Animal (2013), **7**:7, pp 1113–1118 © The Animal Consortium 2013
doi:10.1017/S1751731113000244

animal

Diet choice by goats as effect of milk production level during late lactation

M. Avondo†, R. I. Pagano, A. De Angelis and P. Pennisi

Department of Agricultural and Food Science (DISPA), University of Catania, Via Valdisavoia 5, 95123 Catania, Italy

(Received 30 July 2012; Accepted 14 January 2013; First published online 8 March 2013)

The diet self-regulation ability of goats during late lactation has been studied with regard to their production level. Two groups of seven Girgentana goats producing 1100 ± 157 g/day (H group) and 613 ± 138 g/day (L group) were housed in individual pens and were given alfalfa pelleted hay (1.5 kg), whole grains of maize (0.5 kg), barley (0.5 kg), faba bean (0.5 kg) and pelleted sunflower cake (0.5 kg) on a daily basis. During a 7-day pre-experimental period, goats received a mixed ration based on the same feeds used during the experimental period (1.5 kg of hay and 0.4 kg of each concentrate). Individual choice of feeds was continuously recorded for 7 days using a 24-h IR video surveillance system equipped with four video cameras. The nutrient intake in both groups was much higher than needed. Goats in the H group ate more (2016.3 v. *1744.3 g dry matter (DM)/day) and selected less hay (26.9%* v. *34.6% DM), more high-protein feeds (faba bean and sunflower cake: 14.0% and 15.9%* v. *8.8% and 7.9% DM, respectively) and less maize (21.5%* v. *25.0% DM), reaching a higher CP concentration in the diet (17.3%* v. *15.0% DM) compared with the goats in the L group. During the 24-h trial period, hay was more constantly selected (on average never reaching <20% of the total hourly basis feeding time, apart from the first hour after feed administration) compared with concentrate feeds. This feeding behaviour has probably exercised a 'curative' effect that enabled the goats to continue to take in very high levels of starch and protein, without manifesting any symptom of metabolic disease. Shifting goats from the pre-experimental diet, based on a mixture of the same feeds used during the experimental period, to the free-choice feeding caused more than 20% increase in milk production in both groups. From the results of the intake, we are unable to conclude that the goats can select their diet to meet their requirements, as goats consumed much more than needed. However, when free to choose their diet, the animals improved milk performance, despite the late-lactation stage.*

Keywords: goats, milk production level, free-choice feeding, selective behaviour, late lactation

Implications

The diet self-regulation ability of goats during late lactation was studied with regard to the production level. Five feeds were individually offered to the goats in a free-choice feeding system. The nutrient input was much higher than needed. The study highlighted the ability of goats to self-regulate, during the day, their diet for quality, more than quantity, to reach a 'curative' effect of the selected diet against metabolic discomfort. Indeed, *shifting goats from a feeding system, based on a mixture of the five feeds, to the free-choice feeding system* caused an increase of milk yield, despite the late-lactation stage. In the light of the positive response of goats to the free-choice system, the research could stimulate further studies aimed to optimize the free-choice feeding system, searching for the best combination between less protein-rich feeds and more sources of roughages.

† E-mail: mavondo@unict.it

Introduction

Studies on feeding choice in goats have been mostly focused on grazing or browsing animals, whereas few studies are available on selection activity in lactating goats fed indoors with grains and protein-rich feeds. It has been found that goats are able to self-regulate their nutrients input with regard to their needs (Fedele *et al*., 2002; Mellado *et al*., 2005). Yurtseven and Görgülü (2004) concluded that lactating goats can select their diet according to nutrient requirements when they are free to choose among feeds. Lindberg and Gonda (1997) reported that the selective feeding behaviour of goats improves dry matter (DM) intake, diet nutrient balance and thereby also the potential production. Some studies on the daily pattern of feeding of goats highlighted the ability of goats to behave in a manner to avoid digestive disorders, according to a complete diet (Abijaoudé *et al*., 2000) or a time-restricted feeding single feeding system (Görgülü *et al*., 2008). However, to our

knowledge, no research has been conducted to study the effects of milk production level on a 24-h free-choice feeding pattern among Mediterranean goats.

With the aim to investigate the diet self-regulation ability of lactating goats with regard to their production level, we conducted a free-choice study, allowing the animals to select their diet according to their needs, by making available feeds with differing chemical–nutritive characteristics.

