Nutritional and animal factors affecting nitrogen excretion in sheep and goats

Decandia M., Atzori A.S., Acciaro M., Cabiddu A., Giovanetti V., Molina Alcaide E., Carro M.D., Ranilla M.J., Molle G., Cannas A.

in

Ranilla M.J. (ed.), Carro M.D. (ed.), Ben Salem H. (ed.), Morand-Fehr P. (ed.).
Challenging strategies to promote the sheep and goat sector in the current global context

Zaragoza : CIHEAM / CSIC / Universidad de León / FAO
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 99

2011
pages 201-209

Nutritional and animal factors affecting nitrogen excretion in sheep and goats

M. Decandia*, A.S. Atzori**, M. Acciaro*, A. Cabiddu*, V. Giovanetti*, E. Molina-Alcaide**, M.D. Carro***, M.J. Ranilla***,G. Molle* and A. Cannas****

*Dipartimento per la Ricerca delle Produzioni Animali. AGRIS-Sardegna, 07040 Olmedo (Italy)
**Estación Experimental del Zaidín, CSIC, Profesor Albareda 1, 18008 Granada (Spain)
***Departamento de Producción Animal, Facultad de Veterinaria, Universidad de León, Campus de Vegazana s/n, 24071 León (Spain)
****Dipartimento di Scienze Zootecniche, Università degli Studi di Sassari, Via De Nicola 2, 07100 Sassari (Italy)

Abstract. The relationships between N excretion and diet in sheep and goats are reviewed. A database of 154 mean values concerning diet composition, nutrient intake and digestibility, faecal (FNE) and urinary (UNE) N excretion in sheep and goats at different physiological stages was developed. For each animal species and physiological stage, average and range values of live weight, fat-corrected milk, nutrient intakes, chemical composition of diets, crude protein (CP) apparent digestibility, FNE and UNE were calculated. Total N excretion (TNE) was calculated as the sum of FNE and UNE. Additionally a similar database for goats fed diets containing condensed tannins (CT) was developed and analysed. Values for UNE were higher ($P<0.05$) than those for FNE in each physiological stage examined both in sheep and goats. Lactating sheep showed higher ($P<0.001$) FNE (g/d per head) than lactating goats. Positive relationships were found between TNE, UNE (expressed as g/kg of dry matter (DM) intake) and dietary CP (% DM) in sheep and goats for each physiological stage. Dry goats fed diets with low CP (mean±S.E.: 10.8±1.7% DM) and high condensed tannin levels (8.1±1.9 % DM) showed higher ($P<0.05$) FNE than UNE (mean±S.E.: 8.0±1.4 and 4.3±1.4 g/d per head), in contrast with what usually found in animals fed free-tannin diets.

Keywords. Sheep – Oats – N excretion – Condensed tannins.

Les facteurs nutritionnels et animales affectant l'excrétion d'azote chez les ovins et les caprins

Résumé. *On a étudiée les relations entre l'excrétion azotée et les composants du régime alimentaire chez les ovins et les caprins. On a créé une base de données à partir de 154 moyennes concernant la composition alimentaire, l'ingestion et la digestibilité des nutriments, ainsi que l'excrétion azotée fécale (FNE) et urinaire (UNE) dans les ovins et les caprins à différents stades physiologiques. Pour chaque espèce animale et stade physiologique les valeurs moyennes et la gamme de variations de poids vif, lait normalisé, ingestion des nutriments, composition chimique de la diète, digestibilité de la matière azotée (CP), FNE et UNE ont été calculés. L'excrétion totale d'azote (TNE) a été également calculée comme la somme de FNE et UNE. En outre, une base de données similaire a été mis en place et analysée pour des caprins nourris avec des aliments contenant des tanins condensés (CT). En général les valeurs pour UNE ont été plus élevés (P<0,005) que celles pour FNE dans les deux espèces et tous les stades physiologiques examinés. Les brebis en lactation ont montré un plus haut (P<0,001) niveaux de FNE que les chèvres en lactation. Une relation positive a été trouvée entre TNE, UNE (exprimée en g/kg de matière sèche (DM) ingérée) et le contenu des matières azotées du régime alimentaire (CP, % DM) chez les ovins et les caprins, à tous les stades physiologiques. Les résultats des données concernant les chèvres nourries avec des aliments à faible CP (moyenne±SE: 10,8±1,7% de MS) et haut niveaux de tanins condensés (8,1±1,9% de MS) ont montré une plus grande (P<0,05) FNE que UNE (moyenne±SE: 8,0±1,4 and 4,3±1,4 g/animal/jour) contrairement à ce que l'on retrouve habituellement chez les animaux nourris avec des régimes sans tanins.*

