Among-goat variability in feeding behaviour and feed efficiency under diets differing in the percentage of concentrate

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Abstract

Feeding behaviour in ruminants differs with individuals and diet composition and might have effects on feed efficiency and provide protection especially against rumen disturbances. In this study, we aimed to explore the variability in feeding behaviour and feed efficiency among dairy goats, and their potential link on an initial (control) Total Mixed Ration. Our second aim was to evaluate how these parameters and the link between them change when the percentage of concentrate in this control diet is modified. Our results confirm that feeding behaviour was highly repeatable within goat, but differed among goats fed the control diet. Feed efficiency was also highly variable. There was a moderate correlation between feeding behaviour and feed efficiency when the goats were fed the control diet (40 % concentrate, 20 % sugarbeet pulp silage, 40 % hay). When the percentage of concentrate was decreased by 10 %, feeding behaviour was slightly modified. When this percentage was increased by 10 %, intake and duration of the first meal after feed allowance decreased, but intake rate was not modified. Hierarchy among animals for feed efficiency was not modified by dietary changes, but the link between feed efficiency and feeding behaviour was lost.
Some aspects of feeding behaviour were flexible so that the animals could adapt to different rations, while others were less flexible and seemed to be part of the animals' personality.

Highlights

- Feeding behaviour and feed efficiency are highly variable among goats, but repeatable within goats
- Some parameters of feeding behaviour are adaptable
- Some parameters of feeding behavioural are consistent even in case of dietary changes

Keywords: dairy goats; feeding behaviour; feed efficiency; variability; adaptation

1. Introduction

Feeding behaviour can differ considerably among cows (Melin et al., 2005) or goats housed in the same conditions and fed the same diet (Giger-Reverdin et al., 2020). Feeding behaviour can be described by many variables: one of them, dry matter intake (DMI), is a general estimate of nutrients input. It depends, among others, on the size of the animal, its production level and the composition of the diet. A more specific intake parameter is net energy intake (UFL in the INRA 2018 system; Sauvant et al., 2018b). Intake is not continuous but structured. Dairy animals are often fed at specific times, generally depending on milking schedule, which can have a considerable impact on feeding behaviour (Morand-Fehr et al., 1991; DeVries et al., 2003a). After feed distribution, animals do not eat continuously, but interrupt their intake for varying durations. Based on the length of these durations, meals or feeding bouts can be identified. The first one after feed delivery is the longest one, especially when goats returning from milking were offered fresh feed (Morand-Fehr et al., 1991), as also observed in dairy cows (DeVries et al., 2003a), and can be evaluated to characterize feeding behaviour. Based on intake and the duration of feeding bouts, we can calculate eating rate. This parameter is important because a high eating rate could lead to digestive perturbances as for example with subordinate cows which have short accesses to the feed bunk (Andersson and Lindgren, 1987).

For the animal and the farmer, intake is not the only important aspect. Another one is feed efficiency (FE), the ratio between output and input. Feed efficiency can be measured by different metrics such as Residual Feed Intake or Feed Convertio Ratio (Giger-Reverdin and Berthelot, 2023). In this study, Feed Efficiency was estimated by the ratio between standard milk output (Fat and Protein Corrected Milk Yield, FPCMY) and energy input, because it represents the ratio between valorisation of milk depending on quantity, quality and cost of feed. This seems to us the most relevant expression of FE because the diets used in our trial differed in energy value.

Across two years, feeding behaviour of dairy goats was found to be repeatable within goat, but differed among goats when similar diets were fed (Giger-Reverdin et al., 2020). Is this difference among individuals just 'noise in the system', or does it also have consequences for the animals' fitness, e.g. by affecting their feed efficiency as suggested by some studies in cattle (Brown et al., 2022) or sheep (Muir et al., 2018). When diets change, for instance in their percentage of concentrate, animals can change their behaviour to reduce potential digestive disturbances (Serment and Giger-Reverdin, 2012). It seems that the most efficient animals have less frequent, but larger feeding bouts (Robinson and Oddy, 2004; Muir et al., 2018).

Thus, in this study, we aimed to explore the variability in feeding behaviour and feed efficiency among dairy goats and their potential link on a Total Mixed Ration (TMR), considered as the control diet in our trial. Our second aim was to evaluate how these parameters and the link between them change when the percentage of concentrate in the control diet is modified.

