diet means were compared using orthogonal contrasts. Contrast 1: comparison between RCGS and dried corn grain; and contrast 2: comparing RCGS storage time (45 *vs*90 days).

Results

Intake, apparent digestibility, and degradability *in situ*

Lower intake (P<0.05) of most nutrients (DM, OM, CP, NDFap, NFC, starch, and TC) was observed in the RCGS diet when compared to the control diet. Starch intake increased (P<0.05) 14.03 % in the SMGMR diet stored for 90 days comparison to RCGS diet stored for 45 days (Table 3).

The RCGS diet increased (P<0.05) the digestibility of (MO, EE, CP and CT), and lower amount of starch in the feces, with a reduction of 23.63%, compared to the diet with dry ground corn.

Regardingconcentrate proportion, intake of most nutrients (DM, OM, CP, NDFap, and TC) was higher in the 650 g/kg concentrate diet, with increases ranging from 9.1% for dry matter and 8.7 for CT. However, starch and EE intake (354.12 and 47.95 g/day, respectively) were reduced (P<0.05) when compared to the 850 g/kg concentrate diet (Table 3).

The digestibility of most nutrients (DM, OM, CP, NFC, starch, and TC) was lower (P<0.05) in the 650 g/kg concentrate diet in comparison to the 850 g/kg concentrate diet (Table 3).

It was observed that the RCGS diet favored greater (P<0.05) of the soluble fraction (a) with a mean of 61.91% and higher effective DM degradability at rates of passage of 2, 5, and 8% h^{-1} as well as the potential degradability 48 h, in the RCGS diet in comparison to corn grain (Table 4). The effective degradability of the rates of passage in ED5% h^{-1} (82.26) andED8% h^{-1} (80.24) were greater (P<0.05) in RCGS stored for 90 days than in RCGS stored for 45 days (Table 4).

Performance

Lower (P<0.05) performance (fBW.MDG. TG. FC. and FE) was found in the RCGS, with a decrease of 18.6% for GMD and 14.8% for EA, when compared to diet with ground corn (Table 5). Neither the diets with RCGS stored for 45 and 90 days. nor the concentrate levels (850 vs 650 g/kg) influenced animal performance (Table 5).

Economic analyses of the diets

Diet cost for RCGS was around U$ 5.81 of the diet with RCGS, an increase of 26.33%, in relation to the diet with ground corn, while the cost per weight gain was around U$ 18.53, with increase of 8.29%. In relation to the total feed cost, the diet with SMGMR was 8.28% higher. Soon there was a gross margin in the diet with SMGMR of 13.37% lower, compared to dry ground corn (Table 6).

Diet cost and weight gain cost for RCGS stored for 45 and 90 days did not differ. However, the diet with SMGMR stored for 45 days had a 5.67% lower total feed cost compared to SMGMR stored for 90 days (Table 6).

There was no difference in diet costs with 850 g/kg and 650 g/kg concentrate. The cost per weight gain was 8.29% higher for the diet with 850 g/kg of concentrate. However, it was observed a decrease of 8.28% in the total feed cost, when compared to the diet with 650 g/kg of concentrate.

However, the total recipe for a diet with 650 g/kg concentrate was higher with a value of U$404.54 compared to a diet with 850 g/kg of concentrate with a value of U$389.61 (Table 6).

Discussion

Intake. apparent digestibility. and degradability *in situ*

The RCGS diet showed less nutrient intake. Since dry matter intake is influenced by diet energy concentration, animals tend to reduce ingestion when energy satiety is reached because animal energy demand can be met at lower intake levels in feed with high energy content. (Mertens (1994).

According to Silva. et al. (2007), diets with intensely processed grains or more degradable starch sources in rumen can reduce dry matter consumption due to increased short chain fatty acid concentration.

Another factorwhich may have influenced lower consumption of dry matter and other nutrients is the lower dry matter content in the RCGS dietwhen compared to the with ground corn (Table 1). However, increased digestibility of most nutrients (OM, EE, CP, and TC) was found when animals were offered the RCGS diet. Digestibility outcome is attributed to the amount of available starch, which provides the greatest amount of digestible energy and maximizes utilization.

This fact can be confirmed when lower quantities of starch in feces are observed (8.89 g/kg; Table 3) in animals given an RCGS diet. According to Zinn (2007), the higher the starch digestibility, the lower the starch quantities in feces will be.

