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The efficiency of nitrogen utilization of growing lambs fed maize gluten meal as the protein supplement

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SUMMARY - Three pelleted diets were formulated with a variable quantity of maize meal and maize gluten meal (diet MG0: 69% and 0%; diet MG9: 60% and 9%; diet MG18: 51% and 18%, respectively). Each diet was offered to a group of 12 Bergamasca lambs, half males and half females (25 kg initial live weight, LW) at a daily rate of 100 g/kg $LW^{0.75}$. The ME content of the diets was derived from measured faecal and urinary losses and estimated methane losses; the PDI content was derived from the *in situ* rumen degradability measured on the male lambs by mobile bags recovered at slaughter. Half of the animals were slaughtered at 45 kg LW and the others at 60 kg and their body composition was determined. The initial body fat and protein content was estimated from a control group of comparable 25 kg LW lambs. The inclusion of MG in the diet progressively reduced the ME content (from 11.4 to 10.8 MJ/kg DM) and the effective degradability of the N (from 0.41 to 0.33), but increased the proportion of feed protein absorbed in the intestine. The increase of the MG level determined higher growth rates and a reduction in the fat/N*6.25 ratio of the empty-body gain. The PDI efficiency for N*6.25 body retention diminished from 0.41 in the MG0 diet to 0.22 in the MG18 diet. For each g/MJ ME of incremental PDI due to the substitution of maize by MG, the N*6.25 deposition increased by a value between 0.105 and 0.004 g, according to the stage of physiological maturity of the lambs.

Key words: Nitrogen utilization, maize gluten meal, growing lambs.

RESUME *- "Efficacité de l'utilisation de l'azote par des agneaux en croissance recevant de la farine de gluten de maïs comme supplément protéique". Trois régimes de granulés ont été formulés ayant une quantité variable de farine de maïs et de farine de gluten de maïs (régime MG0 : 69% et 0% ; régime MG9 : 60% et 9% ; régime MG18 : 51% et 18%, respectivement). Chaque régime a été offert à un groupe de 12 agneaux de race Bergamasca, pour moitié mâles et pour moitié femelles (25 kg de poids vif initial, PV) selon un taux journalier de 100 g/kg $PV^{0,75}$. La teneur en énergie métabolisable des régimes a été calculée à partir des pertes dans les faeces et l'urine mesurées et des pertes en méthane estimées ; la teneur en PDI a été calculée à partir de la dégradabilité* in situ *dans le rumen mesurée sur les agneaux mâles par des sachets mobiles récupérés à l'abattage. La moitié des animaux ont été abattus à 45 kg de poids vif et les autres à 60 kg et leur composition corporelle a été déterminée. Le gras corporel initial ainsi que la teneur en protéine ont été estimés sur un groupe témoin d'agneaux comparables de 25 kg de poids vif. L'inclusion de gluten de maïs dans le régime a réduit progressivement la teneur en énergie métabolisable (de 11,4 à 10,8 MJ/kg MS) et la dégradabilité effective de l'azote (de 0,41 à 0,33), mais a augmenté la proportion de protéine alimentaire absorbée dans l'intestin. L'augmentation du niveau de gluten de maïs a déterminé des taux de croissance plus élevés et une réduction du ratio de gras/N*6,25 du gain corporel à vide. L'efficacité des PDI pour la rétention corporelle N*6,25 a diminué de 0,41 dans le régime MG0 à 0,22 dans le régime MG18. Pour chaque g/MJ EM de PDI supplémentaire dû à la substitution du maïs par le gluten de maïs, le dépôt N*6,25 a augmenté d'une valeur allant de 0,105 à 0,004 g, selon le stade de maturité physiologique des agneaux.*

Mots-clés : *Utilisation de l'azote, farine de gluten de maïs, agneaux en croissance.*

Introduction

Maize gluten meal (MG) is a by-product of the maize wet-milling industry which remains after the extraction of germ and starch in the manufacture of starch and syrup. Starting from 100 kg of maize grain (dry matter, DM, basis), 5.3 kg of gluten are eventually separated by centrifugation from the water slurry of starch (Ensminger *et al.*, 1990). The by-product, sold in a dry form as MG, contains over 60% crude protein (616 to 729 g/kg DM) together with small quantities of starch (81 to 245 g/kg

DM) and fibre (12 to 246 g NDF/kg DM; MAFF, 1992) and is used in animal nutrition as a protein supplement for feed compounding.