Since in group-housed cattle or goats (Grant and Albright, 1995; Gipson et al., 2006; Miranda de la Lama et al., 2011; Neave et al., 2018), the behaviour of individuals can be affected by social dominance, the animals in this study were housed in individual pens. To avoid a potential effect of parity, as observed with cows by Grant and Albright (1995), the animals in this study were of the same age and number of lactations.

2. Material and methods

2.1. Animals and housing

Twenty dairy goats (10 Saanen and 10 Alpine) were housed in 2.0 m × 1.0 m individual pens, each with their own feed trough with free access to feed and water (Desnoyers et al., 2009). At the beginning of the trial, they were three years old and in the middle of their third lactation (72 ± 2.5 days). Body weight was measured once a week around 1400 h before the afternoon feed delivery.

2.2. Milk yield and composition

Goats were milked twice a day (at 08:00 and 16:00 h) with milk composition measured once every week on two consecutive milkings. Fat and protein corrected milk yield (FPCMY) was computed using the formula proposed by Sauvant and Giger-Reverdin (2018):

$$FPCMY = MY * [0.389 + 0.0052 \times (MFC - 35) + 0.0029 \times (MPC - 31)] / 0.389$$

where MY is milk yield (kg/d), and MFC and MPC are milk fat and protein contents (g/kg), respectively.

2.3. Feeding treatments and experimental design

Animals were fed *ad libitum* a TMR adapted to their requirements. In a first period of three weeks, they were accustomed to a control diet (C40: 40% hay, 40% concentrate, 20% sugar beet pulp silage; % on a dry matter basis). At the end of these three weeks, they were assigned to three treatments according to their milk yield, body weight and first bout characterization. In the following second period (of four weeks), percentage of concentrate was decreased to 30 % (C30) for 6 goats (three Alpine and three Saanen) or increased to 50% (C50A; A for acidogenic diet) for 2 groups of 7 goats (with at least three Alpine and three Saanen per group), with one supplemented with sunflower grains (to enhance the energy value of the diet: C50AS without increasing the percentage of concentrate that could increase the risk of acidosis). Diets C50A and C50AS were considered as acidogenic, because the percentage of hay was only 30 %, while the two feeds of readily fermentable substrates, concentrate and sugar beet pulp (Malestein et al., 1984; Sauvant et al., 2018a) were 50%

and 20%, respectively. The in sacco degradability of the C50A and C50AS concentrate estimated by an additive method (Grubjesic et al., 2019) were quite similar with an ED6 value (effective degradability assuming a passage rate of 6%) around 68 % (Baumont et al., 2018). Diets were formulated to be isonitrogenous. The hay part of the diet came from a permanent grassland and had been chopped to be incorporated in the TMR. Ingredient composition of the concentrates is given in Table 1.

The DM, ash and starch contents of the TMRs were analysed according to ISO (1978); ISO (1999) and ISO (2004), respectively. The NDF content was estimated by the method of Van Soest and Wine (1967) modified by Giger et al. (1987) with the use of a heat stable α-amylase but without sodium sulphite and decalin. The contents of ADF and acid detergent lignin were obtained using a sequential approach on the NDF residue (Giger et al., 1987). Total N was determined by the Dumas technique (Sweeney and Rexroad, 1987). Composition in ingredients, chemical composition and estimated nutritive value (Baumont et al., 2018) of the diets are given in Table 2. The diets were fed twice a day, after milking, with one third in the morning and two thirds in the afternoon, following the different time intervals between milkings.

Recordings were taken simultaneously and individually for all goats during four successive days at the end of each experimental period, milk yield being associated with the feed intake on the previous day. Feeding behaviour was characterised based on data acquired between the afternoon feeding and the next morning milking (15 h), because this period corresponded to two-thirds of the total feed delivery and was at a part of the day where the goats were not disturbed by activities in the experimental barn.