Material and methods

Animals and feeding management

The trial was conducted in an experimental farm located in Sicily (temperature, minimum 14.7°C, maximum 24.2°C; humidity, 70%; day length, 13.49 h). Two groups (H and L) of seven Girgentana goats at second lactation were formed on the basis of milk production level (H group: milk production, 1100 ± 157 g/day; days of lactation, 144 ± 5.3; BW, 36.1 ± 2.9 kg and L group: milk production, 613 ± 138 g/day; days of lactation, 142 ± 5.4; BW, 35 ± 1.7). Goats were housed in individual pens with mangers subdivided into five separate containers. Goats were offered alfalfa pelleted hay, two sources of starch (whole barley and whole maize) and two sources of protein (whole faba bean and pelleted sunflower cake; Table 1). In each pen, water and salt were always available. During the pre-experimental period of 1 week, animals received a mixed ration of 1.5 kg of hay and 0.4 kg of each concentrate: a 7-day period during which goats received separately 1.5 kg of hay and a quantity of each feed gradually increasing from 0.2 to 0.5 kg. The adaptation period lasted for 7 days during which the animals received the experimental feeds (1.5 kg of hay and 0.5 kg of each concentrate). The free-choice experimental period lasted for 2 weeks. All the animals were managed according to the guidelines of the Animal Ethics Committee of the University of Catania.

Data collection and analysis

During the pre-experimental period, DM intake was measured daily, milk production was recorded twice daily and individual samples of diet refusals and milk samples were collected twice. During the experimental period, individual intake of each feed was measured daily on the basis of residuals. Individual feed choice was continuously recorded for 7 days using a 24-h IR video surveillance system equipped with four video cameras, each pointed at the trough of three or four contiguous pens. The recorded video was then observed, and eating time dedicated by each goat to the single feed during the 24-h trial period was noted.

Twice a week, individual milk production was recorded and milk samples were individually collected from the morning and evening milking. Twenty-eight pre-experimental samples of diet residuals and three samples for each feed were analysed for DM), CP (Association of Official Analytical Chemists, 1990) and structural carbohydrates (Van Soest *et al.*, 1991). Water-soluble carbohydrates were analysed by a modified anthrone method (Deriaz, 1961), starch by an enzymic procedure (Megazyme International Ireland Ltd, Bray, County Wicklow, Ireland). Protein fractions (A, non-protein nitrogen (NPN); B_1, true soluble protein; B_2, neutral detergent-soluble protein; B_3, neutral detergent-insoluble protein, but soluble in acid detergent; and C, insoluble in acid detergent) were determined according to Licitra *et al.* (1996), only for the three samples of each feed. Milk samples, consisting of proportional volumes of morning and evening milk, were analysed for lactose, fat, protein and somatic cells count by an IR method (Combi-foss 6000, Foss Electric, Hillerød, Denmark). Total nitrogen (TN), NPN and non-casein nitrogen (NCN) were determined by FIL-IDF standard procedures (International Dairy Federation, 1964). From these nitrogen fractions, total protein (TN × 6.38) and casein [(TN − (NCN × 0.994)) × 6.38] were calculated. Milk urea content was determined using a differential pH meter (CL10, Eurochem, Savona, Italy).

Table 1 *Chemical composition and protein fractions of the feeds*

Feeds	Alfalfa hay	Barley	Maize	Faba bean	Sunflower cake
Chemical composition					
DM (%)	93.3	89.6	86.4	86.1	89.4
CP (% DM)	15.0	10.9	9.2	27.0	31.9
NDF (% DM)	52.6	22.8	11.4	20.4	44.3
WSC (% DM)	7.12	2.5	1.5	4.7	4.0
Starch (% DM)	1.9	49.0	65.2	46.8	0.7
NE[1] (kcal/kgDM)[1]	1331.6	1815.8	1967.6	1853.3	1349.2
Protein fractions CP (%)					
A	28.2	6.5	11.4	15.6	22.3
B_1	2.2	11.2	5.7	23.8	7.1
B_2	37.1	55.9	60.9	43.7	48.4
B_3	24.5	22.5	14.3	12.2	16.0
C	8.0	3.9	7.7	4.7	6.2

DM = dry matter; WSC = water-soluble carbohydrates.
[1]Net energy for lactation (Conrad *et al.*, 1984).
A, non-protein N; B_1, true soluble protein; B_2, neutral detergent soluble protein; B_3, neutral detergent insoluble protein, but soluble in acid detergent; C, insoluble in acid detergent (Licitra *et al.*, 1996).