The present study was performed to provide information about the efficiency of utilization of the MG-N by growing sheep.

Materials and methods

Three pelleted diets were formulated with a fixed quantity of lucerne meal (12.5%), barley straw (13.5%), $CaCO_3$ (1.0%), NaCl (0.5%), lignosulphonate (1.0%), molasses plus protein hydrolysed (2.0%) a vitamin-trace element supplement (0.5%) and a variable quantity of maize meal and maize gluten meal (diet MG0: 69% and 0%; diet MG9: 60% and 9%; diet MG18: 51% and 18% of maize and MG, respectively). Each diet was offered to a group of 12 heavy Bergamasca lambs (25 kg initial live weight, LW), with 6 males and 6 females housed in individual pens, at a daily rate of 100 g/kg $LW^{0.75}$. The quantity of food supplied was corrected after weighing the animals every 7-10 days. Feed refusals were collected daily and weighed.

The metabolizable energy (ME) content of the diets was derived from measured faecal and urinary losses (Urine energy [kJ/g]= 0.113 + 0.498 N [%]) and estimated methane losses (Methane energy [%GE]= 1.30 + 0.112 dEm + L (2.37-0.05 dEm), where L = level of feeding as a multiple of MJ of digestible energy for maintenance and dEm = energy digestibility at maintenance = (dE + 0.107(L-1)) / (1 + 0.113(L-1)) with dE = measured energy digestibility at the L) (Blaxter *et al.*, 1969) during a 7 days total faecal and urine collection period.

At the end of this period the N degradability of the diets was measured by incubating 0.88 ± 0.02 g milled feed held in small nylon (pore size 40 µm) bags having a useful area for fermentation of 54 cm^2 (sides 4.5 x 6.0 cm, sample to surface area ratio 16.2 mg/cm^2). Duplicate bags were introduced into the rumen orally, using a drenching gun, at 48, 24, 15, 6 and 2 hours before slaughter, for the male lambs only. The bags were recovered immediately after slaughter by opening the rumen and emptying its contents. This operation was preceded by soaking another 2 bags for a few seconds in the rumen contents so as to obtain a control (time 0) for the degradability kinetic. The rumen N degradability kinetic was estimated for each animal using the one component exponential model proposed by Ørskov and McDonald (1979). The N effective degradability (Dg) was calculated at an outflow rate (r) predicted from L (AFRC, 1993): $r = -0.024 + 0.179 (1 - e^{(-0.278 L)})$.

Half of the animals, chosen at random from each diet and sex, were slaughtered at 45 kg LW and the others at 60 kg. The initial energy, fat and protein content of the body of the lambs was estimated from a control group of 25 kg LW comparable lambs. The final energy, fat and protein content of the test lambs was determined directly by chemical analyses.

Statistical analysis was performed with a factorial model having 2 factors: diet and lamb group (males slaughtered at 45 kg LW, M45, or 60 kg, M60, and females slaughtered at 45 kg, F45, or 60 kg, F60).

The incremental efficiencies of MG-N for N retention were calculated from the within-lamb group regression coefficients (b_i) of the retained N*6.25 (y_{ij}) on the protein intake (x_{ij}) data (both expressed in g/MJ ME), using the following model of analysis of covariance: $y_{ij} = \mu + \alpha_i + b_i x_{ij} + \varepsilon_{ij}$.

Results and discussion

The partial replacement of maize with MG led to an increase in the GE and N content of the diet (Table 1). Increasing the proportion of MG led to a reduction in the ME concentration of the diets, due to the N urinary losses which increased dramatically from diet MG0 to diet MG18.

The average effective N Dg of MG0 diet was similar to that reported by AFRC (1993) for ground maize at a rumen outflow rate of 0.06 h^{-1} (0.42). The inclusion of the by-product reduced the N Dg of the diets, confirming the low rumen degradability of the MG-N (at a rumen outflow rate of 0.05 h^{-1}: 0.30 to 0.45; MAFF, 1992).