2.4. Patterns of intake measurements

Dynamic patterns of intake were recorded every 2 minutes by weighing devices placed under the feed trough (Desnoyers et al., 2009). The method of Tolkamp et al. (1998) was used to separate pauses (or plateaus) within feeding bouts from pauses between bouts. It is based on a satiety concept where the distribution of log-transformed plateau durations falls into two populations separated by the most likely bout criterion. The minimum inter-bouts interval (or bout criterion) found using this method in this trial was 11 min. This means that plateaus longer than 11 min were considered as separating two feeding bouts. This method allows to compute for each goat and each afternoon feed delivery several parameters: number of feeding bouts, the duration and dry matter intake (DMI) of each bout. We calculated the parameters for the first bout and for the remaining bouts separately. The parameters retained in this study were DMI, duration and eating rate measured during the whole 15 h or for the first bout and the others separately. The proportion of the 15 h DMI eaten during the first bout was also calculated.

2.5. Feed efficiency

As the experimental diets differed in energy values during the second period (Table 2), feed efficiency was computed as the ratio of FPCMY on energy intake, where energy intake was calculated following the latest INRA recommendations for dairy goats (Sauvant and Giger-Reverdin, 2018).

2.6. Statistical design

For the analysis of the data concerning the control diet, we used the MIXED procedure of SAS (SAS, 2016) for repeated measurements with the following statistical model:

$$Y_{ijk} = a + b_i + c_{j(bi)} + d_k + e_{ijk}$$

where Y_{ijk} is the response variable, a represents the overall mean, b_i the fixed effect of the breed (Alpine vs Saanen), $c_{j(bi)}$ the fixed effect of the goat j nested within breed, d_k the fixed effect of the day as a repeated factor (k = 1 to 4) and e_{ijk} the random residual error. The initial model contained milk production as a covariate. Since it was never significant, it was dropped from the final model. The model was tested with four covariance structures: compound symmetry, heterogeneous compound symmetry, first-order autoregressive, and heterogeneous autoregressive. The covariance structure that provided the smallest Akaike's information criteria was selected.

The repeatability between days (correlation between repeated measures on the same animal at different days) for a given goat within the first period with the control diet was estimated as the proportion of the variance between animals on the sum of the between and within animal variances (Huhtanen et al, 2015). It corresponds to the square of a coefficient of correlation.

Due to the large among-goat variation in feeding behaviour, a paired samples Wilcoxon test was performed within each group during the second part of the trial. Each goat was thus considered as its own control measured when fed the control diet.

3. Results

3.1. Among goat variability, feeding behaviour and feed efficiency in goats fed the control diet (C40)

During this first period, all the animals were fed the same diet (C40 or basal diet).

3.1.1. Among goat variability

The among goat variability was calculated on average values for the 4 test days (Table 3). FPCMY, however, was computed with the milk production corresponding to the day of analysis of samples, and feed efficiency was therefore also computed for the corresponding day. Almost all the parameters showed a large variation among goats as the coefficient of variation ranged from 8.4 to 61.4 %. Feed efficiency was the least variable, and number of bouts, daily dry matter intake (DMI) and duration of bouts, excluding the first one, were the most variable. The FPCMY was quite variable among goats with the C40 diet. It neither differed between breeds (Alpine: 4.14 ± 0.500 vs Saanen: 3.88 ± 0.639), nor between the groups that were subsequently allocated to the different diets (C30: 3.99 ± 0.240, C50A: 4.02 ± 0.647, C50AS: 4.02 ± 0.760). Body weight did not differ significantly between breeds (63.8 ± 6.17 vs 67.8 ± 8.92 kg, for Alpine and Saanen goats respectively), nor between the subsequent treatment groups (C30: 66.4 ± 8.42, C50A: 64.4 ± 5.80, C501S: 66.8 ± 9.66).

3.1.2. Feeding behaviour

The repeatability between days for a given goat was high for all parameters dealing with feeding behaviour (Table 4). The goat effect was significant for almost all parameters. Day and breed effects tended to be significant for the number of feeding bouts during the 15 h following afternoon feed delivery. Day effect was at the limit of significance for the daily DMI and breed effect tended to be significant. These effects were mainly due to two goats: one Alpine with the highest intake of the group and one Saanen with the lowest one. Day and breed effects were not significant for any other parameter. FPCMY was correlated with daily DMI and intake during the 15 h following the afternoon feed allowance (n = 20, r = 0.82 and r = 0.76, respectively) as well as with the number of feeding bouts (r = 0.52). Daily DMI was also correlated with body weight (r = 0.53, n = 20).