Starch available in rumen, due to rehydration and ensiling, contributed to a higher degradation rate in fraction “a” and effective degradability of dry matter (Table 4). Higher DM degradation in the RCGS diet compared to corn grain is related to the ensiling process of rehydrated corn grain, in which the proteins (zeins) surrounding starch granules undergo proteolysis,making starch available and increasing ruminal degradability (Ferraretto. et al. 2014).

According to Arcari et al. (2016),an increase in ruminal degradability of rapidly degradable corn starch (a) occurs when corn undergoes the ensiling process.A similar result was found by Castro (2019), who observed a 39% increase in fraction (a) (rapidly degradable) rehydrated corn silage stored for 247 days when compared to dried corn grain.

Corn grain silage storage time aims to break the protein barrier covering starch granules and increase starch digestibility (Kung. et. al. 2014),explaining greater starch intake (431.43 g/day; Table 3) in the RCGS stored for 90 days diet.

Regarding the diet with 650 g/kg of concentrate, the higher consumption of dry matter and other nutrients may be due to the consumption being controlled by the physiological regulation of the animals, according to the fulfillment of their energy requirements.

On the other hand,higher starch intake by animals receiving an 850 g/kg concentrate diet may be associated with the higher proportion of RCGS in the diet, which is the main source of starch.

According to Forbes (1995), factors such as feeding levels and rumen capacity cause variations in the time the food remains in this compartment and, therefore, the characteristic of the food can reduce digestibility, which may have happened in this study, with less digestibility in the diet with 650 g/kg of concentrate, as it has in its composition (Table 1) higher NDF content.

Performance

According to Berchielli. et al. (2011), intake is one of the factors with greatest impact on animal production and affects performance.

Lower animal performance in the RCGS diet is directly related to lower dry matter intake. since according to Mertens (1994) approximately 60 to 90% of variations in animal performance can be attributed as variations that affect the consumption of nutrients.

The lower performance of animals on the SMGMR diet is directly related to the lower dry matter intake, so factors justify the lower feed efficiency (317.57 g / day) (Table 5) of the animals that received the SMGMR diet when compared with the dry corn diet.

The lower average daily gain - GMD (273.49 g / day) and total gain - GT (13.12 kg) (Table 5) found in this study may also be associated with lower dry matter intake. Although MDG was lower in RCGS diets. it is close to that recommended by NRC (2007) of 250 g/day.

The lack influence of RCGS experimental diets stored at 45 and 90 days and in the form of diets with levels of 850 and 650 g / kg of concentrate can be explained due to the animals having similar weight and age.

Economic analyses of the diets

Due to higher diet cost and lower net revenue. the RCGS diet produces less bioeconomic return, compared to the control diet. The greatest driving factor behind this result was cost per kg of dry matter of the RCGS diet.

However, it is important to evaluate oscillations in the price of corn. as in the case of a reduction in corn price, rehydration and ensiling may bring better financial return.

The RCGS stored for 45 days showed positive results in the total revenue (Table 6). These larger values were due to cost calculations including mean daily gain of animals, which was numerically superior for RCGS stored for 45 days in comparison to that stored for 90 days.

Net margin is obtained through total weight gain by the animal cost price. Weight gain of animals receiving a 650 g/kg concentrate diet enabled better bioeconomic return than the 850 g/kg concentrate diet. while reducing diet costs.

The present study revealed that performance results for animals receiving an RCGS diet fell short of expectations. However,mean daily gain met the requirements recommended by NRC (2007). Additionally,RCGS is an alternative that can take advantage of fluctuating corn prices in the market (low price),favoring better bioeconomic return.

Conclusion

Rehydration and corn silage can be an alternative with the fluctuation in corn price. Otherwise, it becomes unnecessary, since the corn milling process is satisfactory for lambsperformance.

The reduction of starch in the feces of animals fed with rehydrated and ensiled corn shows the use of starch in the gastrointestinal tract.

When choosing to ensile rehydrated corn.silage can be used for animals after 45 days of storage, since starch digestibility was not changed by longer storage times.

The proportion of 650 g/kg of concentrate increases intake nutrient, and in addition to economic return.

