Feed intake and social interactions in dairy goats - the effects of feeding space and type of roughage

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Feed intake and social interactions in dairy goats— the effects of feeding space and type of roughage.

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Abstract

The aim of this experiment was to examine how an increased number of animals per feeding place and type of roughage affected feeding time, feed intake and the level of aggressive competition in groups of dairy goats. We conducted a 3 x 2 factorial experiment with type of roughage (hay or grass silage) and number of goats per feeding place (1, 2 or 3) as the main factors. A total of 48 female goats in mid lactation was randomly divided into eight groups of six animals (mean age 3.7 years). The goats were video recorded for 24 hours at the end of each experimental period, and activity variables such as feeding, queuing, standing/walking and lying were scored using instantaneous sampling with 10 minutes intervals. All incidents of social interactions were scored continuously for six hours between 09:00 and 15:00 hours. Individual goats from each group were ranked as high, medium or low according to the
number of times they were displaced (physically or passively) from the feed barrier by another goat.

Percentage of total observations spent feeding decreased (P<0.0001) and % of total observations spent queuing (P<0.0001) increased with increasing number of goats per feeding place. Silage intake also decreased with 16.2 % from one to three goats per feeding place (P<0.001), but no such effect was found on hay. The reduced feeding space resulted in more than 80 % reduction in feeding time for some individuals. The number of displacements at the feed barrier (P<0.05) and aggressive interactions (P<0.05) increased with an increasing number of goats per feeding place, and the aggression level was higher when offered hay than silage (P<0.0001). Low ranked goats spent significantly less % of total observations feeding (P<0.01) and more % of total observations queuing (P<0.05) than goats in medium and high rank categories, and this effect became more pronounced as the number of goats per feeding place increased.

In conclusion, an increased number of goats per feeding place resulted in a lower % of feeding observations, a larger % of total observations spent queuing, and an increased number of aggressive interactions for both types of roughages. The level of aggressive competition was higher on hay than silage, suggesting a preference for hay. Although the actual feed intake of hay was not reduced by restricting the feeding space as opposed to silage, the dramatic reduction in % of total observations spent feeding for some individuals suggests that more than one goat per feeding place can not be recommended.

Keywords: dairy goats; social interactions; feeding space; roughage; feed intake.
1. INTRODUCTION

Dairy goats in Norway are commonly housed and fed indoors for seven to eight months during winter. Traditionally the goats are fed *ad libitum* with a feeding space of 0.33 – 0.40 m per goat and grouped according to their individual need for feed (Bøe, 2002). Recently there has been an increased interest in simplifying feeding routines by the use of *ad libitum* feeding of roughage in feed racks. These feeding systems may often involve a reduced number of feeding places per animal or a restriction in feeding space and hence competition for access to feed may increase.

Feed can be a limited resource either because the amount of feed is restricted or because the feeding space is not accessible for all individuals in the group. This may not only reduce the average feeding time, but as the competition increases the difference between high and low-status individuals is likely to increase (e.g. Milinski and Parker, 1991; Andersen et al., 1999). Research on housing of goats in general and competition at feeding is scarce. Recent work by Loretz et al. (2004) showed that the proportion of time the animals spent feeding was significantly reduced when the animal/feeding place ratio was increased from 1.0 to 2.0, but surprisingly there was no effect on the number of aggressive interactions. Whereas Henderson (1985) showed that feeding time was reduced and aggressive incidents and queuing increased as ‘face size’ was reduced in ewes fed *ad libitum* on silage, Sveinbjörnsson (1999) did not find any effects of reducing feeding space on feed intake. To maintain a constant level of feed intake as the competition increases, individuals may increase consumption rate or eat at other times of the day, and low-status animals may for example feed when the others are resting.

For dairy cows fed *ad libitum*, several experiments have shown no effect on milk yield or feed
intake of reducing the feeding space (e.g. Friend et al., 1977; Collis et al., 1980), but DeVries et al. (2004) documented an increased feeding time and a decreased aggression level when feeding space was increased from 0.5 to 1.0 m. Furthermore, an increased number of cows per feeding station resulted less time feeding, increased consumption rate and an increased number of displacements (Olofsson, 1999). A similar change in eating strategy towards fewer but longer visits to the feeder and a quicker feeding rate when the level of competition increases, is also documented in pigs (Nielsen et al., 1995).