3.1.3. Feed efficiency and link to feeding behaviour with the control diet (C40)

A variation in feed efficiency (FE) was noted among goats fed the control diet (Table 3). It was correlated positively with the intake rate of the first bout (r = 0.44) and negatively with the duration of the first bout (r = -0.40). In other words, when fed the control diet, faster eating goats had a better feed efficiency. These goats were the most producing and heaviest ones: eating rate during this first bout was correlated with FPCMY (r = 0.69, n = 20) and body weight (r = 0.60, n = 20).

3.2. Effects of dietary change

Due to the significant goat effect, dietary change effects were studied within each group, using each goat as its own control.

3.2.1. Change from the control (C40) to the low concentrate (C30) diet

Daily dry matter intake did not statistically change between the two periods when the percentage of concentrate was decreased from 40 % (C40) to 30 % (C30) (Table 5). Daily net energy intake (UFL) tended to decrease (Table 5), but energy balance did not differ between the two periods (- 0.11 UFL; P = 0.30).

The number of feeding bouts increased when the goats were fed the C30 diet compared to the C40 one. The duration of the bouts other than the 1st one tended to increase. The other variates did not differ statistically (Table 5). Feed efficiency decreased from 1.57 (Diet C40) to 1.53 (Diet C30), but not significantly.

3.2.2. Change from the control (C40) to the high concentrate (C50A) diet

The daily DMI and net energy intake did not differ between the two diets when the percentage of concentrate was increased from 40 % (C40) to 50 % (C50A) (Table 6). Net energy balance tended to increase (C40: 0.03; C50A: 0.023; P = 0.08). DMI intake during the 15 h period and duration of eating did not change between diets C40 and C50A. The DMI during the 1st bout tended to decrease and the DMI during the other bouts increased. The proportion of intake during the 1st bout decreased significantly. The duration of the 1st bout decreased also. Rates of intake did not differ between periods 1 and 2. Thus, there was a shift in intake and duration between the 1st bout and the other bouts. Feed efficiency decreased from 1.63 (C40 Diet) to 1.49 (C50 diet). This decrease was especially large for two goats (-0.27).

3.2.3. Change from the control (C40) to the high concentrate (C50AS) diet supplemented with sunflower seeds

With the C50AS diets, dry matter intake decreased, but net energy intake remained at a similar level (Table7). As with the C50A diet, there was a shift for DMI intake and duration with decreases during the 1st bout and increases with the other bouts when comparing the C40 and C50AS diets (Table 7). Eating rate remained constant. Feed efficiency was numerically lower with Diet C50AS compared to Diet C40 (1.50 vs 1.60), but this decrease was not statistically significant.

3.2.4. Feed efficiency: repeatability across time

Feed efficiency during the second period (FE_2; C30, C50A and C50AS) was directly proportional to feed efficiency during the first one (FE_1; C40), without any diet effect or interaction with the diet (Figure 1):

$$FE\_2 = 0.941\ FE\_1$$

(r = 0.65, n = 20, RSD = 0.135 kg FCPMY/UFL)

Contrary to the first period, there was no significant correlation between FE and eating rate or duration of the first bout.

4. Discussion

In this study, we wanted to explore the variability in feeding behaviour and feed efficiency among dairy goats and their potential link on a control Total Mixed Ration. We also wanted to evaluate how these parameters and the link between them change when the percentage of concentrate in the initial control diet is modified.

4.1. Feeding Behaviour and Feed Efficiency with the control diet

In this study, the minimum inter-bouts interval was 11 minutes. It is in agreement with the definition of a feeding bout or meal given by Morand-Fehr (1981): a meal is a sum of eating behaviour that lasted at least 15 min. without any interruption longer than 10 min. It is higher than the threshold of 8 min with pen fed goats with measurements of weight in the feeding trough every 2 s (Nielsen et al., 2021) but lower than the 13 min. obtained by Görgülü et al. (2011) on dry goats. With the control diet, the day effect was non significant for almost all parameters and the goat effect was highly significant. There was a good repeatability between days for a given goat as the repeatability coefficient was always higher than 0.68 (Kelly et al., 2010), but a high between goats variability in feeding behaviour as expected what confirms previous observations in goats (Morand-Fehr, 1981; Giger-Reverdin et al., 2020), in sheep (Muir et al., 2018) or in cattle (Hesselbarth, 1955; DeVries et al., 2003b).

