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1 **Intake, milk production and grazing behaviour responses of strip-grazing dairy goats to**  
2 **daily access time to pasture and to dehydrated lucerne supplementation**

3

4 A. Charpentier<sup>1,2</sup>, H. Caillat<sup>2</sup>, F. Gastal<sup>2</sup>, R. Delagarde<sup>1</sup>

5 <sup>1</sup> PEGASE, INRA Agrocampus Ouest, 16 Le Clos, F-35590 Saint-Gilles, France

6 <sup>2</sup> FERLus, INRA, F-86600 Lusignan, France

7 Corresponding author: Remy Delagarde. Email: [remy.delagarde@inra.fr](mailto:remy.delagarde@inra.fr)

8

9 **Abstract**

10 The ability of grazing dairy goats to adapt to short daily access time to pasture is not well  
11 known, while, in practice, access time to pasture (AT) is often lower than 12 h/d. A 3-week  
12 trial was carried out in spring with 36 Alpine dairy goats in mid-lactation to study the effect  
13 of a restriction of access time to pasture, coupled or not with a dehydrated lucerne  
14 supplement. Three treatments were compared: (1) 7 h/d of access time to pasture, between  
15 milkings, without dehydrated lucerne (namely AT7); (2) 7 h/d of access time to pasture,  
16 between milkings, with 371 g DM/d of dehydrated lucerne, distributed individually after  
17 evening milking (namely AT7D); and (3) 11 h/d of access time to pasture, 7 h/d between  
18 milkings plus 4 h/d after evening milking, without dehydrated lucerne (namely AT11). The  
19 daily pasture allowance was 2.3 kg DM/goat at 4 cm above ground level in each treatment.  
20 Each goat received 602 g DM/d of a commercial concentrate, given twice daily at milking.  
21 Pasture intake decreased by 433 g DM/d (i.e. 18%) between AT11 and AT7 (P<0.01). Pasture  
22 intake also decreased by 259 g DM/d between AT7 and AT7D (P<0.01), which means a  
23 substitution rate of 0.72 between pasture and dehydrated lucerne. Milk production, and milk  
24 fat and protein concentrations were not affected by AT (P>0.10). Milk production response to  
25 dehydrated lucerne was 0.82 kg of milk/kg DM. Grazing time decreased by 2.5 h/d between

26 AT11 and AT7 or AT7D ( $P < 0.001$ ). The pasture intake rate averaged 272 g DM/h and tended  
27 to increase between AT11 and AT7 ( $P = 0.08$ ). It is concluded that an access time to pasture of  
28 7 h/d may be sufficient for lactating dairy goats receiving 600 g/d of concentrate and grazing  
29 high-quality pastures. Supplying 400 g/d of dehydrated lucerne has a much stronger positive  
30 effect on milk production than an additional grazing period of 4 hours after evening milking.

31

32 **Keywords:** dairy goat, time restriction, pasture intake, behaviour, milk production

33

### 34 **1. Introduction**

35 Grazing is a good way to improve the feed self-sufficiency of dairy goat farms. To help  
36 farmers to optimise their management choices, the impact of grazing management practices  
37 on intake, performance and grazing behaviour of dairy goats need to be quantified. In many  
38 grazing systems, dairy and suckling cows have an unrestricted daily access time to pasture,  
39 being able to graze day and night. Conversely, small ruminants, and particularly lactating  
40 dairy goats, are only allowed to graze during the daytime, with these animals being kept  
41 indoors at night for preventing theft, predation, diseases, or health problems, but also to  
42 facilitate farmers' work organisation (Idele, 2011; Tovar-Luna et al., 2011). Nevertheless,  
43 daily access time to pasture may also be a time constraint for grazing goats that need time to  
44 graze as the other ruminants.

45 Responses of dairy goats to restriction of daily access time lower than 12 h/d are scarce in the  
46 literature. It is, however, probably within this range that access time mostly impacts pasture  
47 intake, milk production and behavioural responses, as shown on meat goats (Berhan et al.,  
48 2005; Romney et al., 1996) and on dairy goats (Charpentier and Delagarde, 2018; Keli et al.,  
49 2017). For lactating dairy goats milked twice daily, the interval between morning and evening  
50 milkings is often close to 7-8 hours. Therefore increasing access time to pasture to 10 to 12

51 h/d implies a new daily pasture allocation, after evening milking and before night. The ability  
52 of goats to eat a large amount of pasture and to produce milk, with or without this post-  
53 evening milking period, as well as the ability to replace it with a dietary supplement, is  
54 unknown.

55 The aim of this experiment was to study the effect of a restriction of access time to pasture, by  
56 suppressing access to pasture after the evening milking and to test the goats' responses to the  
57 replacement of this evening grazing period with a supplement based on dehydrated lucerne.

58

## 59 **2. Materials and methods**

60 This experiment was carried out according to a completely randomised design in spring 2016,  
61 over 3 consecutive weeks, from 1 April to 22 April, at the INRA experimental farm of  
62 Méjusseume (1.71°W, 48.11°N, Le Rheu, Brittany, France). The procedures relating to the  
63 care and management of the animals used for this trial were approved by an animal care  
64 committee from the French Ministry of Agriculture, in accordance with French regulations  
65 (decree-law 2001-464, 29 May 2001).

66

### 67 *2.1 Treatments*

68 Three treatments were compared: (1) 7 h/d of access time to pasture without dehydrated  
69 lucerne (namely AT7); (2) 7 h/d of access time to pasture with a fixed amount of dehydrated  
70 lucerne (namely AT7D); and (3) 11 h/d of access time to pasture without dehydrated lucerne  
71 (namely AT11). Goats had access to pasture from 09:00 to 16:00 in AT7 and AT7D, and from  
72 08:00 to 16:00 and 17:30 to 20:30 in AT11. The AT11 goats had access to pasture one hour  
73 earlier in the morning to be back inside before sunset (between 20:45 and 21:00). Goats on  
74 treatment AT7D received individually 371 g DM/d of dehydrated lucerne distributed once  
75 daily after PM milking (Table 1).

76 The first week of the experiment was an adaptation period and the second and third weeks  
77 were for measurements. For each treatment, the daily pasture allowance was 2.4 kg DM/goat  
78 determined at 4 cm above ground level. Each goat received 301 g DM of a commercial  
79 concentrate (Table 1) through an automatic feeder in the milking parlour twice daily (i.e. 602  
80 g DM/d). The concentrate consisted of the following ingredients on a dry matter basis: barley,  
81 28%; sugar beet pulp, 24%; soyabean meal, 23%; lucerne, 11.5%; wheat bran, 6%; molasses,  
82 3%; linseed, 2%; vegetable oils, 1%; sodium chloride, 0.5%. Goats were milked twice daily at  
83 07:00 and 16:15. Goats were penned inside and bedded on deep litter at night. Water was  
84 available at pasture and indoors and a mineral lick was available only indoors.