When feed quality is improved, the goats behave as specialists and become more selective (Aldos and Escos, 1987; Barroso et al., 2000). Type of roughage also influences feed intake. Voluntary dry matter intake in dairy goats is significantly higher on hay than on high-quality silage, and lowest for goats fed poor quality silage (Hussain et al., 1996). Goat farmers report that hay may be more attractive for goats than silage, but to our knowledge there is no scientific documentation to support this. We would expect the level of aggressive competition to be higher for the most attractive type of roughage.

Compared to other female ungulates, goats are reported to have a significantly higher rate of aggressive interactions (Fournier and Festa-Bianchet, 1995). Although some researchers have found a clear, linear dominance structure in groups of goats (Addison and Baker, 1982; Barroso et al., 2000), others claim that the hierarchic system may be less clear and more dynamic (Scott, 1948; Fournier and Festa-Bianchet, 1995; Andersen and Bøe, unpublished). Age, body size and horns seem to be directly related to dominance at least in wild and feral goats (Schackleton and Shank, 1984; Barroso et al., 2000; Shinde et al, 2004).
The aim of this experiment is to examine how an increased number of animals per feeding place and type of roughage affect feeding time, feed intake and the level of aggressive competition in groups of dairy goats. We predict that an increased number of animals per feeding place will increase the number of agonistic interactions, and that the time spent feeding and feed intake will decline. Since hay appears to be more attractive than silage we predict that the goats will show a higher level of aggressive competition when fed hay. Furthermore, we predict that low-status goats will suffer more from a restricted feeding space in terms of less time spent feeding and more time queuing, than high-status individuals.

2. MATERIALS AND METHODS

2.1 Experimental design

Eight groups, each containing 6 dairy goats, were used to conduct a 3 x 2 factorial experiment with number of goats per feeding place (1, 2 and 3), and type of roughage (silage and hay) as treatments. In period 1, groups 1-4 had free access to silage and groups 5-8 had free access to hay. In period 2, the roughage was switched between groups, so that groups 1-4 were fed hay and groups 5–8 were fed silage. Within each experimental period (1 and 2), all groups were exposed to all feeding space treatments (1, 2 and 3 goats per feeding place), one week for each feeding space treatment. The goats were allowed 10 days to acclimatize to each type of roughage.

2.2 Experimental pens
The experiment was performed in an insulated, mechanically ventilated building where the ambient air temperature was kept around 5 – 10 °C. The experimental pens had expanded metal flooring and were 3.0 m wide and 1.9 m deep, with a space allowance of 0.9 m² per animal. Originally, the pens had 6 feeding places (one goat per feeding place). In order to increase the number of animals per feeding place to 2 and 3 respectively, 3 and 4 of the feeding places were blinded by solid wooden wallboards. In each pen the goats had free access to water from a standard nipple drinker.

2.3 Animals and feeding

Forty-eight healthy, hornless dairy goats of the Norwegian dairy breed, on average 3.7 years old (range 2 – 8 years) and in mid lactation, were used in the experiment. The goats were taken out of their pens and milked twice a day. Duration of milking period was approximately 1.5 hours (between 07.00-08.30 and 15.00-16.30), but each group of goats was in the milking parlour for no more than 25 minutes before it was turned to its home pen. Average milk yield and body weight at start of the experiments was similar in all groups (mean ± SE, milk: 2.7 ± 0.08 kg per day; body weight: 55 ± 0.2 kg). The goats were weighed both at start of period 1 (September) and start of period 2 (January).

The residual roughage from each group was weighed on an electronic balance every morning, the actual feed intake was calculated, and every group was then given 120 % of the calculated feed consumption. Roughage waste in the pens (especially hay) was carefully gathered and weighed together with the residuals. In addition to roughage, the goats were given 1.2 kg of a
standard concentrate (\(^1\)Metabolizable energy content: 1.03 MJ NE\(_1\) / kg DM), twice a day in the milking parlour.