Mots-clés. *Brebis – Chèvres – Excrétion azotée – Tanins condensées.*

I – Introduction

Livestock farming is considered as one of the main sources of N release to the environment, mostly as NH_3 but also as nitrate leached through soil to water tables and water catchments. The N is excreted by livestock both as organic and inorganic compounds. Most research on N excretion has been focussed on intensive livestock farming systems, based on dairy and beef cattle, whereas sheep and goats have received little attention, despite they make around 52% of the world population of domesticated ruminants (FAO-STAT, 2008). In sheep and goats the individual excretion of N is obviously lower than in cattle due to their smaller size and lower intake. In addition, small ruminant farming systems are more often based on low stocking rates and densities than cattle production systems. However, small ruminants often have higher intake per kg of body weight than large ruminants (Cannas, 2004), leading to a potential higher impact in terms of N excretion. It is also noteworthy that retention of N into animal products (milk, meat and wool) is generally low in small ruminants, ranging between 5% and 20 % (Allard *et al*., 2003). Thus, sheep and goats can have a relevant environmental impact that needs to be quantified and predicted. Therefore, the objective of this paper was to study N excretion and its partitioning into faeces and urine in small ruminants and to study its association to the most relevant nutritional variables.

II – Materials and methods

A database was created from available literature on sheep and goat nutrition reporting data on N balance experiments. Table 1 shows a list of references used for each species and breed. Overall 154 observations from 49 papers representing sheep and goats of different breeds at various physiological stages and under different feeding management were obtained. For each species and physiological stage, means, standard error (SE) and range of live weight (LW), fat-corrected milk (FCM), nutrients intake, chemical composition of diets, crude protein (CP) apparent digestibility, faecal (FNE) and urinary (UNE) N excretions were calculated. Total N excretion (TNE) was also calculated as the sum of FNE and UNE. A similar data base only for dry goats fed diets containing condensed tannins (CT) was developed by using 11 observations reported in 7 papers.

Mean values for the differences between FNE and UNE (g/day) were tested within species and physiological stage using PROC GLM statement (SAS, 2001). Treatment means were separated using t-test at $P<0.05$ threshold. The CP and N fractions contents, when available, were regressed against FNE, UNE and TNE, expressed as g per kg dry matter (DM) intake (DMI), testing the linear and non linear effects of each independent variable. Treatment means were used as input variables in the models, without including the effect of the study or weighting for numbers of individual observations behind each mean. A stepwise regression procedure was then adopted in order to find the multiple regression models for FNE/DMI, UNE/DMI and TNE/DMI prediction, with the best goodness of fit evaluated on the basis of both the determination coefficient and the root mean square error (RMSE). Variables used in the stepwise procedure were dietary CP level (CP, % DM), dietary NDF level (NDF, % DM), apparent CP digestibility (CPD, %) and only for "tannin subset" dietary CT level (CT, % DM). Variance inflation factor (VIF) was calculated for each variable entered and kept in stepwise regressions in order to assess multicollinearity, using as a threshold VIF ≤ 10.

Table 1. References used for sheep and goats database

Sheep breed	Source
Barbados Blackbelly	Wildeus *et al*., 2007.
Cheviot	Santoso *et al*., 2004.
Créole	Sanginés *et al*., 2007.
Dorset-Finn	Marini *et al*., 2004.
Katahdin	Wildeus *et al*., 2007.
Merino	Carro *et al*., 2000, 2006; Ngwa *et al*., 2002; Jetana *et al*., 2000; Ramos *et al*., 2009.
Queue Fine de l'Ouest	Ben Salem *et al*., 1999.
Sarda	Cannas *et al*., 2003; Giovanetti, 2006; Molle *et al*., 2009a, 2009b, 2009c; Porcu, 2003; Serra, 1998.
Segureña	Molina *et al*. 1983, 2000; Yáñez-Ruiz, 2003; Yáñez-Ruiz *et al*., 2004a, 2004b.
St. Croix	Cole, 1999; Wildeus *et al*., 2007.
Short-Tail-Han	Liu *et al* 1995, 2005.
Suffolk	Atkinson *et al*., 2007; Kiran & Mutsvangwa, 2007.
Timahdit	Narjisse *et al*., 1995.
Western White-Face	Ludden *et al*., 2002.
Crossbred	Abazinge *et al*., 1994; Berger *et al*., 1981; Puga *et al*., 2001; Ko *et al*., 2006; Swanson *et al*., 2000.
Goat breed	**Source**
Alpine-Saanen	Brun-Bellut, 1996; Ranilla *et al*., 2005.
Mamber	Perevolotsky *et al*., 1993; Silanikove *et al*., 1996, 1997.
Granadina	Cantalapiedra *et al*., 2009; Fernández *et al*., 2003; Molina-Alcaide *et al*., 2000; Sanz Sampelayo *et al*., 1998, 2002a, 2002b; Yáñez-Ruiz, 2003; Yáñez-Ruiz *et al*., 2004a, 2004b; Yáñez-Ruiz and Molina-Alcaide, 2007, 2008.
Sarda	Decandia *et al*., 1999, 2000a, 2000b.
Crossbred	Narjisse *et al*., 1995.