The N Dg values were utilized to calculate the protein fractions of duodenal digesta from the equations predicting the protein value of feeds in the PDI system (Vérité and Peyraud, 1988). All the diets had a high content of rumen escape N and allowed a low synthesis of microbial protein, constrained by the N availability in the rumen. Thus the greatest fraction of the total digestible true protein available to the lamb for metabolism after absorption in the lower intestine (PDI) was of feed origin (PDIA).

Table 1. Composition and feeding value of the diets

		Diet			s.e.
		MG0	MG9	MG18	
Chemical composition					
Gross Energy	MJ/kg DM	18.0	18.2	18.5	
N*6.25	g/kg DM	102	151	203	
Energy digestibility		0.717	0.703	0.701	0.0222
Urinary N*6.25	g/kg DM	20^{c}	58^{b}	102^{a}	8.4
N*6.25 degradability		0.413	0.372	0.325	0.0868
Feeding value:					
ME	MJ/kg DM	11.4^{a}	11.0^{b}	10.8^{b}	0.38
PDIA	g/kg DM	58^{c}	92^{b}	134^{a}	14.2
PDIME	g/kg DM	56^{a}	51^{b}	46^{c}	2.5
PDIMN	g/kg DM	21	26	29	9.4
PDI/ME	g/MJ	6.9	10.7	15.1	

a,b,c: P≤0.05

The mean daily DM intake of the 3 diets was similar (Table 2). The DM intake of M45, F45 and M60 groups was slightly higher than the expected value of fine diets having a metabolizability similar to the experimental diets (82-85 g/kg $LW^{0.75}$; AFRC, 1993), while that of F60 group was lower (74 g/kg $LW^{0.75}$), due to a consistent reduction of intake during the final stage of growth. The daily ME and the PDI intakes for the three diets and the four lamb groups were dependent on the ME and PDI contents of the diets.

Table 2. Daily feed intake

		Diet			Lamb group				s.e.
		MG0	MG9	MG18	M45	F45	M60	F60	
DM	g/kg $LW^{0.75}$	83	82	84	87^{a}	87^{a}	85^{a}	74^{b}	3.1
ME	MJ/day	14.7^{a}	13.9^{b}	14.0^{b}	13.7^{b}	13.7^{b}	15.7^{a}	13.8^{b}	0.46
PDI	g/day	101^{c}	149^{b}	211^{a}	148^{b}	147^{b}	171^{a}	149^{b}	5.3

a,b,c,d: P≤0.05

The empty-body gains (EBG, Table 3), particularly those of MG18 and M60 groups, were good compared with AFRC (1993) standards for a dietary ME concentration of 11.7 MJ/kg DM.

The increase of MG level did not modify the N*6.25 content of the EBG, but reduced its fat: N*6.25 ratio. The F60 group, slaughtered at the latest stage of physiological maturity, grew at the slowest rate and had the least protein and the highest fat content in EBG.

Table 3. Empty body gain (EBG) and its composition

		Diet			Lamb group				s.e.
		MG0	MG9	MG18	M45	F45	M60	F60	
EBG	g/day	239^{b}	242^{b}	260^{a}	264^{a}	235^{b}	282^{a}	207^{c}	17.2
N*6.25	g/kg EBG	174	179	179	185^{a}	184^{a}	176^{ab}	165^{b}	9.2
Fat/N*6.25		2.02^{a}	2.01^{a}	1.74^{b}	1.67^{b}	1.86^{b}	1.69^{b}	2.49^{a}	0.22

a,b,c: P≤0.05

The proportion of MG in the diet positively influenced the daily N*6.25 retention (Table 4), particularly when was scaled to ME intake.

In contrast, the increase in the level of MG led to a progressive reduction of the N*6.25 retention per unit of PDI intake. The PDI efficiency was 0.41 for diet MG0, a quite high value considering the low content of lysine and methionine of maize, and the high proportion of rumen escape protein of the diet. It is likely that under these conditions a considerable proportion of the absorbed AA-N not utilized for protein synthesis could have been recycled to the rumen through the saliva or passage through the rumen wall, thus increasing rumen bacterial synthesis and the efficiency of utilization of the absorbed N.