Abbreviations

aDCP - apparently digestible crude protein

adEE - apparently digestible ether extract

adNDFap - apparently digestible neutral detergent fiber corrected for ash and protein

adNFC - apparently digestible non-fiber carbohydrates

and TDN - total digestible nutrients

AOAC – Official Methods of Analysis

BW - body weight

CD - coefficient of digestibility

CP - crude protein

CPurea - crude protein in urea

CT - total carbohydrates

dCP - digestible crude protein

DE - Digestible energy

DE - effective degradability

dEE - digestible ether extract

DM - Dry matter

DMi - Dry matter indigestible

dNDFap - digestible neutral detergent fiber corrected for ash and protein

dNFC - digestible non-fiber carbohydrates

DP - potential ruminal

DWC - Diet water consumption

EE - ether extract

fBW - final body weight

FE - Feed efficiency

GE - Gross energy

iBW - initial body weight

MDG - Mean daily gain

ME - Metabolizable energy

MM - mineral matter

MO - organic matter

NDF - neutral detergent fiber

NDFap - Neutral detergent fiber corrected for ash and protein

NDFi - Insoluble neutral detergent fiber

NDIN - neutral and acid detergent insoluble nitrogen

NFC - Non-fibre carbohydrates

NRC – Nutrient requeriments of dairy cattle

OWI - Offered water intake

RCGS - rehydrated ground grain corn silage

TDN – Total digestible nutrients

TG - Total gain

TMT - Total mastication time

WB - Water balance

WEF - excretion in feces

WEU - excretion in urine

Declarations

Ethics approval and consent to participate

The study strictly conformed to Brazilian legislation regarding animal research and was approved under protocol number 024/18 by the Commission for Ethical Use of Animals at the State University of Santa Cruz (UESC).

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

There is no conflict of interest to declare.

Consent for publication

Guimarães, G. S – Conducted the experiment, run the statistics and wrote the manuscript; Azevedo, J.A.G – designed the research; Cairo, F.C.; Silva, C.S; Nunes, F.S; Souza, L. L – contributed to the conduct of the experiment and data analysis; Carvalho, G.G.P; Araújo, G.G.L; Silva, R.R contributed with the reagents and correction of the manuscript. All authors read and approved the manuscript.

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Tables

Table 1 - Proportions of ingredients and chemical composition of experimental diets

		Storage time of RCGS				Maize silage	RCGS 45 dias	RCGS 90 dias
		45 d	90 d	45 d	90 d			
Item	Ground corn	850 g/ kg concentrate		650 g/ kg concentrate				
Proportions of ingredients (g/kg MS)								
Maize silage	150.00	150.00	150.00	350.00	350.00			
RCGS	-	658.10	658.10	399.20	399.20			
Ground corn	658.10	-	-	-	-			
Soybean meal	136.30	136.30	136.30	200.80	200.80			
Urea	10.00	10.00	10.00	2.00	2.00			
[1]Mineral premix	12.00	12.00	12.00	12.00	12.00			
Calcitic limestone	18.60	18.60	18.60	20.00	20.00			
Sodium bicarbonate	15.00	15.00	15.00	16.00	16.00			
Chemical composition (g/kg MS)								
Dry matter	773.75	614.41	624.94	580.24	586.63	344.50	603.00	619.00
[2]iDM	99.07	97.54	88.56	142.72	139.08	371.20	36.55	31.30
Organic matter	943.23	944.37	939.76	936.87	934.08	978.50	987.00	980.00
Ether extract	33.72	53.34	45.51	45.41	40.66	44.90	65.15	53.25
Crude protein	171.84	172.65	171.96	172.22	171.80	84.80	96.00	94.95
[3]NDFap	163.76	137.56	134.43	217.37	215.48	443.20	64.85	60.10
[4]iNDF	51.39	53.54	49.16	87.93	86.42	234.90	16.80	14.35
[5]NFC	573.90	580.82	587.86	501.87	506.14	405.60	761.00	771.70
Starch	530.59	453.92	488.54	324.70	343.70	187.40	641.35	693.95
Total carbohydrates	737.66	718.37	722.29	719.24	721.62	848.80	825.85	831.80
[6]TDN	786.41	825.65	818.84	833.98	855.29	758.90	888.20	875.10
*[7]GE (MJ/kg)	4.39	4.50	4.44	4.42	4.39	4.47	4.63	4.53
	4.38	4.49	4.42	4.41	4.37	4.46	4.62	4.52