85

86 *{Insert Table 1 approximately here}*

## 87 2.2 Goats

88 Thirty-six multiparous Alpine goats were selected for the experiment. Their average kidding  
89 date was 10 February 2016. Goats were fed *ad libitum* with grass hay plus concentrate from  
90 kidding until turn-out to pasture on 7 March 2016. After a transition period from hay to  
91 pasture, all goats grazed together as one single herd with 602 g DM/d of concentrate, 371 g  
92 DM/d of dehydrated lucerne and 7 h/d of access to pasture from 20 March to 30 March. Three  
93 homogeneous groups of 12 goats were balanced according to their individual characteristics  
94 measured from 21 March to 27 March: lactation number ( $3.9 \pm 1.6$  lactations), stage of  
95 lactation ( $47 \pm 5.6$  days in milk), milk production ( $3.7 \pm 0.6$  kg/d), milk fat concentration  
96 ( $38.5 \pm 3.9$  g/kg), milk protein concentration ( $31.0 \pm 2.7$  g/kg) and body weight ( $53.6 \pm 7.1$   
97 kg). The difference between groups did not exceed 2% for any of these variables, except for  
98 lactation number (6%). Each group was then affected to one of the three treatments for the  
99 duration of the experiment.

100

101 *2.3 Pasture and grazing management*

102 The pasture used was sown in autumn 2011 with a mixture of perennial ryegrass (*Lolium*  
103 *perenne* L. cv Tryskal, 10 kg/ha), tall fescue (*Festuca arundinacea* Schreb cv Callina, 10  
104 kg/ha), white clover (*Trifolium repens* L. cv Trissid, 3 kg/ha), chicory (*Cichorium intybus* L.  
105 cv Puna, 1 kg/ha) and inoculated lucerne (*Medicago sativa* L. cv Prunelle, 10 kg/ha).

106 The 2-ha pasture was divided into three paddocks: two 6000 m<sup>2</sup> paddocks and one 8000 m<sup>2</sup>  
107 paddock. The largest was grazed during the pre-experimental period. During the experiment,  
108 the two 6000 m<sup>2</sup> paddocks were divided into three sub-paddocks by electric fences for  
109 approximately 10 days of grazing in each paddock. The three groups of goats grazed in  
110 adjacent sub-paddocks, working in a strip-grazing system with the front fence moved daily  
111 and the back fence moved twice weekly. The area allocated daily to each treatment was  
112 calculated from a daily estimate of pre-grazing pasture mass by multiplying daily pre-grazing  
113 sward height by sward bulk density (see 2.4. *Feed and pasture measurements*).

114

115 *2.4. Feed and pasture measurements*

116 The dry matter concentration of the commercial concentrate, of the specific concentrate  
117 containing ytterbium oxide for intake measurement (called Yb-concentrate, see chapter 2.5.2),  
118 and of dehydrated lucerne was determined daily from days 14 to 15 and from days 18 to 21 on  
119 100-g subsamples.

120 On days -2, 4, 8, 13 and 18, pasture was sampled on 2 strips of 0.5 × 5 m per treatment with a  
121 motor-scythe, at a cutting height of 4 cm above ground level. Pasture harvested in each strip  
122 was weighed and pasture DM concentration was determined on a representative 500 g  
123 subsample, to calculate pasture harvested on a DM basis (kg DM/ha). Pre-cut and post-cut  
124 sward heights were measured 10 times on each cut strip with a rising plate meter (30 × 30 cm,  
125 4.5 kg/m<sup>2</sup>, Aurea Agrosiences, Blanquefort, France) to calculate the depth of cutting (cm).

126 The sward bulk density (kg DM per ha per cm) was calculated on each strip by dividing the  
127 pasture harvested (kg DM/ha) by the depth of cutting (cm), and then averaged per date.

128 The chemical composition of pasture offered was determined on other 500 g subsamples  
129 collected on days 13 and 18 in each cut strip, washed to eliminate soil residuals, dried, and  
130 bulked per treatment and per week before analyses.

131 The botanical composition of offered pasture was determined on day 14, from handfuls of  
132 pasture (minimum 1 kg per treatment) cut with scissors, randomly selected in the pasture to be  
133 grazed in the next seven days. Samples were manually sorted into 5 classes: grass, clover,  
134 chicory, dandelion, lucerne and other species, then dried and weighed to calculate the  
135 proportion of each class on a dry matter basis.

136 From days 14 to 15 and from days 18 to 20, every morning before grazing, pasture apparently  
137 selected by goats was sampled (minimum 500 g per treatment), imitating the post-grazing  
138 sward height of the previous day, by cutting handfuls of pasture with scissors. Samples were  
139 oven-dried and bulked per treatment and per week before chemical analyses.

140 Pre- and post-grazing pasture heights were determined daily from 30 random measurements  
141 per treatment with an electronic plate meter on the strip to be grazed the next day and on the  
142 strip just grazed, respectively. Pre-grazing extended tiller height and extended sheath height  
143 were measured with a ruler on days 14, 18 and 20 on 50 randomly selected ryegrass tillers per  
144 treatment. Post-grazing extended tiller height and extended sheath height were measured on  
145 100 randomly selected ryegrass tillers per treatment on days 15, 19 and 21. Pre- and post-  
146 grazing lamina lengths were calculated using the difference between tiller height and sheath  
147 height. The post-grazing proportion of lamina-free tillers was calculated as the proportion of  
148 tillers whose main lamina was totally defoliated.

149

150 *2.5. Animal measurements*

151 *2.5.1. Milk production and body weight*

152 Milk production was measured individually at each milking. Milk fat and protein  
153 concentrations were determined at each milking from days 11 to 13 and from days 18 to 20 by  
154 mid infra-red spectrophotometry (Milkoscan, Foss Electric, Hillerød, Denmark). Body weight  
155 was recorded on day 22 after morning milking.