III – Results and discussion

Means, SE and range of DMI, LW, FCM, dietary CP content, CPD, FNE, UNE and TNE are shown in Table 2. Overall, UNE was more variable, as already reported by Bussinink and Oenema (1998), and higher ($P<0.05$) than FNE in both animal species and for all the physiological states examined. Lactating sheep had higher ($P<0.001$) FNE excretion than goats (15.9±0.9 *vs* 10.4±1.2), probably due to the higher DMI and dietary CP concentrations of the experiments used for the sheep database compared to the goat database (Table 2). A positive relationship was found between TNE/DMI, UNE/DMI and dietary CP in sheep and goats at all physiological states (Fig. 1a-f). On the contrary FNE/DMI seemed not to be affected by the dietary CP level. The model that best described the effect of dietary CP on N excretion was linear, with the only exception of dry sheep that showed an exponential increment of TNE/DMI and UNE/DMI as the CP percentage in the diet increased (Fig. 1c). This probably occurred because dry animals can only eliminate the excess of CP digested through the urine. In growing sheep, all belonging to meat and wool breeds, the relationships between TNE/DMI or UNE/DMI and CP were characterised by high determination coefficients (R^2=0.72 and 0.77, respectively, Fig. 1a). Similar results were observed in rams (Fig. 1b). The N excretion data for lactating ewes were from studies in which the dietary CP levels ranged from 15% to 26% (Figure 1d), with many experiments having dietary CP concentrations higher than those suggested by Cannas (2004) (from 15.5% to 18.5% of CP, DM basis) for ewes with the similar ranges of milk production. The highest values for TNE/DMI and UNE/DMI were

Table 2. Means, ± S.E., and range of the observations in the database on sheep and goats in different physiological states

	Growing Sheep				Rams			
	N	Mean ± S.E.	Min	Max	N	Mean ± S.E.	Min	Max
DM intake (g/day)	52	882±49	355	1600	20	1072±53	692	1511
LW (kg)	52	30.8±0.8	19.9	41.8	20	57.3±1.1	51.7	64.5
CP (% DM)	52	12.8±0.5	5.8	25.3	20	11.9±0.8	6.3	16.7
CP digestibility (%)	45	62.5±9.3	17.8	80.8	16	61.3±2.8	38.5	74.8
FNE (g/head/day)	52	5.8±0.7[a]	1.9	12.4	20	7.4±0.9[a]	3.8	10.6
UNE (g/head/day	52	8.1±0.7[b]	1.2	28.7	20	9.3±0.9[b]	2.7	18.2
TNE (g/head/day)	52	13.9±1.2	3.9	40.2	20	16.7±1.4	6.6	26.2
	Dry Sheep				Lactating Sheep			
	N	Mean ± S.E.	Min	Max	N	Mean ± S.E.	Min	Max
DM intake (g/day)	21	795±56	489	1185	26	1992±86	890	2758
LW (kg)	21	50.6±1.3	43.6	59.3	26	45.8±0.6	36.9	50.4
FCM[†] (kg)					26	1.207±0.1	0.474	1.829
CP (% DM)	21	16.3± 0.6	8.8	19.8	26	19.6±0.6	14.9	26.3
CP digestibility (%)	21	73.2±2.1	54.1	84.0	26	74.1±1.2	60.1	85.5
FNE (g/head/day)	21	4.9±1.0[a]	2.4	7.7	26	15.9±1.7[a]	6.1	26.7
UNE (g/head/day)	21	10.6±1.0[b]	2.7	22.2	26	24.4±1.7[b]	4.8	49.0
TNE (g/head/day)	21	15.5±1.5	6.6	27.5	26	40.4±2.7	24.0	68.0
	Dry Goats				Lactating Goats			
	N	Mean ± S.E.	Min	Max	N	Mean ± S.E.	Min	Max
DM intake (g/day)	21	968±326	387	1568	14	1512±84	1105	2374
LW (kg)	21	46.2±1.4	36.7	61.5	14	45.9±2.0	33.4	54.8
FCM[††] (kg)					10	1.715±0.1	0.943	2.037
CP (% DM)	21	14.9±0.7	10.0	19.7	14	16.0±0.9	9.5	20.8
CP digestibility (%)	21	74.8±1.2	63.4	82.1	14	71.3±2.4	53.0	81.2
FNE (g/head/day)	21	5.7±0.8[a]	2.0	14.0	14	10.4±1.5[a]	5.8	16.7
UNE (g/head/day)	21	11.7±0.8[b]	5.2	22.6	14	19.7±1.5[b]	8.2	30.3
TNE (g/head/day)	21	16.3±6.4	9.7	36.6	14	29.9±2.1	14.1	41.4

[†] Fat-corrected sheep milk (6.5% fat): Pulina *et al*. (1989).

[††] Fat-corrected goat milk (4% fat): Mavrogenis and Papachristoforou (1988).