Table 2 *Effects of milk production level on daily intake, CP, NDF and energy content of the selected diets, milk yield and composition, feed conversion efficiency and energy and CP balance during pre-experimental and experimental periods* (n = *7)*

	Pre-experimental period (mixed ration)				Experimental period (free-choice feeding)			
	High level	Low level	*P*-value	s.e.m.	High level	Low level	*P*-value	s.e.m.
DM intake (g)	2220.7	1542.4	0.005	141.0	2016.3	1744.3	0.011	86.5
CP intake (g/kg $BW^{0.75}$)	27.2	17.7	0.001	1.85	22.6	16.9	0.001	0.67
Energy intake (NE/kg $BW^{0.75}$)[1]	232.5	158.3	0.005	15.3	215.0	175.2	0.003	5.18
Estimated energy requirements (kcal NE/kg $BW^{0.75}$)[1]	108.8	94.4	0.011	3.28	112.4	97.2	0.001	2.06
Estimated CP requirements (g/kg $BW^{0.75}$)	9.92	7.70	0.005	0.46	10.4	8.1	0.005	0.33
Chemical composition of selected diets								
Diet CP (% DM)	18.0	17.4	0.197	0.2	17.3	15.0	<0.001	0.5
Diet NDF (% DM)	35.1	32.5	0.177	0.9	30.8	31.9	0.554	0.6
Milk yield (g/day)	1099.9	656.4	0.005	92.2	1321.9	796.2	<0.001	69.0
Milk composition (%)								
Fat	3.21	3.05	0.419	0.12	2.70	2.94	0.129	0.09
Protein	3.40	3.31	0.611	0.08	3.43	3.42	0.926	0.03
Lactose	4.61	4.54	0.660	0.06	4.42	4.46	0.639	0.04
Casein	2.67	2.53	0.352	0.07	2.62	2.66	0.549	0.02
Urea (mg/dl)	57.3	58.0	0.855	1.8	60.4	58.7	0.376	1.2
Feed conversion ratio (g DMI/g milk yield)	2.03	2.45	0.084	0.12	1.56	2.34	0.001	0.11
Protein conversion ratio (g CP intake/g protein yield)	10.8	13.1	0.292	26.0	7.40	10.29	0.005	0.48

DM = dry matter; NE = net energy; DMI = dry matter intake.
[1]Net energy for lactation (Conrad *et al.*, 1984).

Individual pre-experimental and experimental data for intake, diet selection, diet composition, milk production and composition were analysed using the GLM procedure for repeated measures of SPSS (SPSS for Windows, SPSS Inc., Chicago, IL, USA). The animal was the experimental unit.

Results

The health status of goats, checked during the trial, was good. No clinical signs of disease were detected.

DM, CP and net energy intake were significantly higher in the H group, both with mixed (pre-experimental) and free-choice feeding system (Table 2). When fed with mixed diet, diet CP levels of both groups were similar, whereas it was significantly higher in the H group with free-choice feeding. No differences between the groups were found in NDF content of the selected diet.

The difference in milk production between H and L groups tended to further increase with free-choice feeding. No differences have been found between the groups in milk composition. DM and CP conversion index were significantly improved in the H group only during the free-choice feeding.

No difference was evident in terms of feeding time (Table 3). Diet components in the selected diet have been significantly affected by milk production level. Hay and maize were less selected, whereas faba bean and sunflower cake were more selected by the H group compared with the L group. No difference was found between the groups in barley selection.

Feeding time trend during the day was not significantly influenced by milk production level (Figure 1).

Table 3 *Effects of milk production level on feeding time and feed selection* (n = *7)*

	High level	Low level	*P*-value	s.e.m.
Feeding time (min/day)	118.5	110.7	0.236	6.7
Selected feeds % total DM intake				
Hay	26.9	34.6	0.006	1.7
Maize	21.5	25.0	0.021	1.2
Barley	21.7	23.6	0.324	1.4
Faba bean	14.0	8.8	0.023	1.6
Sunflower cake	15.9	7.9	0.007	1.9

DM = dry matter.