Feed efficiency showed a considerable variation among goats fed the control diet (C40). With the control diet, the most efficient goats were those that spent less time eating or, in other terms, they optimized the energy expense linked to duration of feeding (Lachica et al., 1997). These goats had the highest requirements for maintenance (body weight) and production (milk yield).

4.2. Feeding Behaviour and Feed Efficiency after dietary change

When the goats were moved from the control diet (C40) to the high forage diet (C30), the number of bouts increased and the duration of the bouts without the first one tended to increase. This might be due to an increase in forage percentage, with a higher chewing work due to the increase of 15% in NDF content. This is in agreement with the positive link between NDF and Roughage Value Index (Sudweeks et al., 1981). As it is the only significant change, it might be taken with caution as this criterion seems to be the least repeatable behavioural one (DeVries et al., 2003b). It should also be noted that the dietary change between the periods was small as it concerned only 10 % of the diet with the replacement of 10 % of concentrate by hay (C30 diet) or of 10 % of hay by concentrate (C50A or C50AS diets). It might therefore be stressed that the group of goats fed the C30 was the one with the lowest number of bouts during the first period with the control diet.

When the quality of the forage decreased due to an increase of NDF, the length of the main meal decreased and the number of secondary meals increased in dairy goats (Morand-Fehr et al., 1991). The numerically lower intake during the first bout with the C30 diet compared to the C40 could be explained by the higher fill effect of the C30 linked to a physical regulation of intake (Balch and Campling, 1962).

Goats did not modify their daily intake and their intake following the afternoon feed allowance when C40 diet was replaced by C50, but they modified their intake pattern: duration and quantity of TMR eaten during the first bout decreased. This is in agreement with previous results when the percentage of concentrate increased from 52.5 to 70 % (Serment and Giger-Reverdin, 2012). One explanation might be that they modified their feeding behaviour to avoid a risk of sub-acute ruminal acidosis (Giger-Reverdin, 2018): C50 diet contains 50 % of concentrate and 20 % of sugarbeet pulp silage that is also rich in highly digestible carbohydrates (Michaux, 1950; Tamminga et al., 1990). Both C50A and C50AS diets had a percentage of concentrate and an NDF content close to the thresholds defined as risks of sub-acidosis which are respectively of 50 % concentrate and 300g/kg DM (Sauvant et al., 2018a). Goats decreased their DMI, but not their net energy intake, when they were fed the C50AS instead of the control diet. This can be explained by a physiological regulation of food intake (Forbes, 1980) with the increase of net energy content of the diet due to the inclusion of sunflower seeds. Patterns of intake were quite similar to those observed with C50 diet with a decrease of the duration and DMI during the first bout.

In all comparisons, there was no effect of changes in diet on eating rate, which was on the same range of values previously observed with dairy goats in mid-lactation (Abijaoude et al., 2000). This parameter seems to be a personality trait of the animals, as already suggested (Hesselbarth, 1955; Melin et al., 2005; Neave et al., 2018).

Feed efficiency decreased with all groups during the second period. This can be explained by a later stage of lactation compared to the first period, with a decrease in milk yield and, consequently, a larger part of maintenance requirements.

The hierarchy among goats for feed efficiency measured at the two periods with goats in mid-lactation was the same as there was a significant correlation between the two values for a given goat. Therefore, feed efficiency is a property of the individual and not easily changed by the composition of the diet. In this study, there was no clear link between feeding behaviour and feed efficiency because the relationship found with the C40 diet was not confirmed after dietary change.

5. Conclusion

We could identify certain parameters, such as the intake during the first eating bout, that were affected by diet composition, potentially to allow the animals to adapt to different diet composition. Other parameters, such as eating rate and feed efficiency seemed more stable, potentially reflecting behaviour could be an interesting tool to better understand variability in feed efficiency and detect health problems. Feeding behaviour is an information that will be easy to obtain in real time with the development of feed stations at the farm level.

Ethics approval

Animals were cared for and handled in accordance with the French legislation on animal experimentation and European Convention for the Protection of Vertebrates Used for Experimental and Other Scientific Purposes (European Directive 86/609). All experimental procedures were approved by the Animal Welfare Advisory Board of the experimental unit (MoSAR, INRAE) and by the local Animal Ethics Committee (No. 45) under the number 13_51.