[a, b] means of FNE and UNE with different superscript letters within species and physiological stage were significantly different (P<0.05).

found (data not reported) for lactating sheep fed only at pasture. In these conditions, as observed by Molle *et al*. (2008), forages can have very high levels of CP, often characterized, in early stages of growth, by a high proportion of non protein nitrogen (NPN; fraction A following Licitra *et al*., 1996) and soluble protein N (fraction B_1; Licitra *et al*., 1996). In fact, the relationship between TNE/DMI or UNE/DMI and dietary A+B_1 N fractions (% CP) in lactating sheep were similar (R^2=0.46, P<0.001 and R^2=0.44, P<0.001) to those obtained with dietary CP. The acid detergent insoluble N (ADIN, fraction C following Licitra *et al*., 1996) in lactating sheep was also positively related with TNE/DMI and UNE/DMI, with a moderate determination coefficient (R^2=0.26, P<0.05, and R^2=0.27, P<0.05, respectively). The stepwise procedure confirmed that in growing sheep the best explanatory variable for TNE/DMI is dietary CP content, whereas the strongest predictive equations for UNE/DMI and FNE/DMI were: UNE/DMI = –7.3±3.1 + 0.9±0.1 CP + 0.1±0.03 CPD – 0.04±0.02 NDF (R^2=0.85, P<0.001, RMSE=2.0, CV=19.7), and FNE/DMI = 11.4±0.9 –0.2±0.01 CPD + 0.6±0.05 CP (R^2=0.84, P<0.001, RMSE=1.1, CV=16.9). In rams the best equations found with stepwise procedure were: TNE/DMI = –1.4±4.9 + 2.1±0.3 CP – 0.2±0.1 CPD + 0.07±0.03 NDF (R^2=0.96, $P<0.001$, RMSE=1.2, CV=8.1), UNE/DMI = –13.0±3.8 + 1.5±0.1 CP – 0.07±0.04 NDF (R^2=0.93, $P<0.001$, RMSE=1.4, CV=15.7), and FNE/DMI = 8.2±1.0 + 0.4±0.1 CP – 0.09±0.03 CPD (R^2=0.57, $P<0.001$, RMSE=0.4, CV=6.8). In all these equations DMI, FNE, UNE, TNE are in units of g/d, CP and NDF as % of DM and CPD as % of CP.

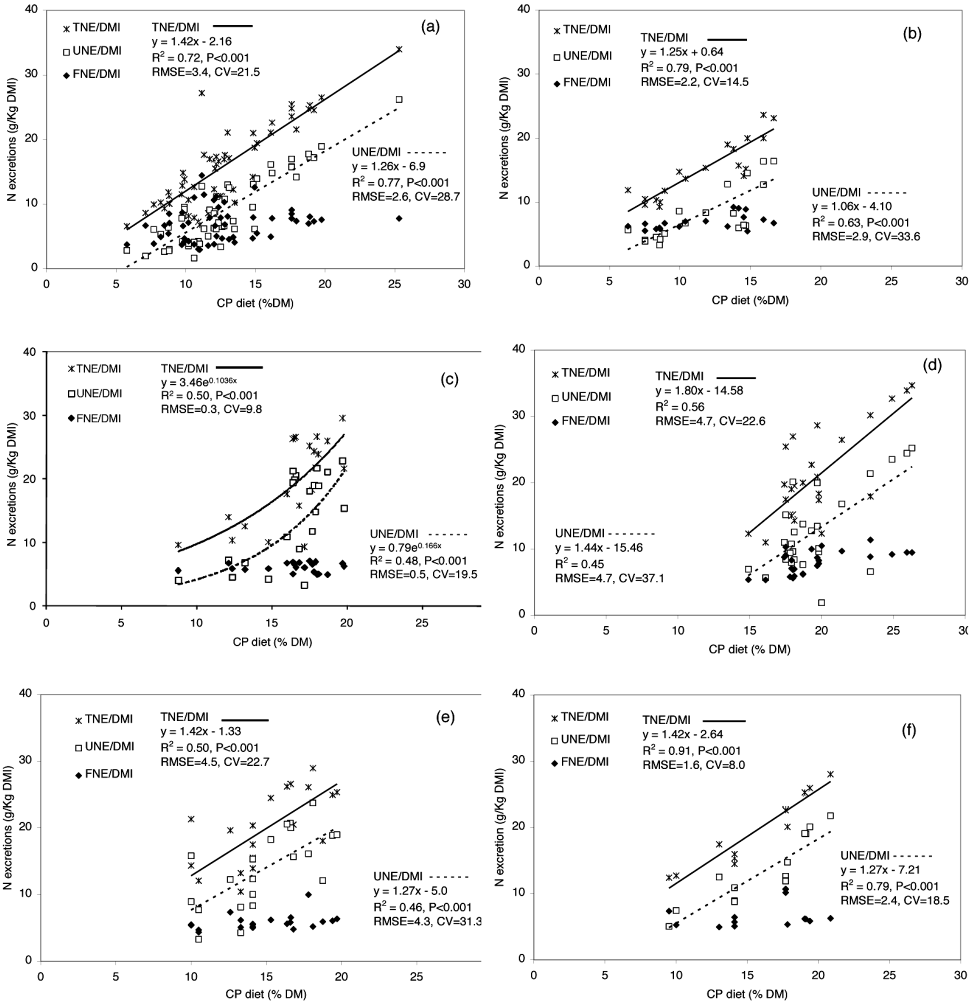

Fig. 1. Relationships between faecal (FNE), urinary (UNE), total (TNE) N excretion [g/kg dry matter intake (DMI)], and crude protein (CP, % DM) in the diet of growing sheep (a), rams (b), dry sheep (c), lactating sheep (d), dry goats (e) and lactating goats (f).