Four days every week samples were taken both from the fresh hay and the silage and from the residuals. The roughage quality was good and the energy content per kg dry matter was 0.9 ± 0.08 MJ NE\(_1\) / kg DM for silage and 0.77 ± 0.02 MJ NE\(_1\) / kg DM for hay (Table 1). Except from an increased content of butyric acid in the silage in period 2 (0.11 ± 0.001) compared to period 1 (0.012 ± 0.0004; \(t=4.30, P=0.02\)), there were no significant differences in roughage quality between the two periods.

Table 1 here

2.4 Behavioural observations

The goats were individually marked on their back and sides using numbers from 1 to 6. A video camera was suspended over each of the eight pens, and connected to a multiplexer unit (Robot MV 16 colour) and a time-lapse video recorder (Panasonic AG6730). The animals were video recorded for 24 hours at the end of each experimental period, and the recording started at 9 a.m., immediately after morning milking. The goats’ behaviours over 24 hours (from 10.00 a.m. to 09.50 a.m. the next morning) were scored using instantaneous sampling every 10 minutes with the following ethogram:

- Feeding (the goat stands with the head over the feed, through the feed barrier)

\(^1\)Metabolizable energy content in the concentrate feed; derived from the Nordic energy evaluation system, feed units milk (FEm), (Ekern, 1991). NE\(_1\) denotes the net energy content for lactation.
• Queuing (head oriented towards the feed barrier, standing less than 0.5 m behind another goat that is feeding)
• Standing / walking (activity outside the feed barrier area)
• Lying
• Out for milking

From the videotapes, social interactions were scored continuously for six hours (between 9 a.m. and 3 p.m.), using the following ethogram of mutually exclusive events (e.g. Shank, 1972):

• Physical displacement at feed barrier (a goat is forced to leave the feed barrier because another goat is butting or pushing her)
• Passive displacement at feed barrier (a goat leaves the feed barrier because another goat is approaching her, but without physical contact)
• Displacement attempt at the feed barrier (a goat does not respond / ignores the attempts of another goat to physically displace her from the feed barrier)
• Frontal clashing (the actor is rearing onto the hind legs with the head and torso twisted followed by descending forcefully onto the hind legs delivering a powerful strike forward and downwards reaching the head of the receiver)
• Butting with the head towards the head or shoulders of another goat
• Butting with the head towards the body of another goat
• Chasing (moving quickly after another goat that tries to escape).
• Withdrawing (a goat moves the head and/or the body away from another goat after an interaction with butting or clashing)
Avoidance (a goat moves the head or body away from an approaching goat, but with no direct physical interaction to avoid physical contact)

Physical displacements, clashing, butting and chasing were summarized into total number of aggressive behaviours.

We also scored which of the goats initiated and received the social behaviours.

Individual goats from each group were ranked as high, medium or low according to the number of times they were displaced (physically or passively) from the feed barrier by another goat. Data from the hay treatment were used, since this was the roughage type causing the most displacements at the feed barrier. By using MatMan 1.1 (software for matrix manipulation and analysis), we converted a matrix of displacement activity among the goats (based on all the treatments) in each group into a matrix of dominance relationships. The dominant animal of each pair was given the value ‘1’ whereas a subordinate individual was assigned the value ‘0’. If the dominance relationship was undecided (either because no dominance interactions occurred or because both animals performed an equal number of interactions to each other), both animals were given the value ‘0.5’. We defined a goat to be high ranking when she was dominant over 4 - 5 other goats, medium ranked when she dominated over 2 – 3 other goats and finally low ranking if she dominated over 0 – 1 goat in the home pen.

2.5 Statistical analysis
In order to test the effect of number of goats per feeding place on the feed intake (difference between weight of daily offered feed and weight of residues) within each roughage type, we used a mixed model of analysis of variance with the following class variables: number of goats per feeding place (1, 2 or 3), day of the week (1, 2, 3, 4 or 5) and group (1 to 8). Group was specified as a random effect (Hatcher and Stepanski, 1994).

A similar mixed model of analysis of variance was also applied to test the effect of number of goats per feeding place and roughage type on activity and social behaviour, using number of goats per feeding place (1, 2 or 3), roughage type (silage or hay), the interaction between number of feeding places and roughage type and group (1 to 8, random effect) as class variables. Mean values per group were used as statistical unit.

