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in

Ben Salem H. (ed.), López-Francos A. (ed.).
Feeding and management strategies to improve livestock productivity, welfare and product quality under climate change

Zaragoza : CIHEAM / INRAT / OEP / IRESA / FAO
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 107

2013
pages 139-143

Effect of the nature of the concentrate feed on the end products of digestion in the Sicilo-Sarde sheep

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Abstract. The pH, VFA concentration, total gas and methane production were determined in the rumen of four Sicilo- Sarde rams fitted with permanent canulas. Rams received a ration that included 1.5 kg DM of oat hay and were supplemented with one of four concentrates: CC (10% barley, 43.3% corn, 25% wheat bran, 17.7% soybean meal, 4% sheep Vitamin and Mineral Mixture (VMM)), SC (66% white sorghum, 30% faba, 4% sheep VMM); TC (71% triticale, 18% faba, 7%, soybean meal, 4% VMM) or BC (71.5% barley, 17.5% faba, 7% soybean meal and 4% VMM). 50 ml samples were taken before, 2, 5 and 8 hours after the morning meal. Total gas was determined on rumen content before the morning meal. The rumen pH was statistically different (P<0.05) before and 2 hours after the morning meal among concentrates feed. It was in favour of TC and BC (P<0.05) concentrates but was comparable at the end of the day. The concentration of VFA was significantly higher (P<0.05) for diets TC and BC following the meal and became comparable among concentrates thereafter. The proportion of acetate and butyrate acids evolved in the same way during the day regardless of the regimen. The total volume of gas was different (P<0.05) among diets, the BC showed the highest value (87.00±17.29 ml) while the lowest value was found in the TC concentrate (56.58±13.06 ml). The CH_4 production for the BC was significantly different (P<0.05) from that of TC. Quantities produced by the CC and SC were similar (22.08±4.18 *vs*. 21.16±3.21).

Keywords. Acetate – Butyrate – Propionate – Rams – Rumen – Total gas.

Effet de la nature des aliments concentrés sur les produits terminaux de la digestion des ovins de race Sicilo-Sarde

Résumé. *Le pH, la concentration des AGV, la production de gaz total et de méthane sont déterminés dans le rumen de quatre béliers Sicilo-Sardes porteurs de canules ruminales permanentes. Les béliers ont reçu une ration de base de foin d'avoine à raison de 1,5 kg MS/j complémentée par l'un des quatre aliments concentrés: CC (10% orge, 43,3% maïs, 25% son de blé, 17,7% tourteau de soja, 4% CMV), SC (66% sorgho blanc, 30% fèverole, 4% CMV); TC (71% triticale, 18% fèverole, 7%, tourteau de soja, 4% CMV) ou BC (71,5% orge, 17,5% fèverole, 7% tourteau de soja, 4% CMV). 50 ml de jus de rumen étaient prélevés avant, 2, 5 et 8 heures après la distribution du repas du matin. Le gaz total a été déterminé sur le contenu de rumen prélevé avant le repas du matin. Le pH ruminal était statistiquement différent (p<0,05) avant et 2 heures après le repas en fonction des aliments concentrés. Il a été en faveur de TC et BC (p<0,05), puis il a été comparable pour tous les aliments concentrés à la fin de la journée. La concentration des AGV était statistiquement élevée (p<0,05) pour les aliments concentrés TC et BC et statistiquement comparable pour les autres aliments concentrés. La proportion d'acétate et de butyrate évolue de façon similaire durant la journée quel que soit le régime alimentaire. Le volume total de gaz a été différent (p<0,05) entre les régimes, l'aliment BC présente la valeur la plus élevée (87,00±17,29 ml) alors que l'aliment TC affiche la valeur la plus faible (56,58±13,06 ml). La production de CH_4 a été significativement différente avec TC (p<0,05). La quantité produite par les aliments concentrés CC et SC était similaire (22,08±4,18* vs. *21,16±3,21).*

Mots-clés. *Acétate – Béliers – Butyrate – Gaz total – Propionate – Rumen.*

I – Introduction

The development of ruminant livestock in needs the parallel use of different sciences (nutrition, reproduction, genetics, health), in an integrated way with the agriculture systems. The conditions of the rearing environment (temperature, humidity, conditions, and quality of fodder, etc.) in sheep farms are frequently difficult and limit individual performances (milk and meat). The feeding of ruminant livestock , the sustainability of the farming system and income of the farmer remain the main areas of research in nutrition.