In dry sheep, the best explanatory variable, in a linear fixed effects regression model for TNE/DMI and UNE/DMI, was CPD: TNE/DMI = –24.6±6.1 + 0.6±0.08 CPD (R^2=0.74, $P<0.001$, RMSE=3.6, CV=17.8) and UNE/DMI = –31.6±6.0 +0.6±0.08 CPD (R^2=0.75, $P<0.001$, RMSE=3.5, CV=25.0); no relationship was detected for FNE/DMI. In lactating sheep CP in diet is confirmed as the best predictive variable for TNE/DMI and UNE/DMI. On the contrary, the best prediction of FNE/DMI in lactating sheep was obtained by the model FNE/DMI=18.5±1.7 + 0.24±0.03 CP –0.21±0.02 CPD + 0.02±0.01 NDF (R^2=0.94, P<0.001, RMSE=0.5, CV=5.6). In goats the level of CP in the diet was found to be strictly positively related to TNE/DMI and UNE/DMI, particularly in lactating goats (R^2=0.91, P<0.001 and R^2=0.79, P<0.001, respectively; Fig. 1f). The results of the stepwise procedure confirmed dietary CP as the best predictive dietary component in dry goats both for TNE/DMI and UNE/DMI, whereas for FNE/DMI the strongest relationships included also CPD (FNE/DMI=18.0±1.0 + 0.44±0.03 CP –0.25±0.02 CPD; R^2=0.93, P<0.001, RMSE=0.3, CV=5.4). In lactating goats the best predictive model found by the stepwise analysis for TNE/DMI included only CP; however, for UNE/DMI and FNE/DMI the model included also CPD: UNE/DMI = – 15.5±4.7 + 0.17±0.1 CPD + 1.0±0.2 CP (R^2=0.85 P<0.001, RMSE=2.1, CV=16.3) and FNE/DMI = 16.6±1.9 – 0.26±0.03 CPD + 0.53±0.08 CP (R^2=0.86 P<0.001, RMSE=0.8, CV=12.3), respectively. As expected and in contrast to what usually found in animals fed free-tannin diets, FNE was on average (mean±S.E. 8.0±1.4 g/d per head) higher (P<0.05) than UNE (4.3±1.4 g/d per head) in goats fed diets with low CP (mean±S.E. 10.8±1.7% of CP, DM basis) and high CT (8.1±1.9 % of CT, DM basis) concentrations. The stepwise procedure showed that the best explanatory variables for TNE/DMI in dry goats fed diets including CT were CP and CT dietary levels: TNE/DMI = –1.8±2.1 + 0.57±0.17 CT + 1.43±0.16 CP (R^2=0.94, P<0.001, RMSE=2.7, CV=14.6); for UNE/DMI the CP was the best explanatory variable: UNE/DMI = –3.5±2.5 + 0.93±0.20 CP (R^2=0.74, P<0.001, RMSE=3.3, CV=48.0) and for FNE/DMI it was CT (as % of DM), even if with a low determination coefficient: FNE/DMI = 8.0±2.2 + 0.48±0.26 CT (R^2=0.29, P<0.10, RMSE=4.1, CV=36.7). These results confirmed that dietary CT increase mainly FNE, as observed by Molle *et al*. (2009a) in dairy sheep grazing a mixture of ryegrass and sulla, probably as a consequence of CP digestibility reduction. However, moderate levels of CT can induce an overall reduction of N excretion, since they slow down protein degradability and allow higher microbial N utilization (Waghorn *et al*., 2002).

IV – Conclusion

Urinary N excretion expressed as g/kg of dry matter intake in sheep and goats was strongly related to dietary CP levels, while faecal N excretion was not associated to this variable. In both species as dietary CP concentration increased the increment of total N excretion was mostly in the form of urinary N. High levels of CT in goats diet increased mainly faecal N excretion, but it is difficult to generalize this conclusion because of the little consistency among studies regarding methods for tannins quantification.

References

Abazinge M.D., Fontenot J.P. and Allen V.G., 1994. Digestibility, nitrogen utilization, and voluntary intake of ensiled crab waste-wheat straw mixtures fed to sheep. In: *J. Anim. Sci.* 72, p. 565-571.

Allard V., Newton P.C.D., Lieffering M., Clark H., Matthew C., Soussana J.F. and Gray Y.S., 2003. Nitrogen cycling in grazed pastures at elevated CO_2: N returns by ruminants. In: *Global Change Biology*, 9, p. 1731-1742.

Atkinson R.L., Toone C.D., Robinson T.J., Harmon D.L. and Ludden P.A., 2007. Effects of supplemental ruminally degradable protein versus increasing amounts of supplemental ruminally undegradable protein on nitrogen retention, apparent digestibility, and nutrient flux across visceral tissues in lambs fed low-quality forage. In: *J. Anim. Sci.* 85, p. 3331-3339.