The relationship between social rank category (high, medium or low) and time spent feeding and queuing within each treatment (1, 2 or 3 goats per feeding place) while fed on hay was investigated by using a mixed model of analysis of variance with group (random effect) and rank category as class variables. Possible weight and age differences between rank categories were revealed by using an analysis of variance (GLM-model) with rank category as class variable.

A Student-Newman Keul’s test was used to find differences between means in the main statistical models. Finally, a two-sample t-test was used to investigate differences in dry matter consumption between hay and silage and difference in silage quality (butyric acid content) between the two experimental periods.

3. Results
3.1 Feed intake

The daily consumption of silage decreased significantly from 4.3 ± 0.15 kg per goat in the treatment with one goat per feeding place to 3.6 ± 0.16 kg per goat (a total reduction of 16.2 %) in the treatment with three goats per feeding place (Fig. 1). For hay, there was no significant effect of number of goats per feeding place on daily consumption.

Figure 1 here.

The dry matter (DM) consumption was greater for hay (1.15 ± 0.05) than for silage (0.9 ± 0.03, \( t=2.0, P<0.01 \)), suggesting a preference for hay. Analysis of the roughage quality showed that the digestible crude protein content and RPB (ruminal protein balance) in hay were both lower and neutral detergent fibre (NDF) was higher in the residuals than in the offered feed, suggesting that the goats were selective in their feed consumption (Table 1). No such effect was found on silage.

3.2 Time spent feeding

The goats spent less % of total observations feeding when offered silage compared to hay, and the % of total observations spent feeding also decreased with increasing number of goats per feeding place (Table 2).

Table 2 here
There was a significant interaction between number of goats per feeding place and roughage type ($F_{2,4}=3.5, P<0.05$). In the hay treatment, time spent feeding decreased from 21.6 % at one goat per feeding place (5.2 h) to 17.3 % (4.1 h) at 2 goats per feeding place and 12.6 % at 3 goats per feeding place (3.0 h), which is equivalent to a total 41.5 % reduction (Fig. 2). In the silage treatment time spent feeding decreased from 16.2 % (3.8 hours) at 1 goat per feeding place to 12.4 % (2.9 hours) and 11.4 % (2.7 hours) at 2 and 3 goats per feeding place respectively (a total reduction equivalent to 28.9 %).

The variation in % of total observations spent feeding (CV) increased significantly when increasing the number of goats per feeding place, and was higher when the goats were fed hay than when fed silage (Table 2). After increasing from 1 to 3 goats per feeding place, 31.2 % (15) of the goats reduced their time spent feeding by more than 40 % when fed silage, and 54.1 % (26) of the goats reduced their feeding time by more than 40 % when fed hay. Two animals (4.1 %) reduced their feeding time by more than 80 % when fed silage, whereas the corresponding number for hay was 5 animals (10.4 %). In fact, two goats in the hay treatment were not observed to feed on roughage at all in the treatment with 3 goats per feeding place (data from video recordings). In two different groups the dominant goat was observed to lie down in front of the feed barrier, thereby controlling access to feed even when this goat had finished feeding.

At 1 goat per feeding place, all six feeding places were only occupied at 0.3 % and 2.3 % of the observations for silage and hay, respectively (Table 3). Furthermore, four or more feeding places were occupied for 6.4 % of the observations when fed silage and 14.0 % of the
observations when fed hay. The data from the treatments with 2 and 3 goats per feeding place showed that the goats utilized all the available feeding places more frequently when fed hay compared to silage (Table 3), indicating a higher degree of synchronisation.

Table 3 here

In the treatments with 1 goat per feeding place, the goats had two peaks in their feeding activity, after morning and afternoon milking (Fig. 3). Especially between 10:00 and 14:00 hours, more goats were feeding simultaneously in the hay than in the silage treatment.

Figure 3 here

3.3 General activity

Percentage of total observations spent lying increased with increasing number of goats per feeding place, and they spent more % of total observations standing/walking when fed silage compared to hay (Table 2).

Queuing at the feed barrier increased with an increasing number of goats per feeding place (Table 2), but there was no significant difference between the treatments with two and three goats per feeding place when fed hay (Fig. 4).