156

157 *2.5.2. Intake and energy balance*

158 Individual pasture DM intake (PI) was determined during the last 5 days of the experiment  
159 from daily faecal output and diet OM digestibility, according to the indirect 2-step calculation  
160 of the ytterbium oxide (Yb)/faecal index method (Pérez-Ramírez et al., 2012; Delagarde et al.,  
161 2018a). Daily faecal output was estimated from the dilution of Yb incorporated in a pelleted  
162 Yb-concentrate. The pelleted Yb-concentrate consisted of the following ingredients on a fresh  
163 matter basis: wheat, 35%; wheat bran, 29.5%; soyabean meal, 16%; maize, 15%; molasses,  
164 4%; ytterbium oxide, 0.5%. Throughout the experiment, each goat received 15.0 g ( $\pm$  0.1 g) of  
165 the Yb-concentrate after each milking (i.e. 0.13 g/d of ytterbium oxide). On the last 7 days,  
166 the straw litter was covered by wood chips to prevent straw intake by goats. Faeces were  
167 rectally sampled from the evening milking on day 17 to the morning milking on day 22, after  
168 each milking. Occasionally, faecal sampling was not successful due to empty rectum, but this  
169 happened at maximum one times per goat over the ten sampling times. Faeces per goat were  
170 then stored at +4°C before oven-drying and chemical analyses. Then, PI was calculated  
171 according to Equation 1 (Pérez-Ramírez et al., 2012):

172 
$$PI = \frac{1}{OM_P} \times \left( \frac{D_{yb}}{F_{yb}} - OMI_s \right) \quad (\text{Eq. 1})$$

173 where PI represents the daily pasture intake (kg DM/d);  $OM_P$  represents the selected pasture  
174 OM concentration (g/kg DM);  $D_{yb}$  represents the daily dose of Yb (mg Yb/day);  $F_{yb}$

175 represents the faecal Yb concentration (mg/ kg OM); OMI<sub>S</sub> represents the OM intake from all  
176 supplements (kg OM/d) and OMD<sub>D</sub> represents OM digestibility of the diet, calculated from  
177 Equation 2:

$$178 \quad \text{OMD}_D = 0.922 - \frac{0.0194 + \Delta}{F_{CP}} - 0.445 \times F_{ADF}^2 \quad (\text{Eq. 2})$$

$$179 \quad (n = 41, R^2 = 0.82, \text{RSD} = 0.017)$$

180 where OMD<sub>D</sub> represents the diet OM digestibility, F<sub>CP</sub> represents the faecal CP concentration  
181 (g/g OM), F<sub>ADF</sub> represents the faecal ADF concentration (g/g OM), and Δ represents a  
182 corrective factor related to dehydrated lucerne (Δ = + 0.00192 for diets containing dehydrated  
183 lucerne and Δ = - 0.00192 for diets without dehydrated lucerne). This equation was built by  
184 multiple regression analysis from a dataset comprised of 5 indoor experiments carried out  
185 between autumn 2015 and spring 2017 (Charpentier et al., 2017; Delagarde *et al.*,  
186 unpublished). In these experiments, goats were fed a large range of diet quality, diet  
187 composition and intake levels which mimic what could happen under grazing conditions.  
188 Intake of each feed and faecal output by total collection was precisely measured during 5  
189 consecutive days at the end of each experimental period.

190 Individual net energy (in UFL, Unité Fourragère Lait, 1 UFL = 7.12 MJ of NE) and  
191 metabolisable protein (PDI) balances were calculated according to INRA (2010) equations  
192 and expressed as the proportion of requirements covered by supply. The UFL and PDI  
193 requirements for maintenance and milk production were calculated from body weight (BW)  
194 and 3.5% fat corrected milk (FCM) production. The UFL and PDI supplies were calculated  
195 using pasture intake and supplement intake and based on their respective concentrations in  
196 UFL and PDI. Nutritive values (UFL and PDI) of pre-grazing and selected pasture were  
197 calculated using their chemical composition according to INRA (2010). The digestive  
198 interactions related to feeding level and to concentrate supplementation level were considered

199 in the calculations, estimated from the ratio between milk production and live weight (INRA,  
200 2010).

201

### 202 *2.5.3. Blood metabolites*

203 Blood glucose, urea and NEFA (Non-Esterified Fatty Acids) concentrations were collected on  
204 the morning of day 22, after weighing. A blood sample was withdrawn in each goat by jugular  
205 venepuncture into evacuated collection tubes containing Lithium heparin. After centrifugation  
206 ( $2\ 000 \times g$  at  $4^{\circ}\text{C}$  for 15 min), the plasma was stored at  $-20^{\circ}\text{C}$ .

207

### 208 *2.5.4. Grazing behaviour*

209 Grazing activities were determined with the Kenz Lifecorder Plus Device (LCP, Suzuken Co.  
210 Ltd., Nagoya, Japan) placed in a waterproof box under the goat's neck. This device makes it  
211 possible to record grazing time with a good level of accuracy on dairy cows (Delagarde and  
212 Lamberton, 2015) and dairy goats (Delagarde et al., 2018b). Grazing time was recorded from  
213 days 15 to 21, with at least 3 or 4 recording days per goat. As only 21 devices were available,  
214 7 goats per treatment were first equipped from days 15 to 17, the other 5 goats being equipped  
215 from days 18 to 21, along with 2 goats for which the first days of recordings were eventually  
216 unsatisfactory. Grazing meal and grazing time were defined in accordance with Charpentier  
217 and Delagarde (2018). The pasture intake rate (g DM/h) was calculated per goat by dividing  
218 the average PI by the average grazing time.

219

### 220 *2.6. Chemical analyses*

221 The DM concentration of all feeds was measured by drying in a ventilated oven at  $60^{\circ}\text{C}$  for  
222 48 h for pasture and supplements, and for 72 h for faeces. All oven-dried feed and faecal  
223 samples were ground through a 0.8 mm screen before chemical analyses. The OM

224 concentration was determined by ashing at 550°C for 5 h in a muffle furnace (AOAC, 1990).  
225 Nitrogen concentration was determined using the Dumas method (AOAC, 1990) on a Leco  
226 apparatus (Leco, St Joseph, MI). The concentrations of neutral detergent fibre (NDF), acid  
227 detergent fibre (ADF), and acid detergent lignin (ADL) were measured according to AOAC  
228 (1990) on a Fibersac extraction unit (Ankon Technology, Fairport, NY). Pepsin-cellulase  
229 digestibility was determined according to Aufrère and Michalet-Doreau (1988). Ytterbium  
230 oxide was determined by atomic absorption spectrophotometry with a nitrous oxide/acetylene  
231 flame after calcination and digestion in nitric acid, in accordance with Siddons et al. (1985).  
232 Blood metabolites concentration was assessed using a multi-parameter analyser (KONE  
233 Instruments 200 Corporation, Espoo, Finland).

234

### 235 *2.7. Statistical analyses*

236 Data from the adaptation period (days 1 to 7) were not considered for statistical analyses. The  
237 pasture data, averaged per treatment and per week, were analysed according to the principles  
238 of the Generalised Linear Model of SAS Institute (2008) as follows:

$$239 Y_{ij} = \mu + \text{Treatment}_i + \text{Week}_j + e_{ij}$$

240 Where  $Y_{ij}$  represents the analysed variable,  $\mu$  represents the overall mean,  $\text{Treatment}_i$   
241 represents the fixed effect of the treatment ( $n=3$ ),  $\text{Week}_j$  represents the fixed effect of the  
242 week ( $n=2$ ), and  $e_{ij}$  represents the residual error term.