Ben Salem H., Nefzaoui A., Ben Salem Lamia and Tisserand J.L., 1999. Intake, digestibility, urinary excretion of purine derivatives and growth by sheep given fresh, air-dried or polyethylene glycol-treated foliage of *Acacia cyanophylla* Lindl. In: *Anim. Feed Sci. Technol.,* 78, p. 297-311.

Berger J.C.A., Fontenot J.P., Kornegay E.T. and Webb K.E., 1981. Feeding swine waste. II. Nitrogen utilization, digestibility and palatability of ensiled swine waste and orchardgrass hay or corn grain fed to sheep. In: *J. Anim. Sci.* 52, p. 1404-1420.

Brun-Bellut J., 1996. Urea recycling in the rumen of dairy goats: effects of physiological stage and composition of intake. In: *Small Rumin*. *Res*. 23, p. 83-90.

Bussinink D.W. and Oenema O., 1998. Ammonia volatilisation from dairy farming systems in temperate areas. In: *Nutr. Cycling Agroecosyst*. 51, p. 19-33.

Cannas A., Cabiddu A., Bomboi G., Ligios S. and Molle G., 2003. Effects of dietary non-fiber carbohydrates concentration on intake, in vivo digestibility and milk yield in Sarda ewes. In: 54th Annual Meeting of the EAAP, Rome, Italy, August 28-30, 2003.

Cannas A., 2004. Feeding of lactating ewes. In: Pulina G. (Ed.), *Dairy sheep nutrition*. CAB International, Wallingford, Oxon, UK, p. 79-108.

Cantalapiedra-Híjar G., Yáñez-Ruiz D.R., Martín-García A.I. and Molina-Alcaide E., 2009. Effects of forage:concentrate ratio and forage type on apparent digestibility, ruminal fermentation, and microbial growth in goats. In: *J. Anim. Sci*. 87, p. 622-631.

Carro M.D., Valdés C., Ranilla M.J. and González J.S., 2000. Effect of forage to concentrate ratio in the diet on ruminal fermentation and digesta flow kinetics in sheep. In: *Anim. Sci*. 70, p. 127-134.

Carro M.D., Ranilla M.J., Giráldez F.J. and Mantecón, A.R., 2006. Effects of malate on diet digestibility, microbial protein synthesis, plasma metabolites, and performance of growing lambs fed a high-concentrate diet. In: *J. Anim. Sci*. 84, p. 405-410.

Cole N.A., 1999. Nitrogen retention by lambs fed oscillating dietary protein concentrations. In: *J. Anim. Sci.* 77, p. 215-222.

Decandia M., Molle G., Ligios S. and Scanu G., 1999. Effect of different levels of polyethylene glycol and concentrate on the nutritional value of *Pistacia Lentiscus* L. fed to goats. In: *Atti XIII° Congresso ASPA*, Piacenza, Italy, 21-24 June, 1999, p. 384-386.

Decandia M., Sitzia M., Cabiddu A., Kababya D. and Molle G., 2000a. The use of polyethylene glycol to reduce the anti-nutritional effects of tannins in goats fed woody species. In: *Small Rumin. Res*. 38, p. 157-164.

Decandia M., Molle G., Sitzia M., Cabiddu A., Ruiu P.A., Pampiro F. and Pintus A., 2000b. Responses to an antitannic supplementation by browsing goats. In: *Proc. of VII° International Conference on Goats*, Tours France, 15-18 Mai, 2000, p. 71-73.

Fernández C., Sánchez-Seiquer P. and Sánchez A., 2003. Use of a Total Mixed Ration with Three Sources as an Alternative Feeding for Dairy Goats on Southeast of Spain. In: *Pak. J. Nutr*. 2, (1), p. 8-24.

FAO-STAT, 2008. Food and Agriculture Organization of the United Nations. Available: *http://faostat.fao.org/site/573/default.aspx*. Accessed December 2008.

Giovanetti V., 2006. Urea as indicator of nitrogen metabolism and excretion in dairy sheep. PhD thesis, University of Sassari, Italy.

Jetana T., Abdullah N., Halim R.A. Jalaludin, S. and Ho Y.W., 2000. Effects of energy and protein supplementation on microbial-N synthesis and allantoin excretion in sheep fed guinea grass. In: *Anim. Feed Sci. Technol.* 84, p. 167-181.

Kiran D. and Mutsvangwa T., 2007. Effects of barley grain processing and dietary ruminally degradable protein on urea nitrogen recycling and nitrogen metabolism in growing lambs. In: *J. Anim. Sci.* 85, p. 3391-3399.

Ko Y.D., Kim J.H., Adesogan A.T., Ha H.M. and Kim S.C., 2006. The effect of replacing rice straw with dry wormwood (*Artemisia* sp.) on intake, digestibility, nitrogen balance and ruminal fermentation characteristics in sheep. In: *Anim. Feed Sci. Technol.* 125, p. 99-110.