Credit Author Statement

S. Giger-Reverdin: Conceptualization, Data analysis, Interpretation, Writing – Original draft preparation, Writing – Reviewing and Editing

H. W. Erhard: Data analysis, Interpretation, Writing – Reviewing and Editing

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Table 1. Composition of concentrate in the four diets with 40, 30 and 50 % concentrate (C40, C30, C50A and C50AS) respectively

%DM	C40	C30	C50A	C50AS
Corn	37	32	42	32
Wheat	37	32	42	32
Soybean cake	22	32	12	8
Sunflower seeds	0	0	0	24
Molasses	3	3	3	3
Vitamin and minerals	1	1	1	1

Table 2. Ingredient composition, chemical composition and nutritive value of the four diets

	C40	C30	C50A	C50AS
%DM in diet				
Concentrate	40	30	50	50
Hay	40	50	30	30
Sugarbeet Pulp	20	20	20	20
Chemical composition (g/kg DM)				
Ash	76	76	71	72
Crude Protein	107	108	105	106
Starch	188	109	230	204
NDF	392	448	331	299
ADF	200	243	174	159
ADL	17	24	14	15
Nutritive value*				
UFL/kg DM	0.96	0.91	1.01	1.07
PDI/kg DM	89	88	88	87

*Estimation of the nutritive values with INRA 2018 tables (Baumont et al., 2018)

Table 3. Among goat variability in Body Weight, Fat and Protein Corrected Milk Yield (FPCMY), dry matter intake (DMI), Feed Efficiency (FPCMY/Energy intake) and feeding behaviour (Nbouts: number of feeding bouts; Intake, Part DMI 1^{st} Bout: Ratio between intake during the 1^{st} bout after feed delivery and intake during 15 h, Duration and rate of eating) of 20 goats (average value for the 4 test days) fed the control C40 diet

	Mean	Standard deviation	Coefficient of variation	Minimum	Maximum
Body weight (kg)	65.8	7.74	11.8	57.3	82.3
FPCMY (kg/day)	4.01	0.574	14.3	14.3	5.34
DMI kg/day	2.91	0.288	9.9	9.9	3.67
Feed efficiency (kg/UFL)	1.60	0.135	8.4	8.4	1.85
Nbouts in 15 h	5.15	1.866	36.2	36.2	8.25
Intake (kg)					
DMI in 15h	1.86	0.188	10.1	10.1	2.29
DMI 1^{st} Bout	1.42	0.231	16.3	16.3	1.82
DMIOtherBouts	0.44	0.270	61.4	61.4	1.20
Part DMI 1^{st} Bout	0.767	0.1270	16.6	16.6	0.976
Duration (min) in 15 h					
Eating	216	28.7	13.3	13.3	278
1^{st} Bout	131	36.7	28.0	28.0	213
Other Bouts	85	39.0	45.9	45.9	159
Eating rate					
1^{st} Bout	11.5	2.99	26.0	8.3	20.1
Mean 15 h	5.36	0.769	14.3	4.18	6.90

Table 4 Dry matter Intake (DMI) and feeding behaviour (Nbouts: number of feeding bouts; Intake, Part DMI 1^{st} Bout: Ratio between intake during the 1^{st} bout after feed delivery and intake during 15 h, Duration and rate of eating) of 20 goats (10 Saanen and 10 Alpine) fed the control C40 diet

		Breed		P Value			StandardError
	Repeatability	Alpine	Saanen	Day	Breed	Goat	
DMI kg/day	0.91	2.97	2.81	0.05	0.06	0.12	0.012
Nbouts in 15 h	0.79	5.40	4.90	0.07	0.06	0.0002	0.249
Intake (kg)							
DMI in 15h	0.88	1.89	1.83	0.22	0.11	0.05	0.005
DMI 1^{st} Bout	0.78	1.44	1.40	0.91	0.36	0.19	0.004
DMIOtherBouts	0.85	0.46	0.42	0.94	0.60	0.09	0.014
Part DMI 1^{st} Bout	0.82	0.760	0.774	0.98	0.70	0.34	0.0099
Duration (min) in 15 h							
Eating	0.68	218	214	0.20	0.52	0.01	4.04
1^{st} Bout	0.87	133	128	0.54	0.19	<0.0001	60.5
Other Bouts	0.79	85	86	0.71	0.92	0.14	1.9
Eating rate							
1^{st} Bout	0.83	11.3	11.8	0.57	0.34	0.01	1.17
Mean 15 h	0.68	5.44	5.28	0.80	0.46	0.19	0.25