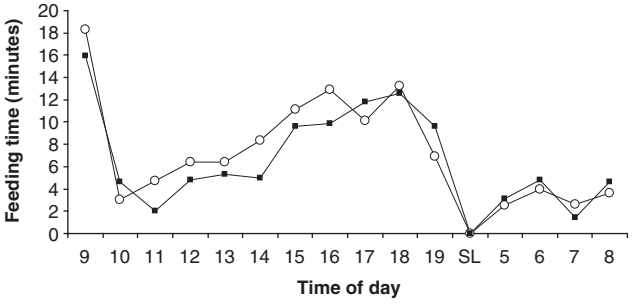

Figure 1 Hourly feeding time (minutes dedicated to feeding during each hour of the day) in high production level group, H (-○-) and low production level group, L (-■-) (*n* = 7; s.e.m. = 0.40; SL = sleeping).

Hourly feed-selection daily trend, expressed as the feeding time dedicated to each feed in percent of the total feeding time (Figure 2), was partially affected by milk production level. Significant differences were detectable in the choice of maize,

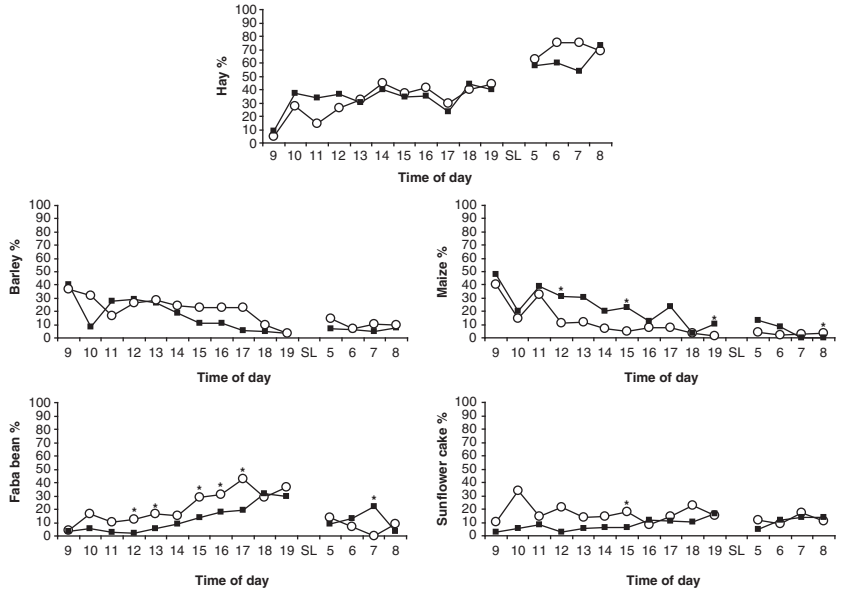

Figure 2 Hourly feed selection (feeding time for each feed, expressed in percentage of the total feeding time during each hour of the day) in high production level group, H (-○-) and low production level group, L (-■-). The s.e.m. for hay, barley, maize, faba bean and sunflower cakes were 1.87, 1.35, 1.38, 1.17 and 1.02, respectively ($n = 7$; $^*P < 0.05$; SL = sleeping).

sunflower cakes and faba bean. According to the mean results for each feed (Table 3), maize was more selected in the L group at 1200, 1500 and 1900 h and was less selected at 0800 h (it should be specified that no more maize was available from 0700 h); sunflower cakes were more selected in the H group at 1500 h; and faba bean was more selected in the H group at, 1200, 1300, 1500, 1600 and 1700 h, and was less selected at 0700 h. No significant difference was evident between the groups in hay and barley selection, despite the higher level of hay found in the L group (Table 3).

Discussion

The feeds were the same as those utilized in a previous free-choice study conducted on other goats, to evaluate whether the different genotype at αs_1-casein locus (goats homozygous for weak, FF or strong alleles, AA) could affect diet selection (Avondo *et al*., 2009). In such conditions, significant effects of genotype were reported. For this reason, in the present trial, we selected goats heterozygous at this locus (AF) to avoid any interference of genotype in the results.

Intake and diet composition

DM intake was higher than the data reported in literature for goats fed high-concentrate diets (Tovar-Luna *et al*., 2010; Serment *et al*., 2011), but lower than what we previously found in similar experimental conditions (Avondo *et al*., 2009).