*[8]DE (MJ/kg)								
*[9]ME (MJ/kg)	4.11	4.31	4.21	4.20	4.14	4.25	4.50	4.35

RCGS (rehydrated ground corn silage); [1]mineral premix composition per kg: Calcium, 160 g; Phosphorus, 16 g; Sulfur, 36 g; Magnesium 20 g; Potassium 34 g; Sodium 56 g; Cobalt 8 mg; Copper 540 mg; Chromium 6.7 mg; Iodine 27.5 mg; Manganese 1.070 mg; Selenium, 6.7 mg; Zinc, 2000 mg; Vitamin A, 168.000 IU; Vitamin D 317.000 IU; Vitamin E; Biotin, 90 mg; Amylase, 11.400 KNU; D-Limonese, 3000 mg; Saccharomycescerevisiae, 2.7x10E9 UFC; Fluorine 160 mg. [2]Indigestible dry matter; [3]Neutral detergent fiber corrected for ash and protein; [4]Insoluble neutral detergent fiber; [5]Non-fibre carbohydrates; [6]Total digestible nutrients; [7]Gross energy; [8]digestible energy; [9]Metabolizable energy - *Calculated according to NRC (2001).

Table 2. Distribution of coefficients in orthogonal contrasts

		Storage time of RCGS			
		45 d	90 d	45 d	90 d
Contrasts	Ground corn	850 g/ kg concentrate		650 g/ kg concentrate	
1	2	-1	-1	0	0
2	0	1	-1	1	-1
3	0	1	1	-1	-1

Table 3 - Intake, apparent digestibility coefficients of nutrients from experimental diets

Item	Ground corn	Concentrate g/Kg		Storage time of RCGS		SEM	P Value		
		850	650	45 d	90 d		C1	C2	C3
Intake (g/dia)									
Dry matter	1057.71	949.08	1043.92	982.51	1010.49	20.19	0.0045	0.2559	0.0370
DM (g/ kg BW)	31.98	30.35	32.96	31.08	32.23	0.45	0.1137	0.1297	0.0039
Organic matter	1003.24	900.63	979.45	928.16	951.92	18.47	0.0039	0.2922	0.0096
Ether extract	35.60	51.22	47.95	51.86	47.22	1.10	<.0001	0.0033	0.0148
Crude protein	188.35	158.61	179.09	168.04	169.65	3.65	0.0003	0.6120	0.0063
[1]NDFap	185.21	140.94	217.67	174.06	184.55	5.24	<.0001	0.0697	<.0001
[2]NFC	594.08	545.67	534.78	532.10	548.35	10.91	0.0201	0.2296	0.4456
Starch	539.22	463.61	354.12	386.30	431.43	13.09	0.0002	0.0034	<.0001
[3]TC	779.31	686.62	752.46	706.17	732.91	14.38	0.0009	0.1559	0.0052
Digestibility (g/kg de MS)									
Dry matter	719.33	764.65	660.90	720.79	704.76	11.81	0.1235	0.4086	<.0001
Organic matter	745.38	781.20	692.84	746.50	727.54	10.7	0.0182	0.9118	<.0001
Ether extract	763.32	877.02	862.75	877.91	861.86	10.37	<.0001	0.3748	0.4296
Crude protein	674.17	723.37	668.91	689.16	703.12	9.52	0.0304	0.5319	0.0082
[1]NDFap	503.74	497.07	503.73	487.55	513.25	11.51	0.8342	0.4145	0.6191
[2]NFC	759.57	810.41	710.83	760.67	760.67	15.5	0.1941	0.9819	0.0062
Starch	940.74	957.24	913.92	932.30	938.86	4.67	0.1380	0.4089	<.0001
[3]TC	760.88	795.98	720.34	757.05	759.26	7.41	0.0491	0.9821	<.0001
[4]TDN	735.27	736.95	698.38	704.27	731.06	20.60	0.9775	0.5711	0.4166
[5]DE (MJ//kg)	13,57	13,63	13,00	13,04	13,54	0.36	0.9518	0.5506	0.4148
Starch in feces	11.64	8.89	9.35	9.35	8.90	0.54	0.0456	0.6090	0.7726

RCGS = ground and rehydrated corn silage; SEM, standard error of the mean; Contrast 1: control x RCGS; Contrast 2: storage time 45 x 90 d; Contrast 3: 850 g/kg x 650 g/kg concentrate; [1]Neutral detergent fiber corrected for ash and protein; [2]Non-fibre carbohydrates; [3]Total carbohydrates; [4]Total digestible nutrients, [5]Digestible energy in megajoule.

Table 4 - Estimation of the parameters of *in situ* degradation of ground corn and RCGS.