Repeatability: proportion of the variance between animals on the sum of the between and within animal variances

Table 5. Body weight, Fat and Protein Corrected Milk Yield (FPCMY), dry matter (DMI) and energy (UFL) intake, Feed Efficiency (FPCMY/Energy intake), and feeding behaviour (Nbouts: number of feeding bouts; Intake, Part DMI 1^{st} Bout: Ratio between intake during the 1^{st} bout after feed delivery and intake during 15 h, Duration and rate of eating) changes for six goats changing from the C40 to the C30 diet

	Period 1 (C40)	Period 2 (C30)	P Value
Body weight (kg)	66.3 (8.42)	65.9 (6.82)	0.79
FPCMY kg/day	3.99 (0.240)	3.59 (0.303)	0.04
DMI kg in 24 h	2.92 (0.184)	2.83 (0.242)	0.21
UFL/day	2.55 (0.213)	2.35 (0.245)	0.08
Feed efficiency	1.57 (0.115)	1.53 (0.128)	0.30
Nbouts in 15 h	4.29 (2.009)	6.08 (2.396)	0.04
Intake (kg)			
DMI in 15h	1.88 (0.142)	1.83 (0.149)	0.14
DMI 1^{st} Bout	1.56 (0.232)	1.30 (0.199)	0.14
DMIOtherBouts	0.32 (0.276)	0.53 (0.255)	0.14
Part DMI 1^{st} Bout	0.834 (0.1369)	0.713 (0.1199)	0.14
Duration (min) in 15 h			
Eating	226 (25.8)	237 (38.3)	0.40
1^{st} Bout	161 (44.9)	134 (57.3)	0.17
Other Bouts	65 (44.1)	103 (48.3)	0.09
Eating rate			
1st Bout	10.1 (1.55)	10.4 (2.39)	0.68
Mean 15 h	8.37 (0.538)	7.88 (1.096)	0.30

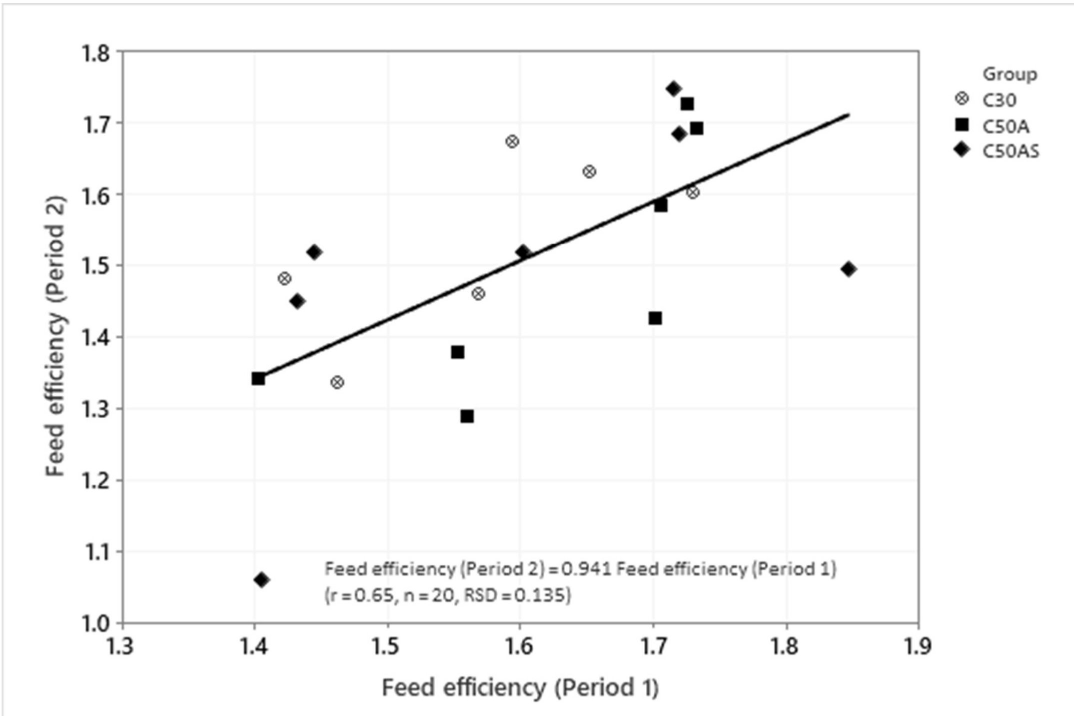
Table 6 Body weight, Fat and Protein Corrected Milk Yield (FPCMY), dry matter (DMI) and energy (UFL) intake, feed efficiency (FPCMY/Energy intake), and feeding behaviour (Nbouts: number of feeding bouts; Intake, Part DMI 1st Bout: Ratio between intake during the 1st bout after feed delivery and intake during 15 h, Duration and rate of eating) changes for seven goats changing from the C40 to the C50A diet