Supplementation with concentrated feed rations remains at high costs, which is not a stimulating factor for high production (Poncet *et al*., 2003).

Indeed, in the current global economic environment characterized by rising prices of these ingredients, using local raw materials (barley, triticale, sorghum and faba bean white) in total or partial replacement of imported raw materials (corn meal soybeans) is an alternative to be tested. It is within this framework that fits our work which aims to measure the effect of nature of supplementation on ruminal fermentation parameters.

II – Materials and methods

Animals and diets

Four rams of Sicilo-Sarde breed with an average live weight at the beginning of the trial of 45.25±3.5 kg and aged 4.8±0.5 years, fitted with permanent canulas in the rumen, were used in this experiment. Animals had a common basal diet at 1.5 kg DM/head/day of oat hay supplemented by four concentrates differing by the nature of protein and energy ingredients they contained: CC (10% barley, 43.3% corn, 25% wheat bran, 17.7% soybean meal, 4% sheep Vitamin and Mineral Mixture (VMM)), SC (66% white sorghum, 30% faba, 4% sheep VMM); TC (71% triticale, 18% faba, 7%, soybean meal, VMM) or BC (71.5% barley, faba 17.5%, 7% soybean meal and VMM) at 500 g / head / day. Food values were 0.98, 0.99, 0.98 and 1.01 UFL / kg DM respectively and similar protein (104.9; 95; 103; 103 g PDIE/kg DM, respectively) and (99; 96; 102; 100 g PDIE/kg DM, respectively).

Rumen fermentation

The samples for the determination of various parameters of rumen fermentation took place just before serving meals in the morning (before, 2, 5 and 8 hours after the meal). The pH of the inoculum was measured just after each sampling. The concentrations of VFA were measured by gas chromatpgraphy. Determining the total gas (CO_2 and CH_4) was performed on the filtered rumen contents, collected before the distribution of the morning meal. 0.5 g of substrate (oat hay milled at 1 mm), 10 ml of rumen fluid and 40 ml of artificial saliva (Menke and Steingass, 1988) were put in syringes, and at the end of each incubation, 5 ml of NAOH (10 N) were injected in each syringe to determine the amount of methane.

Statistical analysis

The results of the effects of diets on the parameters measured were subjected to analysis of variance by GLM procedure of SAS (1989) and compared by the Duncan test (1955). The kinetics of gas production used is analyzed using nonlinear regression on the model by Orskov and MacDonald (1979): Gas = b (1 - e^{-ct}).

III – Results and discussion

The pH of the rumen before the morning meal distribution was statistically comparable (p> 0.05) for diets CC, TC and BC (6.67±0.34; 6.60±0.27 and 6.71±0.27, respectively) and significantly lower ($p<0.05$) for the SC system (6.28 ± 0.22). This result is similar to those of Rouissi (1994) and Hammami *et al*. (2009) and below the range of pH in the rumen of sheep receiving hay alone (Giger *et al*. 1988). Two hours postprandial, pH decreases for the four diets, but the decrease is larger for BC and TC (0.44 and 0.49 points respectively), while in the other two concentrates this decrease is minimal (0.19 to 0.1 for CC and SC). After 5 hours the pH continues to decrease: 6.22±0.42; 5.97±0.22; 6.06±0.29 and 6.01±0.12, respectively for concentrates CC, SC, BC and TC. Statistical analysis reveals that there is no difference between the pH of the different diets ($p>0.05$). At the end of the day, the pH increased significantly ($p<0.05$), being more stable in buffered diets TC and BC thanin CC and SC.