Figure 4 here

3.4 Social interactions
The number of aggressive interactions increased significantly with increasing number of goats per feeding place (Table 2). Furthermore, number of physical displacements and number of aggressive behaviours in general were significantly higher when the goats were given hay as opposed to silage (Table 2). There was also an interaction between feeding space and type of roughage, showing an increased number of aggressive interactions with increasing number of goats per feeding place on hay, but not on silage (Fig 5).

Figure 5 here

Concerning butting towards head and shoulders, there was a significant interaction between number of goats per feeding place and roughage type ($F_{2,34}=3.5; P<0.05$), showing a decreased frequency with an increased number of goats per feeding place in the silage treatment, whereas in the hay treatment the frequency of this behaviour was highest at 2 goats per feeding place and lowest at 3 goats per feeding place.

The number of avoidances and displacement attempts at the feed barrier increased when fed hay compared to silage (Table 2).

Butting towards the body of another goat ($0.4 \pm 0.1$), chasing ($0.2 \pm 0.0$), and withdrawing ($1.0 \pm 0.1$) were all social behaviours rarely seen, and none of them were significantly affected by feeding place treatment or type of roughage.

Social dominance
Goats in the high rank category tended to have larger body weights (mean ± SE kg, 62.6 ± 1.9) than goats in the medium (58.2 ± 1.6) and low rank category (56.8 ± 2.2, $F_{2,45} = 1.0$, $P<0.1$). Since only data from the hay treatments were used, the weight data for groups 1-4 is based on the live body weights in January and hence these are higher than initial weights. Age did not differ significantly between rank categories in any of the treatments.

High ranked goats spent significantly more % of total observations feeding hay than goats in medium and low rank categories, and this effect became more pronounced as the number of goats per feeding place increased (mean ± SE %, 1 goat per feeding place: high: 24.0 ± 1.2, medium: 21.3 ± 1.5, low: 18.7 ± 2.0, $F_{2,38} = 2.7$, $P<0.1$; 2 goats per feeding place: high: 20.9 ± 1.4, medium: 15.5 ± 1.7, low: 15.6 ± 1.3, $F_{2,38} = 4.4$, $P<0.05$; 3 goats per feeding place: Fig 6).

High ranked goats spent less % of total observations queuing than goats in the medium and low rank categories (mean ± SE %, 1 goat per feeding place: high: 0.4 ± 0.2, medium: 0.7 ± 0.3, low: 1.6 ± 0.5, $F_{2,38} = 4.0$, $P<0.05$; 2 goats per feeding place: high: 2.5 ± 0.6, medium: 6.0 ± 0.8, low: 4.4 ± 0.8, $F_{2,38} = 5.4$, $P<0.01$; 3 goats per feeding place: high: 3.5 ± 0.8, medium: 4.2 ± 0.7, low: 4.4 ± 0.7, $F_{2,38} = 3.0$, $P<0.1$).

4. Discussion

As predicted and previously documented in sheep and cattle (Arnold and Dudzinski, 1987; Bøe and Andersen, unpublished; Olofsson, 1999; DeVries et al., 2004), increasing the number of goats per feeding place from 1 to 3 resulted in a decreased % of total observations spent...
feeding, an increased % of total observations spent queuing and an increased number of
displacements and aggressive interactions. In comparison, Loretz et al. (2004) found a
decrease in time spent feeding when the number of goats per feeding place was increased
from 0.5 to 1.0. Reduced feeding space is not reported to have any effects on performance in
sheep and cattle (Sveinbjörnsson, 1999; Friend et al., 1977; Collis, 1980). In the present
experiment, the feed intake of silage declined with an increasing number of goats per feeding
place but not for hay. A change in eating rate and feeding strategy with increased competition
is documented both in cattle and pigs (Nielsen et al., 1995; Olofsson, 1999). However, it is
important to be aware that feed intake was recorded on group-level only in the present
experiment, and that the total feed intake for each group may be maintained if some
individuals eat more whereas others eat less. The goats in our experiment also showed a larger
individual variation in % of total observations spent feeding hay compared to silage, and this
supports the suggestion that some individuals spent more % of total observations feeding,
whereas others hardly had any access to feed, as the number of goats per feeding place
increased.