243 Animal data from days 8 to 21 were averaged per goat before statistical analyses.

244 The animal data for which a covariate from the reference period was available (milk  
245 production, milk composition, and body weight) were analysed according to the Generalised  
246 Linear Model of SAS Institute (2008):

$$247 Y_{ij} = \mu + \text{cov}_i + \text{Treatment}_j + e_{ij}$$

248 Where  $Y_{ij}$  represents the analysed variable,  $\mu$  represents the overall mean,  $cov_i$ , represents the  
249 covariate,  $Treatment_j$  represents the fixed effect the treatment, and  $e_{ij}$  represents the residual  
250 error term.

251 The animal data with no available covariates (feed intake, blood metabolites, grazing  
252 behaviour) were analysed according to the following model:  $Y_i = \mu + Treatment_i + e_i$

253 Where  $Y_i$  represents the analysed variable,  $\mu$  represents the overall mean,  $Treatment_i$   
254 represents the fixed effect the treatment, and  $e_i$  represents the residual error term.

255 In the Results section, treatment effect ( $P < 0.05$ ) or tendency ( $P < 0.10$ ) refer to the global F  
256 test. Pairwise comparisons between treatments were tested by Student T-test and differences  
257 between adjusted means are presented only if  $P < 0.05$ .

258

### 259 **3. Results**

#### 260 *3.1. Weather*

261 The weather conditions were typical of spring conditions for the region. The mean  
262 temperature and total rainfall in April 2016 were 9°C and 51 mm, respectively. This figure  
263 was colder than the average April period for 2011-2015 (11°C and 55 mm).

264

#### 265 *3.2. Pre-grazing pasture characteristics*

266 As expected, pre-grazing pasture characteristics were not different between treatments (Table  
267 2). The pasture botanical composition was on average 50% grass (ryegrass and fescue), 29%  
268 dandelion (naturally present), 11% chicory, 8% clover, 1% lucerne and 1% other species, on a  
269 DM basis. Pre-grazing pasture mass at 4 cm above ground level averaged 2467 kg DM/ha.  
270 Pre-grazing rising plate meter, extended tiller height, extended sheath height and extended  
271 lamina length averaged 14.2, 26.3, 7.3 and 19.0 cm, respectively. Average pre-grazing pasture

272 OM digestibility (0.776), CP concentration (196 g/kg DM) and NDF concentration (463 g/kg  
273 DM) are indicative of high-quality pastures.

274 *{Insert Table 2 approximately here}*

275

### 276 *3.3. Grazing management and post-grazing pasture characteristics*

277 Pasture allowance averaged 2.3 kg DM/d per goat, regardless of treatments. Post-grazing  
278 rising plate meter height (6.2 cm), extended sheath height (5.3 cm) and extended lamina  
279 length (4.5 cm) were unaffected by treatments (Table 3). Post-grazing extended tiller height  
280 was greatest in AT7D and lowest in AT11 ( $P<0.05$ ). Thereby, the percentage of lamina-free  
281 tillers was greatest in AT11 and lowest in AT7D ( $P<0.05$ ). The quality of the apparently  
282 selected pasture was in general unaffected by treatments and was numerically greater than that  
283 of offered pasture by 0.032 for OM digestibility and by 22 g/kg DM for CP concentration.

284 The ADF concentration of apparently selected pasture was greater by 11 g/kg DM on AT11  
285 than on AT7 and AT7D ( $P<0.01$ ). The ADL concentration of apparently selected pasture  
286 averaged 30 g/kg DM and was lowest on AT11, greatest on AT7D and intermediate on AT7  
287 ( $P<0.05$ ).

288 *{Insert Table 3 approximately here}*

289

### 290 *3.4. Milk production, milk composition and body weight*

291 Milk production and 3.5% FCM production were respectively greater by 0.30 kg/d and 0.28  
292 kg/d on AT7D than on AT7 and AT11 ( $P<0.001$ ; Table 4). Without dehydrated lucerne  
293 supplementation, the increase in access time from 7 to 11 h/d did not affect milk, fat or  
294 protein productions. The milk response to dehydrated lucerne supplementation at 7 h/d of  
295 access time to pasture was 0.82 kg of milk/kg DM of dehydrated lucerne. Milk fat and milk  
296 protein concentrations were unaffected by treatments and averaged 35.1 and 29.9 g/kg of

297 milk, respectively. Milk fat production was greater by 11 g/d on AT7D than on AT7 and  
298 AT11 (P<0.01). Milk protein production was greater by 10 g/d on AT7D than on AT7  
299 (P<0.01). Body weight averaged 52.1 kg and was unaffected by treatments.

300 *{Insert Table 4 approximately here}*

301

### 302 *3.5. Faecal output, diet OM digestibility, intake and energy balance*

303 Faecal output was greater by 78 g OM/d on AT7D and AT11 than on AT7 (P<0.001; Table  
304 4). Diet OM digestibility was lower on AT7D than on AT7 and AT11 (0.791 vs 0.823;  
305 P<0.001). There was no concentrate or dehydrated lucerne refusal throughout the experiment.  
306 The total supplement intake was of 602 g DM/d for concentrate, 27 g DM/d for Yb-  
307 concentrate and 361 g DM/d for dehydrated lucerne. Pasture intake increased by 433 g DM/d  
308 when access time was increased from 7 to 11 h/d (P<0.01). Pasture intake decreased by 259 g  
309 DM/d when dehydrated lucerne was supplied (P<0.01), which means an average substitution  
310 rate of 0.72 between pasture and dehydrated lucerne. Total intake was greater by 383 g DM/d  
311 on AT11 than on AT7 and AT7D (P<0.01). Energy (UFL) and protein (PDI) supplies covered  
312 100 to 150% of the requirements according to treatments and were greater by 19 and 26% on  
313 AT11 than on AT7 and AT7D, respectively.

314

### 315 *3.6. Blood metabolites*

316 Blood urea concentration was greater on AT7D than on AT7 (59.4 vs 53.2 mg/dl; P<0.05;  
317 Table 4). Blood glucose and NEFA concentrations were unaffected by treatments and  
318 averaged 61.1 mg/dl and 414 µmol/l, respectively.

319 *{Insert Table 5 approximately here}*

320

### 321 *3.7 Grazing behaviour*

322 The grazing time and the number of grazing meals were greater on AT11 than on AT7 and  
323 AT7D by 154 min and 3.0 meals, respectively (Table 6). Consequently, the proportion of time  
324 spent grazing was lower on AT11 than on AT7 and AT7D (0.81 vs 0.90;  $P < 0.001$ ). Mean  
325 grazing meal duration was lower on AT11 than on AT7D (84 vs 129 min;  $P < 0.05$ ). The first  
326 grazing meal duration averaged 247 min and was unaffected by treatments. The pasture intake  
327 rate tended to be lower on AT7D and AT11 than on AT7 (260 vs 295 g DM/h;  $P = 0.08$ ).