Table 4. Body retention of N*6.25

	Diet			Lamb group				s.e.
	MG0	MG9	MG18	M45	F45	M60	F60	
g/day	42^{b}	44^{ab}	47^{a}	49^{a}	43^{b}	50^{a}	34^{c}	3.5
g/MJ ME	2.8^{c}	3.1^{b}	3.4^{a}	3.6^{a}	3.2^{b}	3.2^{b}	2.5^{c}	0.21
g/g PDI	0.41^{a}	0.29^{b}	0.22^{c}	0.35^{a}	0.31^{b}	0.31^{b}	0.25^{c}	0.02
As a function of PDI (g/MJ ME):								
intercept					2.405			0.138
slope				0.105^{a}	0.074^{b}	0.071^{b}	0.004^{c}	0.013

a,b,c: P≤0.05

The slope of the retained N*6.25 on the PDI intake, both expressed in g/MJ ME (Fig. 1), is representative of the net effect of an incremental unit of available PDI, due to the addition of the by-product in place of maize, on N utilization for protein growth. This incremental efficiency reflects both the increase supply of rumen escape MG-N and the decrease in the relative supply of bacterial N obtained in response to the substitution of maize with its by-product (Table 1).

The incremental efficiency of PDI for N*6.25 growth (Table 4) was low and lamb group dependent as was the total PDI efficiency. The result is likely to have been due to the stage of physiological maturity of the lambs: the M45 group showed the highest PDI efficiencies, followed by F45 and M60 groups which had the same value, and by F60 ewelambs. In effect, the adult weight of a Bergamasca sheep is about 110 kg for a ram and 80 kg for a ewe.

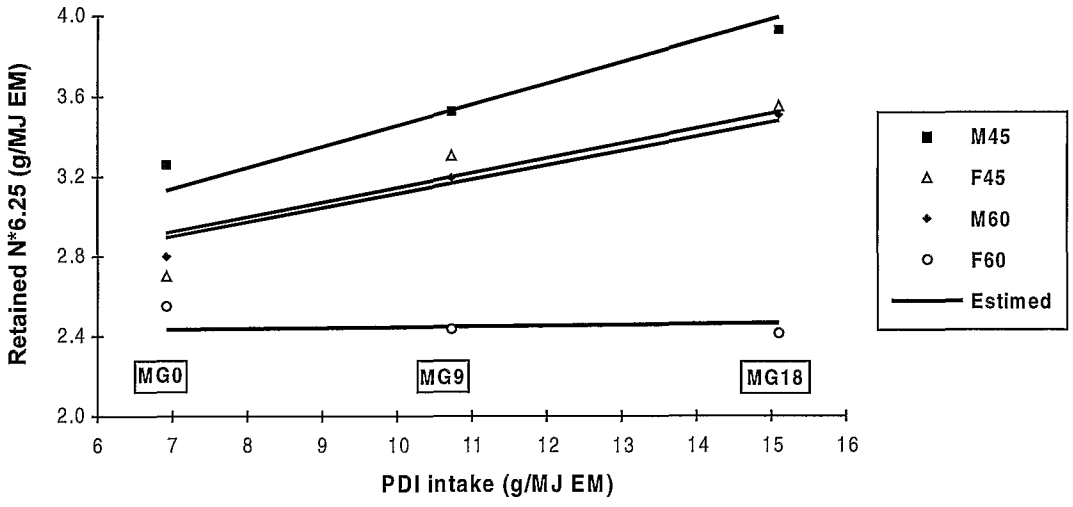

Fig. 1. Relationship between retained N*6.25 and PDI intake in different groups of lambs. The fitting model (r^2 = 0.88) is described in "Materials and methods" and its parameters are reported in Table 4.

Conclusions

The modest total PDI efficiency of the diets containing MG was due to the low retention of the incremental PDI unit supplied by the introduction to the diet of the by-product in substitution of the maize. This result confirms the low value of the MG protein for supplying limiting amino acids to the small intestine. However, it should also be considered that the animals were close to their potential maximum protein growth rate allowed by the adopted energy intake.

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