As pointed out by Shinde et al. (2004) and Olofsson (1999), the easiest way to maintain
feeding time when the feeding space is reduced would be to consume the feed at different
times of the day. At three goats per feeding place, the two feeding places were occupied less
than 50 % of the observations. Even in the ‘1 goat-per-feeding place’ treatment, four or more
feeding places were occupied less than 6 % (silage) and 14 % (hay) of the observations. These
results correspond to what is previously found in ewes (Bøe and Andersen, unpublished).
Hence, it seems that the goats are not well synchronized in their feeding behaviour, especially
in a competitive environment where one dominant goat easily can monopolize the space in
front of the feed barrier. In some pens the subordinate goats could feed as soon as the more
dominant goats were finished, but in other groups the dominant goat would control the feed barrier area by simply lying there. Shinde et al. (2004) also argues that in some cases the dominant goats do not allow sub-ordinates to consume sufficient feed. In the present experiment, low-status goats spent less % of total observations feeding and more % of total observations queuing than high-status goats, and this effect became more evident as the feeding space was restricted. Thus, the cost of increased competition is much higher for subordinates than dominants.

Generally, the dry matter intake (DMI) of hay was greater than silage. This corresponds well with previous findings (e.g. Hussain et al., 1996), and also explains the longer eating time on hay. Interestingly, the quality of hay residuals were lower than in the offered feed, but for silage no such difference was found. This implies that the goats were more selective when feeding on hay than on silage. Usually hay is harvested at a later stage of growth, and this makes it possible for the goats to distinguish the more preferred parts like leaves from the less palatable and more fibrous stalks. In a comprehensive review, Baumont et al. (2000) concluded that on a heterogeneous pasture, goats graze selectively and choose the best parts of what is offered. Correspondingly, Barroso et al. (2000) and Alados and Escos (1987) stated that when forage quality is improved in controlled experimental situations, the goats behave as specialists and become more selective in their feed intake.

The goats spent more % of total observations feeding hay than silage and the individual variation in % of total observations feeding was greater on hay. Similar to what is found in sheep (Bøe and Andersen, unpublished), % of total observations spent queuing and the number of displacements and aggressive interactions was higher when the goats were offered
hay compared to silage. Since the goats were more willing to compete aggressively for access
to recently offered hay, this suggests that the goats preferred hay to silage.

Restricting the feeding space had more dramatic effects on some individuals than others. For
example, some goats reduced their % of total observations feeding by more than 80 %
irrespective of roughage type. This appears to be a larger problem than that reported in sheep
and cattle (Henderson, 1985; Olofsson, 1999; Bøe and Andersen, unpublished; DeVries et al.,
2004), and may reflect the more competitive nature in goats compared to other ungulates
(Fournier and Festa-Bianchet, 1995). Goats in the high rank category tended to weigh more
than goats in medium and low rank categories, but neither weight nor age seemed to be good
predictors of dominance in the present study. Comparatively, Shinde et al. (2004) found that
weight was correlated to social rank, but not age.

In conclusion, an increased number of goats per feeding place resulted in a lower % of total
observations spent feeding, a larger % of total observations spent queuing, and an increased
number of aggressive interactions for both types of roughages. The level of aggressive
competition was higher on hay than silage, suggesting a preference for hay. Although the
actual feed intake of hay was not reduced by restricting the feeding space as opposed to
silage, the dramatic reduction in % of total observations spent feeding for some individuals
suggests that more than one goat per feeding place is not recommended.

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and Erling Thuen for the valuable comments on the analysis of feed quality. The experiment was funded by the Norwegian Research Council.