328 The daily pattern of grazing activity was similar between AT7 and AT7D, with an intense  
329 grazing activity (more than 50 min/h) during the first 6 hours of access to the pasture (Figure  
330 1). Goats on these treatments still grazed actively, i.e. approximately 40 min/h the seventh  
331 hour of access. On AT11, grazing activity decreased progressively from the second hour (60  
332 min/h) to the seventh hour (38 min/h) of access between the two milkings. After PM milking,  
333 grazing activity was intense (more than 50 min/h) for at least 2 hours (Figure 1).

334 *{Insert Table 6 approximately here}*

335 *{Insert Figure 1 approximately here}*

336

337

#### 338 **4. Discussion**

339 This experiment was carried out under good weather conditions, in early spring, and on high-  
340 quality multi-species pastures, as shown by the botanical and chemical composition of the  
341 pasture offered and selected in all treatments. The results may thus not be extrapolated to  
342 more adverse grazing conditions, such as summer or autumn seasons, with lower pasture  
343 quality. This study would need to be repeated, particularly considering the very few data  
344 available in the literature on intake regulation of grazing dairy goats. Although this study was  
345 of short duration, the number of goats per treatment was sufficient to detect significant effects  
346 of treatments.

347 Total DM intake in our study (5.2% of BW or 139 g/kg BW<sup>0.75</sup>) was greater than the average  
348 value reported for grazing Alpine dairy goats supplemented with 1 kg DM/d of concentrates  
349 (3.0% of BW or 82 g/kg BW<sup>0.75</sup>; Keli et al., 2017). It was however close to the voluntary DM  
350 intake predicted from pre-experimental BW and milk production, supplementation level and  
351 pasture fill value (4.8% of BW or 130 g/kg BW<sup>0.75</sup>, INRA, 2010). The great intake level  
352 observed in our study may be clearly related to the high-quality of the pasture offered, that  
353 increases its ingestibility (INRA, 2010). The method used to estimate pasture DM intake has  
354 been validated indoors against actual intake in lactating goats and seems greatly accurate over  
355 the range of feeding conditions studied in this experiment (Delagarde et al., 2018a).

356

357 Goat responses to access time to pasture

358 *The effect of AT on pasture intake*

359 Studies on the effect of daily access time to pasture on intake or performance are scarce and  
360 mainly carried out on meat goats, with young castrated males (Berhan et al., 2005), dried  
361 meat goats (Romney et al., 1996), or suckling goats (Tovar-Luna et al., 2011). Two recent  
362 studies were carried out on Alpine dairy goats in early lactation (Keli et al., 2017) or mid-  
363 lactation (Charpentier and Delagarde, 2018).

364 The decrease in pasture intake when access time was restricted from 11 to 7 h/d was  
365 significant (-433 g DM/d, i.e. 18% or 108 g DM/d per hour of reduction of access time). The  
366 reduction of pasture intake with restriction of access time has already been observed in  
367 grazing goats, but generally to a lesser extent. Tovar Luna et al. (2011) reported a decrease in  
368 pasture intake of 36 g DM/d per hour of AT less when AT decreased from 24 h to 12 h/d. A  
369 similar range of variation of pasture intake (-34 g DM/d per h of AT less) was observed for a  
370 reduction of AT from 8 h to 4 h/d on growing meat goats or dried meat goats (Berhan et al.,  
371 2005; Romney et al., 1996). At the contrary, Keli et al. (2017) reported no effect of AT on

372 pasture intake, either between 22 h and 8 h/d or between 8 h and 6 h/d), probably due to a  
373 high supplementation level and a low pasture intake. Lower pasture intake with restricted AT  
374 has also been observed on sheep (Iason et al., 1999; Molle et al., 2014) and dairy cows  
375 (Kennedy et al., 2009 ; Pérez-Ramírez et al., 2008).

376

### 377 *The effect of AT on grazing behaviour*

378 Daily grazing time was greatly impacted by AT restriction, with an 18% reduction (-2.5 h/d)  
379 between 11 and 7 h/d of AT. Grazing times recorded are close to those observed on grazing  
380 dairy goats with 8 h/d of AT (Charpentier and Delagarde, 2018; Keli et al., 2017) or with 13  
381 h/d of AT (Charpentier and Delagarde, 2018). It is also within the range of grazing time  
382 observed on meat goats with 8 h of AT (319 to 381 min/d; Berhan et al., 2005 ; Romney et al.,  
383 1996) or with an AT of at least 12 h/d (434 to 624 min/d; Berhan et al., 2005; Keli et al.,  
384 2017; Tovar-Luna et al., 2011). The reduction of grazing time with decreasing AT is high (-39  
385 min/d per h of AT less), and close to the reduction observed between 8 and 6 h/d or between 8  
386 and 4 h/d of AT in dairy goat studies (31 min/d per h of AT less on average; Berhan et al.,  
387 2005; Charpentier and Delagarde, 2018; Keli et al., 2017; Romney et al., 1996).

388 The average pasture intake rate observed (272 g DM/h) is within the greatest values of the  
389 range reported for grazing adult goats (105 to 276 g DM/h; ; Askar et al., 2013; Keli et al.,  
390 2017; Romney et al., 1996; Tovar-Luna et al., 2011). This should be related to the high milk  
391 production level (> 3.5 kg/d) that can stimulate intake and motivation to eat fast (INRA,  
392 2010), but also to the high quality of the pasture and to the high pre-grazing height that makes  
393 it possible to maximise intake rate (Edwards et al., 1995). The trend on the increase in pasture  
394 intake rate when AT was reduced is consistent with previous studies on dairy goats (Keli et  
395 al., 2017), meat goats (Berhan et al., 2005; Romney et al., 1996), sheep (Molle et al., 2017)  
396 and dairy cows (Pérez-Ramírez et al., 2008), and shows the ability of ruminants to eat the

397 same feed faster when under greater time constraint (Ginane and Petit, 2005). In our  
398 experiment, the relative increase in pasture intake rate between 11 to 7 h/d of access time is  
399 about 13%, which is lower than the values reported by the above-cited studies (20-40%),  
400 suggesting that the time constraint to graze was not so significant.

401 Goats also showed a great ability to postpone activities other than grazing (i.e. rumination and  
402 rest) to prioritise intake, with more than 90% of available time spent grazing, as already  
403 observed by Charpentier and Delagarde (2018). In all treatments, goats showed a great ability  
404 to maintain a long grazing activity period from the beginning of the grazing session in the  
405 morning, with a first mean grazing meal duration of more than 4 h and then a slow  
406 progressive reduction of grazing activities until the evening milking. This was also reported  
407 by Keli et al. (2017), with an AT of 6 h/d, but not for an AT of 8 h/d, where 2 mean grazing  
408 activity periods were observed. Grazing cows do not seem to have the ability to graze for such  
409 long periods of time, with a clear interruption of grazing at midday after 3 h of grazing,  
410 including when access time to pasture is short (Pérez-Prieto et al., 2011; Pérez-Ramírez et al.,  
411 2009).