	Period 1 (C40)	Period 2 (C50A)	P Value
Body weight (kg)	64.4 (5.80)	63.7 (6.52)	0.59
FPCMY kg/day	4.02 (0.647)	3.77 (1.111)	0.80
DMI kg in 24 h	2.85 (0.362)	2.88 (0.568)	0.27
UFL/day	2.47 (0.305)	2.50 (0.595)	0.27
Feed efficiency	1.63 (0.124)	1.49 (0.175)	0.035
Nbouts in 15 h	5.21 (2.043)	6.43 (2.414)	0.21
Intake (kg)			
DMI in 15h	1.83 (0.252)	1.93 (0.371)	0.27
DMI 1st Bout	1.37 (0.260)	0.97 (0.312)	0.08
DMIOtherBouts	0.46 (0.208)	0.96 (0.272)	0.04
Part DMI 1st Bout	0.751 (0.1092)	0.496 (0.1306)	0.04
Duration (min)			
Eating	210 (40.4)	216 (49.9)	1.00
1st Bout	118 (6.8)	81 (26.6)	0.04
Other Bouts	93 (38.5)	135 (41.5)	0.04
Eating rate			
1st Bout	11.8 (2.95)	12.1 (2.484)	0.80
Mean 15 h	8.92 (1.761)	9.15 (1.898)	0.67

Table 7. Body weight, Fat and Protein Corrected Milk Yield (FPCMY), dry matter (DMI) and energy (UFL) intake, Feed Efficiency (FPCMY/Energy intake), and feeding behaviour (Nbouts: number of feeding bouts; Intake, Part DMI 1st Bout: Ratio between intake during the 1st bout after feed delivery and intake during 15 h, Duration and rate of eating) changes for seven goats changing from the C40 to the C50AS diet

	Period 1 (C40)	Period 2 (C50AS)	P Value
Body weight	66.8 (9.66)	66.4 (9.52)	0.45
FPCMY kg/day	4.02 (0.760)	3.76 (0.706)	0.21
DMI kg in 24 h	2.93 (0.213)	2.69 (0.408)	0.04
UFL/day	2.50 (0.218)	2.51 (0.363)	0.93
Feed efficiency	1.60 (0.173)	1.50 (0.222)	0.35
Nbouts in 15 h	5.82 (1.491)	6.21 (1.758)	0.40
Intake (kg)			
DMI in 15h	1.88 (0.173)	1.74 (0.209)	0.02
DMI 1st Bout	1.35 (0.166)	0.93 (0.229)	0.04
DMIOtherBouts	0.53 (0.313)	0.81 (0.289)	0.04
Part 1st Bout	0.725 (0.128)	0.540 (0.1423)	0.04
Duration (min)			
Eating	214 (17.4)	196 (30.1)	0.20
1st Bout	118 (35.3)	77 (17.3)	0.05
Other Bouts	96 (33.1)	120 (35.1)	0.15
Eating rate			
1st Bout	12.3 (3.82)	12.2 (1.66)	0.93
Mean 15 h	8.83 (1.186)	9.09 (1.928)	0.80

Figure 1: Relationship between feed efficiencies (FPCMY/Energy intake (kg/UFL)) of 20 individual goats measured during period 1 with a diet containing 40 % concentrate (C40) and period 2 with diets containing either 30 (C30) or 50 % concentrate (C50A or C50AS)



Groups corresponded to the diet fed during the second period