		Storage time of RCGS		SEM	P Value	
Parameter	Corn	45d	90d		C1	C2
a: [%]	30.90	70.57	57.26	7.60	0.0077	0.1107
b [%]	31.52	27.41	29.55	2.87	0.7157	0.8224
c [%h^{-1}]	0.04	0.02	0.31	0.06	0.3498	0.1004
Effective degradability kp2 [%]	52.05	84.02	84.76	6.85	0.0005	0.7775
Effective degradability kp5 [%]	45.29	78.42	82.26	7.42	<.0001	0.0123
Effective degradability kp8 [%]	41.86	76.14	80.24	7.69	<.0001	0.0022
Degradabilidade potencial 48 h [%]	59.35	83.23	75.64	4.90	0.0137	0.3244

RCGS = ground and rehydrated corn silage; SEM. standard error of the mean; Contrast 1: control x RCGS; Contrast 2: storage time 45 x 90 d; Contrast 3: 850 g/kg x 650 g/kg concentrate; a. soluble fraction; b. insoluble fraction potentially degradable; c. rate of degradation of the potentially degradable insoluble fraction; kp. changeover rates in 2. 5. 8% h^{-1}

Table 5 - Performance of lambs confined according to experimental diets

Item	Ground corn	Concentrate g/kg		Storage time of RCGS		SEM	P Value		
		850	650	45 d	90 d		C1	C2	C3
[1]iBW (kg)	24.01	24.01	24.01	24.01	24.01	—	—	—	—
[2]fBW (kg)	40.14	37.13	38.05	37.64	37.54	0.91	0.0032	0.8900	0.2537
[3]MDG (g/day)	336.06	273.49	292.48	284.12	281.85	7.82	0.8900	0.2537	0.8900
[4]TG (kg)	16.13	13.12	14.03	13.63	13.52	0.37	0.0032	0.8900	0.2537
[5]FC (g/day)	2.79	3.31	3.34	3.24	3.43	0.11	0.0246	0.3315	0.9301
[6]FE (g/day)	372.90	317.57	306.91	318.48	306.00	11.13	0.0116	0.4736	0.5401

RCGS = ground and rehydrated corn silage; SEM. standard error of the mean; Contrast 1: control x RCGS; Contrast 2: storage time 45 x 90 d; Contrast 3: 850 g/kg x 650 g/kg concentrate; [1]initial body weight; [2]final body weight; [3]Mean daily gain; [4]Total gain; [5]Feed conversion and; [4]Feed efficiency.

Table 6 - Economic evaluation based on experimental diets

Indicators	Concentrate g/kg						Storage time of RGMS			
	Ground corn		850		650		45 d		90 d	
	U$	%	U$	%	U$	%	U$	%	U$	%
[1]Cost of the diet (U$/ kg)	4.60	100.00	5.81	126.33	5.81	126.34	5.81	126.34	5.81	126.34
Daily cost of the diet (U$/ animal)	4.87	100.00	5.70	116.94	5.88	121.11	5.61	115.31	5.96	122.74
Confinement time (days)	48	48	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00
[2]Cost of weight gain (U$ / kg)	12.83	100.00	19.54	108.29	19.11	105.80	19.03	105.31	19.65	108.78
[3]Total cost with feed (U$)	206.78	100.00	260.44	108.28	264.34	109.91	254.16	105.67	270.62	112.52
Total cost (%)	-	61.73	-	89.94	-	87.06	-	86.25	-	90.75
[4]Total revenue (U$)	417.82	100.00	386.61	100.00	404.54	103.83	312.21	100.41	402.90	103.42
[5]Net margin (U$)	265.04	100.00	129.16	86.638	404.54	94.02	312.21	91.93	402.90	88.73
Net margin (U$/ day)	5.53	100.00	2.69	86.638	2.92	94.02	2.84	91.93	2.76	88.73
Dry matter intake (kg/ day)	1057.71		949.08		1043.92		982.51 3.24		1010.49	
Food conversion	2.79		3.31		3.34				3.43	
Total weight gain (kg)	16.13		13.12		14.03		13.63		13.52	
Animal prices U$/ kg of live body weight			U$29.25							

[1]Average values (U$) per kg of dry matter of the food: U$ 2,92 (corn silage); U$ 5,18 (RGMS); U$ 3,12 (grain corn); U$ 8,70 (soy bran); U$ 11,93 (urea); U$ 33,89 (mineral supplement); U$ 1,48 (Calcite limestone) and (Bicarbonate) U$ 23,43, [2]Food conversion multiplied by the cost of the diet, [3]Cost of weight gain multiplied by total weight gain, [4]total weight multiplied by the price received, [5]Revenue minus the total cost of feed.