412

#### 413 *The effect of AT on milk production and composition*

414 The lack of significant effect of AT on milk production between 7 and 11 h/d of AT has  
415 already been observed in dairy goats (Charpentier and Delagarde, 2018; Keli et al, 2017) and  
416 in dairy cows (Kennedy et al., 2009; Pérez-Ramírez et al., 2009) within the same range of  
417 access time to pasture. In our study, this result may also be related to the fact that goats grazed  
418 on high quality pastures and received 600 g/d of concentrate, which seems not restrictive  
419 nutritional conditions even at 7 h/d of AT. The lack of effect of AT on milk fat and protein  
420 concentrations is also consistent with previous studies done with grazing lactating goats  
421 (Charpentier and Delagarde, 2018; Keli et al., 2017; Tovar-Luna et al., 2011). It is not clear

422 however why the reduction in pasture intake when access time was restricted to 7 h/d was not  
423 reflected by a similar reduction in milk production. We can hypothesise greater extent of  
424 digestion of pasture, with more time for rumination after evening milking, and less energy  
425 requirement for grazing activities, as grazing time was reduced by 2.5 h/d (-28%) when access  
426 time at pasture was reduced from 11 to 7 h/d.

427

#### 428 *Goat responses to supplementation*

429 With a daily access time to pasture of 7 h/d, the substitution rate between pasture and  
430 dehydrated lucerne averaged 0.72, which is intermediate between substitution rates observed  
431 for concentrates (0.2 to 0.4) and for conserved forages (0.8 to 1.1) used as supplements  
432 (INRA, 2010) for a similar level of inclusion in the diet. Dehydrated forages may be  
433 considered as concentrates when given as pellets, as in this experiment, due to their low  
434 rumen filling effect (INRA, 2010). The value of 0.72 may thus be regarded as relatively high:  
435 this can be explained by the high quality of the pasture grazed (NRC, 2007) and by the fact  
436 that goats already receive 600 g/d of commercial concentrate, leading to a greater marginal  
437 substitution rate than when compared to goats fed only on forages (INRA, 2010; Sauvant et  
438 al., 2012). In the conditions of this experiment, the relatively high substitution rate also  
439 suggests that pasture intake was not restricted by access time itself for goats not receiving  
440 dehydrated lucerne. In fact, substitution rate is lower when pasture intake is restricted by a  
441 grazing management factor than when ruminants are fed *ad libitum* (Delagarde et al., 2011).

442 The increase in milk production with supplementation was high (+0.82 kg/kg DM of  
443 dehydrated lucerne) and within the range observed for milk production response to  
444 concentrate supplementation of grazing dairy goats (Lefrileux et al., 2008; Rubino et al.,  
445 1995). The reason for such a high milk production response to the supply of pelleted  
446 dehydrated lucerne is unclear, particularly considering the relatively great substitution rate

447 and the fact that energy and protein supplies did not increase when goats received the lucerne.  
448 The fact that milk fat and protein concentrations were unaffected by dehydrated lucerne  
449 supplementation is consistent with the results of Lefrileux et al. (2008), who tested several  
450 levels and sources of concentrates at grazing. In large databases, concentrate supplementation  
451 generally leads to a decrease of milk fat concentration, but to no variation of milk protein  
452 concentration (Sauvant et al., 2012), contrary to what occurs in grazing or stall-fed dairy cows  
453 (Delaby et al., 2003; INRA, 2010).  
454 The results of this experiment suggest that providing 400 g/d of dehydrated lucerne to grazing  
455 goats has a much stronger positive effect on milk production than an additional grazing period  
456 of 4 hours after evening milking. This does not come from a greater intake, as total intake was  
457 greater in the AT11 than in the AT7D treatment, due to the great substitution rate between  
458 pasture and dehydrated lucerne. It can be hypothesised that the increase in energy  
459 requirements in relation to greater access time and effective grazing time and activities in  
460 AT11 leads at least partly to an increase in DM intake not reflected in milk production.

461

## 462 **5. Conclusions**

463 Dairy goats under rotational grazing systems on multispecies temperate pastures in spring  
464 demonstrated their ability to adapt their grazing behaviour to an access time restriction from  
465 11 to 7 h/d. However, these adaptations were not sufficient to maintain daily pasture intake.  
466 Despite the reduction of pasture intake, it seems that 7 h/d of access time to pasture was  
467 sufficient for goats to produce their expected milk production, because of the 600 g/d of  
468 concentrate fed and to the high quality of the pastures. The results of this experiment also  
469 suggest that providing to grazing dairy goats 400 g/d of dehydrated lucerne has a much  
470 stronger positive effect on milk production than an additional grazing period of 4 hours after  
471 evening milking.

472

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482

483 **References**

484 Association of Official Analytical Chemists (AOAC), 1990. Official methods of analysis. 15<sup>th</sup>  
485 Edition. Volume 1. AOAC Inc., Arlington, US. 771 pp.

486 Askar, AR., Gipson, TA., Puchala, R., Tesfai, K., Detweiler, G., Asmare, A., Keli, A., Sahlu,  
487 T., Goetsch, AL., 2013. Effects of stocking rate and physiological state of meat goats grazing  
488 grass/forb pastures on forage intake, selection, and digestion, grazing behavior, and  
489 performance. *Livestock Science* 154, 82–92. <https://doi.org/10.1016/j.livsci.2013.02.015>

490 Aufrère, J., Michalet-Doreau, B., 1988. Comparison of methods for predicting digestibility of  
491 feeds. *Anim. Feed Sci. Technol.* 20, 203–218.

492 Berhan, T., Puchala, R., Sahlu, T., Merkel, R.C., Goetsch, A.L., 2005. Effects of length of  
493 pasture access on energy use by growing meat goat. *J. Appl. Anim. Res.* 28, 1–7.

494 Charpentier, A., Delagarde, R., 2018. Milk production and grazing behaviour responses of  
495 Alpine dairy goats to daily access time to pasture or to daily pasture allowance on temperate

496 pastures in spring. *Small Rumin. Res.* 162, 48–56.  
497 <https://doi.org/10.1016/j.smallrumres.2018.03.004>

498 Charpentier, A., Mendowski, S., Delagarde, R., 2017. Prediction of in vivo digestibility of  
499 pasture-based diets in dairy goats from faecal indicators., in: *Grassland Resources for*  
500 *Extensive Farming Systems in Marginal Lands: Major Drivers and Future Scenarios.*  
501 *Proceedings of the 19th Symposium of the European Grassland Federation, Alghero, Italy, 7-*  
502 *10 May 2017, Grassland Science in Europe 22, 533–535.*

503 Delaby, L., Peyraud, J.L., Delagarde, R., 2003. Faut-il compléter les vaches laitières au  
504 pâturage? *Prod. Anim.* 16, 183-195.