Taking into account the milk production levels and BWs in the L and H groups, the nutrients input was much higher than needed (Cannas *et al*., 2008), both with mixed (pre-experimental period) and free-choice feeds. As a result, there was a significant increase in BWs (162.8 and 88.6 g/day, respectively, in the H and L groups) throughout the trial. In addition, Bava *et al*. (2001) found that lactating goats fed with a non-forage diet reached higher levels of intake than needed. What is rather surprising is that, despite the high-nutrient input, we found greater intake in the H group, which should be explained only with the different requirements associated with different milk productions. We could hypothesize that goats consumed more, simply as a consequence of the high palatability of feeds and the low fill effect of the concentrates and the pelleted hay. Increased feed consumption has been found directly proportional to ruminal escape (Huntington, 1997) and inversely proportional to total digestive tract retention time (Lindberg, 1988). Indeed, taking into account that goats received whole grains, we could suppose that digestibility of feeds in the small intestine was reduced further. In such conditions, these assumptions could have, as a consequence, a lower-nutrient availability for lactation that, in turn, could also justify the different intake found in the two groups.

The H group selected less hay and maize and more faba bean and sunflower cake, reaching higher CP input and similar NDF input because of high fibre content in sunflower cake.

CP intakes were much greater than required (Cannas *et al*., 2008); however, even in this case, differences between the groups seem to be coherently associable with different needs for lactation.

Selective behaviour

Video recording allowed the observing of the eating activity very clearly, even during the night, thanks to the IR system. When the goat heads were in each container on the

trough, it was supposed that they were eating that feed, in accordance with Abijaoudé *et al*. (1999). The jaw movements showed by the animals as soon as they moved their head from the containers confirmed the eating activity. In both the groups, the eating pattern was similar, showing a peak after the administration of feeds in the morning, followed by a period of lower feeding activity. Then the animals showed an increased eating activity until afternoon milking (1800 h). During the night, there was a negligible eating activity. Another period of intake occurred in correspondence with the morning milking. Fedele *et al*. (2002) and Görgülü *et al*. (2008) found a similar concentration in feeding activity during the day and just a small activity overnight in free-choice fed goats.

Soon after feed administration, the diet choice in both groups was mainly addressed to maize and barley, and then the goats increased their selection for hay, the most selected feed, and to a lesser extent, for faba bean and sunflower cake, with the H group showing higher selectivity throughout the daylight for the protein-rich feeds. As mentioned earlier (Avondo *et al*., 2009), the feeding behaviour observed during the 24 h could explain the good tolerance showed by goats to the high-nutrient input. In fact, apart from the 1st hour, it is possible to note that hay was more constantly present in the diet, on average, never $<$20% of hourly total feeding time, compared with concentrate feeds. As a consequence, the NDF content of the diet, associated with hay selection, has probably exercised a 'curative' effect that enabled the goats to continue the intake of very high levels of starch, without manifesting any signs of disease. Moreover, it must be taken into account that maize, barley and faba bean were given as whole grains. This certainly contributed to a more intense chewing activity for these feeds, allowing the animals to produce more saliva, whose buffering effect in ruminal environment is well known. Previous studies, conducted in similar high-concentrate feeding systems, report no metabolic disorders derived from feeding: Yurtseven and Görgülü (2004) concluded that goats could consume high-level concentrate (75% to 77%) without having any metabolic problem. Abijaoudé *et al*. (2000) reported that goats avoided acidosis with their feeding behaviour, organizing the distribution of the diet throughout the day. In turn, Görgülü *et al*. (2008) affirm that the success in diet selection in free-choice fed lactating goats can be explained by hourly arrangements of feeding behaviour. All these findings seem to support the hypothesis that animals can learn the metabolic consequence of feed intake and modify their feeding behaviour to avoid negative perceptions (Provenza, 1995).

Total time spent in eating was lower in comparison with the data in literature (Morand-Fehr *et al*., 1991; Rapetti *et al*., 2005). This result could be justified by the type of feeds on offer, represented by concentrates and pelleted hay. In fact, our results were in line with the data reported by Abijaoudé *et al*. (2000) in goats fed with high concentrate levels. The time dedicated to feeding was not significantly affected by the level of milk production.