References


2 Landbruksforlaget, Oslo, pp. 193-213.


### Table 1. Nutritional values (mean ± SE) of the roughage.

<table>
<thead>
<tr>
<th></th>
<th>Silage</th>
<th>Hay</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Offered</td>
<td>Residue</td>
</tr>
<tr>
<td>Number of samples</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Dry matter (%)</td>
<td>23.4 ± 0.38</td>
<td>26.2 ± 0.64</td>
</tr>
<tr>
<td>Digestible crude protein (g/kg DM)</td>
<td>120.8 ± 3.35</td>
<td>122.0 ± 3.77</td>
</tr>
<tr>
<td>Neutral detergent fibre, NDF (g/kg DM)</td>
<td>89.3 ± 0.55</td>
<td>85.3 ± 0.80</td>
</tr>
<tr>
<td>pH</td>
<td>3.9 ± 0.03</td>
<td>4.0 ± 0.06</td>
</tr>
<tr>
<td>Metabolizable energy, FEm(^1) (MJ NE(_{1})/Kg DM)</td>
<td>0.9 ± 0.08</td>
<td>0.8 ± 0.007</td>
</tr>
</tbody>
</table>

\(^1\)FEm, feed unit milk (Ekern et al., 1991), calculated energy content in feed, 1 FEm = 6900 kJ NE\(_{1}\), where NE\(_{1}\) is the net energy for lactation. FEm is equivalent to the net energy of 1 kg barley with 86 % DM.
Table 2. Activity pattern and social behaviours in the different treatments (mean ± SE). All variables related to activity pattern except for CV for feeding, are given in % of total observations, whereas social interactions are given in number of incidents /6 hours.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number of goats per feeding place</th>
<th>Roughage type</th>
<th>F 2,34</th>
<th>P</th>
<th>Silage</th>
<th>Hay</th>
<th>F 1,34</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td></td>
<td>Silage</td>
<td>Hay</td>
<td></td>
<td></td>
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<tr>
<td>Feeding</td>
<td>19.9 ± 1.1 ^a</td>
<td>14.9 ± 0.8 ^b</td>
<td>12.0 ± 1.7 ^c</td>
<td>33.41</td>
<td>&lt;0.0001</td>
<td>13.4 ± 0.5 ^a</td>
<td>17.2 ± 1.0 ^b</td>
<td>30.42</td>
</tr>
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<td>CV for feeding (%)</td>
<td>23.8 ± 2.5 ^a</td>
<td>31.9 ± 3.4 ^a</td>
<td>43.2 ± 5.5 ^b</td>
<td>8.69</td>
<td>&lt;0.001</td>
<td>27.7 ± 2.2 ^a</td>
<td>38.4 ± 4.4 ^b</td>
<td>8.20</td>
</tr>
<tr>
<td>Queuing</td>
<td>0.6 ± 0.2 ^a</td>
<td>2.8 ± 0.5 ^b</td>
<td>3.2 ± 0.4 ^b</td>
<td>23.31</td>
<td>&lt;0.0001</td>
<td>1.4 ± 0.2 ^a</td>
<td>3.1 ± 0.5 ^b</td>
<td>25.52</td>
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<tr>
<td>Standing/walking</td>
<td>27.1 ± 1.3</td>
<td>25.7 ± 1.0</td>
<td>25.2 ± 1.0</td>
<td>0.82</td>
<td>ns</td>
<td>27.5 ± 0.8 ^a</td>
<td>24.5 ± 0.9 ^b</td>
<td>5.72</td>
</tr>
<tr>
<td>Lying</td>
<td>51.0 ± 1.7 ^a</td>
<td>54.1 ± 1.2 ^ab</td>
<td>56.5 ± 1.2 ^b</td>
<td>4.08</td>
<td>&lt;0.05</td>
<td>55.1 ± 1.0</td>
<td>52.6 ± 1.4</td>
<td>2.64</td>
</tr>
<tr>
<td>Physical displacements</td>
<td>12.4 ± 1.0 ^a</td>
<td>16.4 ± 1.4 ^b</td>
<td>20.0 ± 2.2 ^b</td>
<td>4.95</td>
<td>&lt;0.05</td>
<td>9.2 ± 0.6 ^a</td>
<td>23.4 ± 1.6 ^b</td>
<td>46.36</td>
</tr>
<tr>
<td>Passive displacements</td>
<td>0.8 ± 0.15 ^a</td>
<td>0.4 ± 0.1 ^b</td>
<td>0.4 ± 0.12 ^b</td>
<td>5.62</td>
<td>&lt;0.01</td>
<td>0.5 ± 0.1</td>
<td>0.6 ± 0.1</td>
<td>0.08</td>
</tr>
<tr>
<td>Displacement attempt</td>
<td>0.1 ± 0.05</td>
<td>0.2 ± 0.06</td>
<td>0.2 ± 0.05</td>
<td>0.8</td>
<td>ns</td>
<td>0.1 ± 0.03 ^a</td>
<td>0.3 ± 0.05 ^b</td>
<td>11.5</td>
</tr>
<tr>
<td>Avoidance</td>
<td>0.5 ± 0.2</td>
<td>0.3 ± 0.07</td>
<td>0.6 ± 0.2</td>
<td>1.7</td>
<td>ns</td>
<td>0.3 ± 0.05 ^a</td>
<td>0.7 ± 0.17 ^b</td>
<td>4.3</td>
</tr>
<tr>
<td>Frontal clashing</td>
<td>2.8 ± 0.2</td>
<td>3.0 ± 0.3</td>
<td>2.4 ± 0.3</td>
<td>0.55</td>
<td>ns</td>
<td>2.3 ± 0.2</td>
<td>3.2 ± 0.2</td>
<td>3.47</td>
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<tr>
<td>Butting towards the head</td>
<td>0.4 ± 0.07 ^a</td>
<td>0.3 ± 0.07 ^ab</td>
<td>0.1 ± 0.04 ^b</td>
<td>3.67</td>
<td>&lt;0.05</td>
<td>0.2 ± 0.04 ^a</td>
<td>0.3 ± 0.06 ^b</td>
<td>4.52</td>
</tr>
<tr>
<td>Aggressive behaviours</td>
<td>16.4 ± 1.8 ^a</td>
<td>19.1 ± 2.3 ^ab</td>
<td>23.2 ± 3.9 ^b</td>
<td>3.70</td>
<td>&lt;0.05</td>
<td>12.2 ± 0.9 ^a</td>
<td>26.8 ± 2.3 ^b</td>
<td>51.3</td>
</tr>
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</table>
Table 3. Number of animals feeding at the same time (mean ± SE % of total observations).