505 Delagarde, R., Lamberton, P., 2015. Daily grazing time of dairy cows is recorded accurately  
506 using the Lifecorder Plus device. *Appl. Anim. Behav. Sci.* 165, 25–32.  
507 <https://doi.org/10.1016/j.applanim.2015.01.014>

508 Delagarde, R., Valk, H., Mayne, C.S., Rook, A.J., González-Rodríguez, A., Baratte, C.,  
509 Faverdin, P., Peyraud, J.L., 2011. GrazeIn: a model of herbage intake and milk production for  
510 grazing dairy cows. 3. Simulations and external validation of the model. *Grass Forage Sci.* 66,  
511 61-77. <https://doi.org/10.1111/j.1365-2494.2010.00770.x>

512 Delagarde, R., Belarbre, N., Charpentier, A., 2018a. Accuracy of the ytterbium-faecal index  
513 method for estimating intake of pasture-fed dairy goats. *Proceedings of the 20th Symposium*  
514 *of the European Grassland Federation, Cork, Ireland, 17-21 June 2018, Grassland Science in*  
515 *Europe 23, 419-421.*

516 Delagarde, R., Piriou, M., Charpentier, A., 2018b. The recording of grazing time of dairy  
517 goats is accurate by using the Lifecorder Plus device, in: *Herbivore Nutrition Supporting*  
518 *Sustainable Intensification and Agro-Ecological Approaches. Proceedings of the 10th*  
519 *International Symposium on the Nutrition of Herbivores, Clermont-Ferrand, France.*

520 Edwards, G.R., Parsons, A.J., Penning, P.D., Newman, J.A., 1995. Relationship between  
521 vegetation state and bite dimensions of sheep grazing contrasting plant species and its  
522 implications for intake rate and diet selection. *Grass For. Sci.* 50, 378-388.  
523 <https://doi.org/10.1111/j.1365-2494.1995.tb02332.x>

524 Ginane, C., Petit, M. 2005. Feeding behaviour and diet choices of cattle with physical and  
525 temporal constraints on forage accessibility: an indoor experiment. *Anim. Sci.* 81, 3-10.  
526 <https://doi.org/10.1079/ASC41230003>

527 Iason, G., Mantecon, A.R., Sim, D.A., Gonzalez, J., Foreman, E., Bermudez, F.F., Elston,  
528 D.A., 1999. Can grazing sheep compensate for a daily foraging time constraint ? *J. Anim.*  
529 *Ecol.* 68, 87–93. <https://doi.org/10.1046/j.1365-2656.1999.00264.x>

530 Institut de l'élevage (Idele), 2011. L'alimentation pratique des chèvres laitières. Institut de  
531 l'élevage, Paris, 216 pp.

532 Institut National de la Recherche Agronomique (INRA), 2010. Alimentation des bovins, ovins  
533 et caprins: besoins des animaux, valeurs des aliments, Guide pratique. Editions Quae,  
534 Versailles, France.

535 Keli, A., Ribeiro, L.P.S., Gipson, T.A., Puchala, R., Tesfai, K., Tsukahara, Y., Sahlu, T.,  
536 Goetsch, A.L., 2017. Effects of pasture access regime on performance, grazing behavior, and  
537 energy utilization by Alpine goats in early and mid-lactation. *Small Rumin. Res.* 154, 58–69.  
538 <https://doi.org/10.1016/j.smallrumres.2017.07.004>

539 Kennedy, E., McEvoy, M., Murphy, J.P., O'Donovan, M., 2009. Effect of restricted access  
540 time to pasture on dairy cow milk production, grazing behavior, and dry matter intake. *J.*  
541 *Dairy Sci.* 92, 168–176. <https://doi.org/10.3168/jds.2008-1091>

542 Lefrileux, Y., Morand-Fehr, P., Pommaret, A., 2008. Capacity of high milk yielding goats for  
543 utilizing cultivated pasture. *Small Rumin. Res.* 77, 113–126  
544 <https://doi.org/10.1016/j.smallrumres.2008.03.011>

545 Molle, G., Decandia, M., Giovanetti, V., Manca, C., Acciaro, M., Epifani, G., Salis, L.,  
546 Cabiddu, A., Sitzia, M., Cannas, A., 2014. Effects of restricted time allocation to pasture on  
547 feeding behaviour, intake and milk production of dairy sheep rotationally grazing Italian  
548 ryegrass (*Lolium multiflorum* Lam) in spring. Anim. Prod. Sci. 54, 1233–1237.  
549 <https://doi.org/10.1071/AN14376>

550 Molle, G., Decandia, M., Giovanetti, V., Manca, C., Acciaro, M., Epifani, G., Salis, L.,  
551 Cabiddu, A., Sitzia, M., Cannas, A., 2017. Grazing behaviour, intake and performance of  
552 dairy ewes with restricted access time to berseem clover (*Trifolium Alexandrinum* L.) pasture.  
553 Grass For. Sci. 72, 194–210. <https://doi.org/10.1111/gfs.12228>

554 National Research Council (U.S.) (Ed.), 2007. Nutrient requirements of small ruminants:  
555 sheep, goats, cervids, and New World camelids. National Academies Press, Washington, D.C.

556 Pérez-Prieto, L.A., Peyraud, J.L., Delagarde, R., 2011. Pasture intake, milk production and  
557 grazing behaviour of dairy cows grazing low-mass pastures at three daily allowances in  
558 winter. Livest. Sci 137, 151-160. <https://doi.org/10.1016/j.livsci.2010.10.013>

559 Pérez-Ramírez, E., Delagarde, R., Delaby, L., 2008. Herbage intake and behavioural  
560 adaptation of grazing dairy cows by restricting time at pasture under two feeding regimes.  
561 Animal 2, 1384–1392. <https://doi.org/10.1017/S1751731108002486>

562 Pérez-Ramírez, E., Peyraud, J.L., Delagarde, R., 2009. Restricting daily time at pasture at  
563 Low and High pasture allowance: Effects on pasture intake and behavioural adaptation of  
564 lactating dairy cows. J. Dairy Sci. 92, 3331–3340. <https://doi.org/10.3168/jds.2008-1951>

565 Pérez-Ramírez, E., Peyraud, J.L., Delagarde, R., 2012. N-alkanes v. ytterbium/faecal index as  
566 two methods for estimating herbage intake of dairy cows fed on diets differing in the  
567 herbage : maize silage ratio and feeding level. Animal 6, 232–244.  
568 <https://doi.org/10.1017/S1751731111001480>