Milk production and quality

Shifting goats from the pre-experimental diet, based on a mixture of the same feeds used during the experimental period, to the free-choice feeding caused more than 20% increase of milk production in both the groups. This result could be because of the increased levels of concentrate consumed by goats. Such an increase occurred, despite the late-lactation stage of goats, at the end of the trial on average at 178 days from parturition, and it is known that the effects of nutritional treatments in mid-late lactation are often more evident on BW gains than on milk yield (often unchanged or reduced; Bocquier and Caja, 1993). However, Görgülü *et al*. (2003 and 2008) hypothesized that choice feeding has a potential to increase lactating performance. Lindberg and Gonda (1997) emphasized that the selective feeding behaviour of goats can have a marked influence on the dynamics of digestion and, as a consequence, on the nutrient utilization of a diet.

Milk composition was similar in both groups. No dilution effect was evident in the H group for milk components. As expected, milk fat was low and concentration was further depressed by high starch levels in the diet selected by the goats. An inverse fat-to-protein ratio has been found in both the groups. As reported earlier, the frequency of this phenomenon is not rare in goats and it tends to increase from a low roughage to concentrate ratio (Morand-Fehr *et al*., 2000; Avondo *et al*., 2009), but is also evident in grazing goats (Di Grigoli *et al*., 2009). As mentioned earlier (Avondo *et al*., 2009) urea content was high, coherently with the high protein input reached by goats, both with mixed and free-choice diets and independently from milk productions. It could be assumed that more CP consumed by the H goats was more efficiently utilized to support the higher milk output. Milk urea content was high because of the protein inputs reached by the goats and the results were over the range values for Girgentana goats as reported by Bonanno *et al*., 2008). However, Rapetti *et al*. (2009) reported that about 75% of the bulk milk urea content in dairy goat farms of Lombardy was higher than these standard levels, which also report 68.8 mg/l of range variability.

Conclusions

From these results, we are unable to conclude that the goats can select their diet to meet their requirements. In fact, goats ate much more than what was needed. However, when free to choose their diet, the animals improved their milk performance, despite the late-lactation stage. Indeed, the group at higher production level showed higher intake and selected more protein-rich feeds, coherently with higher milk yield. During the 24-h trial period, hay was the feed more constantly selected. This behaviour has probably exercised a 'curative' effect that enabled the goats to continue the intake of very high levels of nutrients, increasing their milk production with no clinical signs of disease. In the light of positive response of goats to the free-choice system, further studies are needed to optimize the system, testing less protein-rich feeds and more sources of roughages.

References

Abijaoudé JA, Morand-Fehr P, Tessier J, Schmidely P and Sauvant D 2000. Diet effect on daily feeding behaviour, frequency and characteristics of meals in dairy goats. Livestock Production Science 64, 29–37.

Abijaoudé JA, Morand-Fehr P, Béchet G, Brun JP, Tessier J and Sauvant D 1999. A method to record the feeding behaviour of goats. Small Ruminant Research 33, 213–221.

Association of Official Analytical Chemists 1990. Official Methods of Analysis, 15th edition. AOAC, Arlington, VA, USA.

Avondo M, Pagano RI, Guastella AM, Criscione A, Di Gloria M, Bernardo V, Piccione G and Pennisi P 2009. Diet selection and milk production and composition in Girgentana goats with different α_{s1}-casein genotype. Journal of Dairy Research 76, 202–209.

Bava L, Rapetti L, Crovetto GM, Tamburini A, Sandrucci A, Galassi G and Succi G 2001. Effects of nonforage diet on milk production energy and nitrogen metabolism in dairy goats throughout lactation. Journal of Dairy Science 84, 2450–2459.

Bocquier F and Caja G 1993. Recent advances on nutrition and feeding of dairy sheep. Hungarian Journal of Animal Production 1, 580–607.

Bonanno A, Todaro M, Di Grigoli A, Scatassa ML, Tornambè G and Alicata ML 2008. Relationships between dietary factors and milk urea nitrogen level in goats grazing herbaceous pasture. Italian Journal of Animal Science 7, 219–235.

Cannas A, Atzori AS, Boe F and Teixeira IAMA 2008. Energy and protein requirements of goats. In Dairy goats feeding and nutrition (ed. A Cannas and AG Pulina), pp. 118–146. CAB International, Wallingford, UK.

Conrad HR, Weiss WP, Odwongo WO and Shockey WL 1984. Estimating net energy lactation from components of cells solubles and cell walls. Journal of Dairy Science 67, 427–436.