Licitra G., Hernández T.M. and Van Soest P.J., 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. In: *Anim. Feed Sci. Technol.* 57, p. 347-358.

Liu J.-X., Wu Y.-M. and Xu N.-Y., 1995. Effects of ammonia bicarbonate treatment on kinetics of fiber digestion, nutrient digestibility and nitrogen utilization of rice straw by sheep. In: *Anim. Feed Sci. Technol.* 52, p. 131-139.

Liu J.-X., Wang Z. and Lee F., 2005. Influence of concentrate level on dry matter intake, N balance, nutrient digestibility, ruminal outflow rate, and nutrient degradability in sheep. In: *Small Rumin. Res.* 58, p. 55-62.

Ludden P.A., Wechter T.L. and Hess B.W., 2002. Effects of oscillating dietary protein on nutrient digestibility, nitrogen metabolism, and gastrointestinal organ mass in sheep. In: *J. Anim. Sci*. 80, p. 3021-3026.

Marini J.C., Klein J.D., Sands J.M. and Van Amburgh M.E., 2004. Effect of nitrogen intake on nitrogen recycling and urea transporter abundance in lambs. In: *J. Anim. Sci.* 82, p. 1157-1164.

Mavrogenis A.P. and Papachristoforou C., 1988. Estimation of energy value of milk and prediction of fat-corrected milk yield in sheep and goats. In: *Small Rumin Res*. 1, p. 229-236.

Molina-Alcaide E., Boza J. and Aguilera J.F., 1983. Nutritive value for ruminants of sugar cane bagasse ensiled after spray treatment with different levels of NaOH. In: *Anim. Feed Sci. Technol*. 9, p. 1-17.

Molina-Alcaide E., Martín García A.I. and Aguilera J.F., 2000. A comparative study of nutrient digestibility, kinetics degradation and passage and rumen fermentation pattern in goats and sheep offered good quality diets. In: *Livest. Prod. Sci*. 64, p. 215-223.

Molle G., Decandia M., Cabiddu A., Landau S.Y. and Cannas A., 2008. An update on the nutrition of dairy sheep grazing Mediterranean pastures. In: *Small Rumin. Res*. 77, p. 93-112.

Molle G., Giovanetti V., Cabiddu A., Cuccureddu M., Sitzia M. and Decandia M., 2009a. The effect of different grass-legume mixtures on nitrogen excretion of grazing sheep. In: *Options Méditerranéennes*, Series A, 85, p. 55-60.

Molle G., Giovanetti V., Cabiddu A., Cuccureddu M., Scanu G. and Decandia M., 2009b. Milk urea as nutritional indicator in sheep grazing legume-based mixtures. In: *Options Méditerranéennes*, Serie A, 85, p. 141-146.

Molle G., Decandia M., Giovanetti V., Cabiddu A., Fois N. and Sitzia M., 2009c. Responses to condensed tannins of flowering sulla (*Hedysarum coronarium* L.) grazed by dairy sheep. Part 1: Effects on feeding behaviour, intake, diet digestibility and performance. In: *Liv. Sci*. 123, p. 138-146.

Narjisse H., Elhonsali M.A. and Olsen J.D., 1995. Effects of oak (*Quercus ilex*) tannins on digestion and nitrogen balance in sheep and goats. In: *Small Rumin*. *Res.* 18, p. 201-206.

Ngwa A.T., Nsahlai I.V. and Iji P.A., 2002. Effect of supplementing veld hay with a dry meal or silage from pods of *Acacia sieberiana* with or without wheat bran on voluntary intake, digestibility, excretion of purine derivatives, nitrogen utilization, and weight gain in South African Merino sheep. In: *Livest. Prod. Sci.* 77, p. 253-264.

Perevolotsky A., Brosh A., Ehrlich O., Gutman M., Henkin Z. and Holzer Z., 1993. Nutritional value of common oak (*Quercus calliprinos*) browse as fodder for goats: Experimental results in ecological perspective. In: *Small Rumin*. *Res*. 11, p. 95-106.

Porcu F., 2003. Aspetti relativi alla stima delle sintesi di proteine microbiche ed all'effetto della fibra nella razione di pecore in lattazione. PhD. Thesis. University of Perugia, Italy.

Puga D.C., Galina H.M., Peréz-Gil R.F., Sanginés G.L., Aguilera B.A., Haenlein G.F.W., Barajas C.R. and Herrera H.J.G., 2001. Effect of a controlled-release urea supplementation on feed intake, digestibility, nitrogen balance and ruminal kinetics of feed sheep low quality tropical forage. In: *Small Rumin. Res.* 41, p. 9-18.

Pulina G., Serra A., Cannas A. and Rossi G., 1989. Determinazione del valore energetico di latte di pecore di razza Sarda. In: *Atti XLIII Congr. Naz. S.I.S.Vet.*, p. 1867-1870.

Ramos S., Tejido M.L., Martínez M.E., Ranilla M.J. and Carro M.D., 2009. Microbial protein synthesis, ruminal digestion, microbial populations and N balance in sheep fed diets varying in forage to concentrate ratio and type of forage. In: *J. Anim. Sci*. 89, p. 2924-2934.