Volatile fatty acids are the end products of rumen digestion of carbohydrate foods that include various compounds which are derived from either plant cell walls such as cellulose, hemicelluloses and pectin, or the cell contents, such as the starch and soluble sugars (Jarrige *et al*,. 1995; Sauvant, 1997), their concentration depends on the amount of energy provided by the food and the quality of starch and its speed of degradation (Sauvant *et al*., 1994; Cuvelier *et al.*, 2005).

The study of the effect of the nature of the energy source at the complementation showed that the concentration of total VFA in the rumen just before the distribution of the morning meal is lower compared to other periods of control during the day with a minimum value observed for the concentrate SC ($p<0.05$). This can be explained by the absorption of VFA across the rumen wall on one side and use the bacteria to produce their own proteins. Two hours after the distribution of the morning meal, the concentration increases with an intense speed ($p<0.05$) for diets TC and BC (86.5±1.76 and 85.45±0.69 mmol/l respectively) compared to diets CC and SC. This result is consistent with that of Chikagwa-Malunga *et al.* (2009). This trend can be explained by the rapid rumen degradability of the starch to contained in the seeds of barley and triticale.

After five hours of the morning meal, the concentration of VFA from the schemes CC and SC reached the peak (89.03±0.82 and 87.28±1.05 mmol/l respectively), this would be attributed to degradation of starch grains of white maize and sorghum. This corroborates the results of Russell and Gahr (2000), no statistical difference between the means of four concentrates ($p>0.05$). It is also noted that the high concentration of VFA for concentrate TC is correlated with the low gas production especially at the beginning of incubation. At the end of the day, the VFA concentration is stabilized ($p>0.05$) for the different regimes, this decrease in concentration can be explained by the rate of absorption and activity of micro organisms in the rumen (Rouissi, 1994) (Table 1).

The proportion of acetic acid changes similarly for concentrated feeds TC and BC, the minimum value being observed after two hours of the distribution (65.4 and 66.06% respectively). Then, it increases after 5 hours and is stabilized at the end of the day with no statistical difference between the regimes ($p>0.05$). This trend is similar to that demonstrated by Chikagwa-Malunga *et al.* (2009) and can be explained by the orientation of the fermentation of starch grains of barley and triticale with a strong and rapid degradation thereby reducing the synthesis of acetate and promoting that of propionate, which increases after the circulation of morning meal and the maximum value is displayed after two hours ($p>0.05$) (17.08 and 16.83% respectively for TC and BC) (Jouany *et al.,* 1995) and partly explains what is reported by Giger *et al*. (1988) who observed that the concentration of acetate and propionate in the rumen are reversed during the day. For diets of slowly degradable starch resources minimum value is reached after 5 hours (65.63 and 65.58%), while propionate is maximum at this time. Comparing regimes, the proportion of acetate is stable at the beginning and the end of the day ($p>0.05$), and this is mainly due to the rate of absorption through the rumen wall and use by bacteria in the presence of ammonia nitrogen for the synthesis of their protein, whereas it is statistically higher ($p<0.05$) for CC and SC, 2 hours post prandial. The concentration of butyric acid in the rumen operates in the same direction as that of acetate; the proportion is 11 to 13%

during the day regardless the diet ($p>0.05$). This is consistent with those of Rouissi (1994) shows lower values than those of Jouany *et al.* (1995), especially when the diet was based on beet.