<table>
<thead>
<tr>
<th>Number of goats feeding together</th>
<th>Silage</th>
<th>Hay</th>
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<tbody>
<tr>
<td></td>
<td>Goats per feeding place</td>
<td>Goats per feeding place</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
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<tr>
<td>0</td>
<td>53.2 ± 1.4</td>
<td>52.5 ± 2.6</td>
</tr>
<tr>
<td>1</td>
<td>19.8 ± 1.4</td>
<td>25.3 ± 3.0</td>
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<tr>
<td>2</td>
<td>11.9 ± 1.3</td>
<td>16.1 ± 0.8</td>
</tr>
<tr>
<td>3</td>
<td>8.7 ± 1.0</td>
<td>5.6 ± 1.1</td>
</tr>
<tr>
<td>4</td>
<td>3.9 ± 0.6</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>2.2 ± 0.3</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0.3 ± 0.2</td>
<td>0</td>
</tr>
</tbody>
</table>
**Legend to figures**

Figure 1. Daily intake of silage and hay (mean intake per goat + SE kg). Difference between number of goats per feeding place, within feed type: a, b, c: P<0.001.

Figure 2. Feeding (mean + SE % of observations) in the different experimental treatments. Number of goats per feeding place: a, b, c: P<0.0001. Roughage treatment: ** P<0.01.

Figure 3. Differences over 24 hours in mean number of goats per pen feeding on hay or silage in the treatment with 1 goat per feeding place.

Figure 4. Queuing (mean + SE % of observations) in the different experimental treatments. Number of goats per feeding place: a, b: P<0.0001. Roughage treatment: * P<0.05, ** P<0.01.

Figure 5. Number of aggressive behaviours (mean + SE incidents / 6 hours) in the different experimental treatments. Number of goats per feeding place: a, b, c: P<0.05. Roughage treatment: * P<0.05, ** P<0.01.

Figure 6. Differences between high, medium and low-ranked goats in the % of total observations spent feeding hay with 3 goats per feeding place. a, b: P<0.01.
Fig 1.
Fig 2.
Mean number of goats feeding

New feed offered
Afternoon milking
Morning milking

Hay
Silage

Fig 3.
Fig 4.
Fig 5.
Fig 6.