Ranilla M.J., Carro M.D., Valdés C. and González J.S., 2005. Digestion and digesta flow kinetics in goats fed two diets differing in forage to concentrate ratio. In: *Options Méditerranéennes,* Series A, 67, p. 537-544.

Sanginés G.L., Nahed T.J., Juárez S.M.E. and Pérez-Gil R.F., 2007. *In vivo* and *in situ* digestibilities and nitrogen balance of *Buddleia skutchii* as a sole component and mixed with *Pennisetum clandestinum* in sheep diets. In: *Small Rumin. Res.* 69, p. 129-135.

Santoso B., Mwenya B., Sar C., Gamo,Y., Kobayashi T., Morikawa R., Kimura K., Mizukoshi H. and Takahashi J., 2004. Effects of supplementing galacto-oligosaccharides, *Yucca schidigera* or nisin on rumen methanogenesis, nitrogen and energy metabolism in sheep. In: *Livest. Prod. Sci.* 91, p. 209-217.

Sanz Sampelayo M.R., Pérez L., Boza J. and Amigo L., 1998. Forage of different physical forms in the diets of lactating Granadina goats: Nutrient digestibility and milk production and composition. In: *J. Dairy Sci*. 81, p. 492-498.

Sanz Sampelayo M.R., Pérez L., Martín Alonso J.J., Gil Extremera F. and Boza J., 2002a. Effects of concentrates with different contents of protected fat rich in PUFA son the performance of lactating Granadina goats 1. Feed intake, nutrient digestibility, N and energy utilisation for milk production. In: *Small Rumin. Res*. 43, p. 133-139.

Sanz Sampelayo M.R., Pérez L., Martín Alonso J.J., Amigo L. and Boza J., 2002b. Effects of concentrates with different contents of protected fat rich in PUFA son the performance of lactating Granadina goats. Part II, Milk production and composition. In: *Small Rumin*. *Res.* 43, p. 141-148.

SAS, 2001. *SAS/Stat User's Guide*. Cary, NC, USA: SAS Institute Inc.

Serra A., 1998. La valutazione degli alimenti ed il razionamento negli ovini da latte. PhD. Thesis. University of Perugia, Italy.

Silanikove N., Gilboa N., Nir I., Perevolotsky A. and Nitsan Z., 1996. Effect of a daily supplementation of polyethylene glycol on intake and digestion of tannin-containing leaves (*Quercus calliprinos, Pistacia lentiscus* and *Ceratonia siliqua*) by goats. In: *J. Agric. Food Chem.* 44, p. 199-205.
Silanikove N., Gilboa N. and Nitsan Z., 1997. Interactions among tannins, supplementation and polyethylene glycol in goats given oak leaves: effects on digestion and food intake. In: *Anim. Sci*. 64, p. 479-483.
Swanson K.C., Caton J.S., Redmer D.A., Burke V.I. and Reynolds L.P., 2000. Influence of undegraded intake protein on intake, digestion, serum hormones and metabolites, and nitrogen balance in sheep. In: *Small Rumin. Res.* 35, p. 225-233.
Waghorn G.C., Tavendale M.H. and Woodfield D.R., 2002. Methanogenesis from forages fed to sheep. In: *Proc. NZ Grassl. Assoc.,* 64, p. 159-165.
Wildeus S., Turner K.E. and Collins J.R., 2007. Growth, intake, diet digestibility, and nitrogen use in three hair sheep breeds fed alfalfa hay. In: *Small Rumin. Res.* 69, p. 221-227.
Yáñez Ruiz D.R., 2003. Utilización digestiva de dietas a base de orujo de dos fases y hoja de olivo en ovino y caprino. Efecto de factores no nutritivos. PhD. Thesis, University of Córdoba, Spain.
Yáñez Ruiz D.R., Moumen A., Martín García, I. and Molina-Alcaide E., 2004a. Ruminal fermentation and degradation patterns, protozoa population and urinary purine derivatives excretion in goats and wethers fed diets based on two-stage olive cake: Effect of PEG. In: *J. Anim. Sci*. 82, p. 2023-2032.
Yáñez Ruiz D.R., Martín García I., Moumen A. and Molina-Alcaide E., 2004b. Ruminal fermentation and degradation patterns, protozoa population and urinary purine derivatives excretion in goats and wethers fed diets based on olive leaves. In: *J. Anim. Sci*. 82, p. 3006-3014.
Yáñez Ruiz D.R. and Molina-Alcaide E., 2007. A comparative study of the effect of two-stage olive cake added to alfalfa on digestion and nitrogen losses in sheep and goats. In: *Animal*, 1, p. 227-232.
Yáñez Ruiz D.R. and Molina-Alcaide E., 2008. A comparative study of nutrients utilization, alkaline phosphatase activity and creatinine concentration in the serum of sheep and goats fed diets based on olive leaves. In: *J. Anim. Physiol. Anim. Nutr*. 92, p. 141-148.