Table 1. Effect of the nature of energy sources on the ruminal pH and Total VFA (mmol/l)

	Hours after the morning feeding			
	0	**2**	**5**	**8**
pH				
CC	$6.67^{a} \pm 0.34$	$648^{a} \pm 0.38$	$6.22^{a} \pm 0.42$	$6.25^{b} \pm 0.34$
SC	$6.28^{b} \pm 0.22$	$6.18^{b} \pm 0.13$	$5.97^{a} \pm 0.22$	$5.99^{b} \pm 0.31$
TC	$6.60^{a} \pm 0.27$	$6.16^{b} \pm 0.21$	$6.06^{a} \pm 0.29$	$6.40^{a} \pm 0.35$
BC	$6.71^{a} \pm 0.27$	$6.16^{b} \pm 0.12$	$6.01^{a} \pm 0.12$	$6.34^{a} \pm 0.24$
SME	0.084	0.069	0.083	0.091
Total VFA (mmol/l)				
CC	$76.85^{a} \pm 1.1$	$81.4^{b} \pm 1.46$	$89.03^{a} \pm 0.82$	$86.3^{a} \pm 0.83$
SC	$70.33^{b} \pm 1.58$	$78.36^{b} \pm 1.3$	$87.28^{a} \pm 1.05$	$83.9^{a} \pm 1.22$
TC	$75.45^{a} \pm 0.59$	$86.5^{a} \pm 1.76.$	$88.55^{a} \pm 07$	$83.3^{a} \pm 1.24$
BC	$74.68^{a} \pm 1.49$	$85.45^{a} \pm 0.69$	$87.58^{a} \pm 0.74$	$84.66^{a} \pm 1.03$
SME	1.96	2.74	1.09	1.87

a, b and c: Means with different superscripts within a row differ significantly ($p<0.05$).

The total volume of gas after 36 hours incubation was statistically different ($p<0.05$) between diets. The concentrate (BC) displays the highest value (87.00±17.29 ml), which is similar to the results of Selmi *et al.* (2009). This could be explained by the rich grain of barley and faba bean starch, rapidly degradable in the rumen, thereby fostering an environment rich in VFA and NH3-N used by bacteria and protozoa to their development and proliferation (Michalet-Doreau and Sauvant, 1989). The lowest volume of gas is observed in the concentrate (TC) (56.58±13.06 ml). The proportion of methane (CH4) produced for the four concentrates is in the range of 25 to 35% from the total gas as shown in Table 2. CH4 production in the rumen is significant difference ($p<0.05$) with the concentrate, which is similar to the work of Sauvant (2000). The potential gas production represented in the model Orskov and Macdonald (1979) by the constant "b" is higher ($p<0.05$) for the regime CC (58.7) while the BC diet displays lowest value (34.5).

Table 2. Gas volume and methane (ml) in the rumen

	Type of Concentrate				SME
	CC	**SC**	**TC**	**BC**	
Gas_{24} (ml)	66.41 ± 11.53^{a}	64.33 ± 16.37^{a}	44.33 ± 12.83^{b}	70.91 ± 14.79^{a}	2.78
Total gas (ml)	77.66 ± 11.65^{a}	78.41 ± 16.61^{a}	56.58 ± 13.06^{b}	87.00 ± 17.29^{a}	1.07
CH_4 (ml)	22.08 ± 4.18^{ab}	21.16 ± 3.21^{ab}	19.75 ± 3.88^{b}	24.91 ± 5.69^{a}	1.25
b	58.7^{a}	50.3^{ab}	48.1^{b}	34.5^{c}	0.84
c	0.001^{a}	0.002^{a}	0.002^{a}	0.003^{a}	0.03

Gas24: gas to 24 h of incubation; CH4: methane; b: potential gas production, c: velocity of gas production. a, b and c: Means with different superscripts within a row differ significantly ($p<0.05$).

IV – Conclusions

Following this experiment, it appears that the effect of the incorporation of local raw materials instead of imported raw materials in the formulation of feed concentrate feed can maintain or improve some parameters of rumen and *in situ* digestibility of the basic ration. Indeed, the rumen pH varies intensely with concentrates based on cereals as their starches are rapidly degradable. This trend explains well the general shape of the concentration of ammonia nitrogen during the day. Gas production is remarkable for the concentrates containing barley compared with the other schemes so that the production of methane may represent a loss of energy up to 10% of the digestible energy of the ration.

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