Deriaz RE 1961. Routine analysis of carbohydrates and lignin in herbage. Journal of the Science of Food and Agriculture 12, 152–160.

Di Grigoli A, Todaro M, Di Miceli G, Alicata ML, Cascone G and Bonanno A 2009. Milk production and physiological traits of ewes and goats housed indoor or grazing at different daily timing in summer. Italian Journal of Animal Science 8 (suppl. 2), 616–618.

Fedele V, Claps S, Calandrelli M and Pilla AM 2002. Effect of free-choice and traditional feeding systems on goat feeding behaviour and intake. Livestock Production Science 74, 19–21.

Görgülü M, Kutlu HR, Demir O, Torun O, Ozuyamik O and Kutulu HR 2003. An alternative feeding system for dairy goats: effect of free-choice feeding on milk yield and milk composition in early lactation of Damascus goats. Journal of Animal and Feed Sciences 12, 33–44.

Görgülü M, Boga M, Sahin A, Serbester U, Kutlu HR and Sahinler S 2008. Diet selection and eating behaviour of lactating goats subjected to time restricted feeding in choice and single feeding system. Small Ruminant Research 78, 41–47.

Huntington GB 1997. Starch utilization by ruminants: from basics to the bunk. Journal of Animal Science 75, 852–867.

International Dairy Federation 1964. Determination of the casein content of milk. FIL-IDF Standard no. 29. Brussels, Belgium.

Licitra G, Hernandez TM and Van Soest PJ 1996. Standardization of procedures for nitrogen fractionation of ruminant feeds. Animal Feed Science and Technology 57, 347–358.

Lindberg JE 1988. Influence of cutting time and N fertilization on the nutritive value of timothy. 2. Estimates of rumen degradability of nitrogenous compounds. Swedish Journal of Agricultural Research 18, 85–89.

Lindberg JE and Gonda HL 1997. Fibre and protein digestion in goats. In Recent advances in goat research (ed. P Morand-Fehr), pp. 47–58. CIHEAM-IAMZ, Zaragoza, Spain.

Mellado M, Rodriguez A, Villareal JA and Olvera A 2005. The effect of pregnancy and lactation on diet composition and dietary preference of goats in a desert rangeland. Small Ruminant Research 58, 79–85.

Morand-Fehr P, Tessier J, Meschy F and Sauvant D 2000. Effect of roughage level and source in diets on the risk of reversing fat and protein percentages in goat milk. Cahier Options Mediterraneennes 52, 115–118.

Morand-Fehr P, Bas P, Blanchart G, Daccord R, Giger-Reverdis S, Gihad EA, Hadjpanayiotou M, Mwlem A, Remeuf F and Sauvant D 1991. Influence of feeding on milk composition and technological characteristics. In Goat nutrition vol. 46 (ed. P Morand-Fehr), pp. 209–224. EAAP, Wageningen, The, Netherlands.

Provenza FD 1995. Post-ingestive feedback as an elementary determinant of food preference and intake in ruminants. Journal of Range Management 48, 2–7.

Rapetti L, Bava L, Tamburini A and Crovetto GM 2005. Feeding behaviour, digestibility, energy balance and productive performance of lactating goats fed forage-based and forage-free diets. Italian Journal of Animal Science 4, 71–83.

Rapetti L, Bruni G, Zanatta G and Colombini S 2009. The milk urea content in dairy goat farms of Lombardy. Italian Journal of Animal Science 8 (suppl. 2), 356.

Serment A, Schmidely P, Giger-Reverdin S, Chapoutot P and Sauvant D 2011. Effects of the percentage of concentrate on rumen fermentation, nutrient digestibility, plasma metabolites, and milk composition in mid-lactation goats. Journal of Dairy Science 94, 3960–3972.

Tovar-Luna I, Puchala R, Sahlu T, Freetly HC and Goetsch AL 2010. Effects of stage of lactation and level of feed intake on energy utilization by Alpine dairy goats. Journal of Dairy Science 93, 4829–4837.

Van Soest PJ, Robertson JB and Lewis BA 1991. Methods for dietary fiber, neutral detergent fiber and nonstarch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74, 3583–3597.

Yurtseven S and Görgülü M 2004. Effects of grain sources and feeding methods, free-choice *v.* total mixed ration, on milk yield and composition of German Fawn × Hair crossbred goats in mid lactation. Journal of Animal and Feed Sciences 13, 417–428.