569 Rubino, R., Moioli, B., Fedele, V., Pizzillo, M., Morand-Fehr, P., 1995. Milk production of  
570 goats grazing native pasture under different supplementation regimes in southern Italy. *Small*  
571 *Rumin. Res.* 17, 213–221. [https://doi.org/10.1016/0921-4488\(95\)00696-I](https://doi.org/10.1016/0921-4488(95)00696-I)

572 Romney, D.L., Sendalo, D.S.C., Owen, E., Mtenga, L.A., Penning, P.D., Mayes, R.W.,  
573 Hendy, C.R.C., 1996. Effects of tethering management on feed intake and behaviour of  
574 Tanzanian goats. *Small Rumin. Res.* 19, 113–120. [https://doi.org/10.1016/0921-](https://doi.org/10.1016/0921-4488(95)00753-9)  
575 [4488\(95\)00753-9](https://doi.org/10.1016/0921-4488(95)00753-9)

576 SAS Institute, 2008. *SAS/STAT® 9.2 User’s Guide*. SAS Institute Inc., Cary, NC, USA.

577 Sauvant, D., Giger-Reverdin, S., Meschy, F., Puillet, L., Schmidely, P., 2012. Actualisation  
578 des recommandations alimentaires pour les chèvres laitières. *Prod. Anim.* 25, 259.

579 Siddons, R.C., Paradine, J., Beever, D.E., Cornell, P.R., 1985. Ytterbium acetate as a  
580 particulate-phase digesta-flow marker. *Br. J. Nutr.* 54, 509.  
581 <https://doi.org/10.1079/BJN19850136>

582 Tovar-Luna, I., Puchala, R., Gipson, T.A., Detweiler, G.D., Dawson, L.J., Sahlu, T., Keli, A.,  
583 Goetsch, A.L., 2011. Effects of night-locking and stage of production on forage intake,  
584 digestion, behavior, and energy utilization by meat goat does grazing grass/legume pasture.  
585 *Livest. Sci.* 140, 225–245. <https://doi.org/10.1016/j.livsci.2011.03.034>

586 van Soest, P.J., Roberson, J.B., Lewis, B.A., 1991. Carbohydrate methodology, metabolism,  
587 and nutritional implications in dairy cattle. *J. Dairy Sci.* 2215–2225.

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590

591 **Table 1** *Chemical composition and nutritive value of supplements*

Supplement	Concentrate	Dehydrated lucerne	Yb-concentrate
Chemical composition (g/kg DM)			
DM (g/kg of fresh)	906	929	901
OM	937	903	954
CP	210	177	188
NDF	379	490	238
ADF	156	322	67
ADL	20	72	16
Nutritive value			
PDIN (g/kg DM) <sup>1</sup>	150	120	135
PDIE (g/kg DM) <sup>1</sup>	135	104	117
UFL (/kg DM) <sup>2</sup>	1.05	0.70	1.05

592 <sup>1</sup> Metabolisable Protein when Nitrogen (PDIN) or Energy (PDIE) is limiting for microbial protein synthesis in  
593 the rumen ( INRA, 2010)

594 <sup>2</sup> UFL: Unité Fourragère Lait, 1 UFL = 7.115 MJ of Net Energy (INRA, 2010)

595

596

597

598

599 **Table 2** *Pre-grazing pasture characteristics: pasture mass, sward height, chemical*  
600 *composition and nutritive value of offered pasture.*

Variables	Treatment			SEM	P-value
	AT7	AT7D	AT11		
Pasture mass (kg DM/ha) <sup>1</sup>	2415	2472	2513	70.0	0.670
<i>Pre-grazing sward height (cm)</i>					
Rising plate meter	14.0	14.2	14.4	0.29	0.659
Extended tiller	26.5	26.0	26.5	0.90	0.915
Extended sheath	7.4	7.7	6.8	0.16	0.096
Extended lamina <sup>2</sup>	19.1	18.3	19.7	0.87	0.594
<i>Chemical composition (g/kg DM)</i>					
DM (g/ kg of fresh)	148	155	149	4.2	0.560
OM	907	909	905	2.8	0.605
CP	200	178	200	5.1	0.149
NDF	472	461	456	10.2	0.599
ADF	231	228	227	3.6	0.778
ADL	27	30	28	1.4	0.611
<i>Nutritive value</i>					
OM digestibility (g/g) <sup>3</sup>	0.773	0.771	0.783	0.0087	0.639
PDIN (g/kg DM) <sup>4</sup>	128	114	129	3.6	0.157
PDIE (g/kg DM) <sup>4</sup>	100	97	100	1.5	0.375
UFL (/kg DM) <sup>5</sup>	0.96	0.95	0.97	0.012	0.737

601 Access time to pasture (AT) : 7 h/d without dehydrated lucerne (AT7); 7 h/d with dehydrated lucerne (AT7D);  
602 and 11 h/d without dehydrated lucerne (AT11). SEM = Standard Error of the Mean.

603 <sup>1</sup> Measured at 4 cm above ground level

604 <sup>2</sup> Difference between extended tiller height and extended sheath height.

605 <sup>3</sup> Calculated from pepsin-cellulase digestibility (Aufrière and Michalet-Doreau, 1988)

606 <sup>4</sup> Metabolisable Protein when Nitrogen (PDIN) or Energy (PDIE) is limiting for microbial synthesis in the rumen  
607 (INRA, 2010)

608 <sup>5</sup> UFL = Unité Fourragère Lait (1 UFL = 7.115 MJ of Net Energy; INRA, 2010).

609 <sup>a,b</sup> For each variable, mean values with different superscript letters are significantly different (P < 0.05)

610

611

612

613 **Table 3** *Effect of daily access time to pasture and of dehydrated lucerne supplementation on*  
614 *post-grazing pasture characteristics and on quality of the pasture apparently selected by*  
615 *goats.*

Variables	Treatment			SEM	P-value
	AT7	AT7D	AT11		
<i>Post-grazing sward height (cm)</i>					
Rising plate meter	6.0	6.7	6.0	0.20	0.201
Extended tiller	9.7 <sup>ab</sup>	10.4 <sup>b</sup>	9.3 <sup>a</sup>	0.11	0.037
Extended sheath	5.3	5.2	5.3	0.16	0.834
Extended lamina <sup>1</sup>	4.4	5.2	4.0	0.28	0.165
Lamina-free tillers (%)	19 <sup>ab</sup>	16 <sup>a</sup>	24 <sup>b</sup>	0.9	0.049
<i>Chemical composition (g/kg DM)</i>					
DM (g/ kg of fresh)	140	135	146	3.1	0.229
OM	906	899	900	1.3	0.095
CP	210	216	218	3.3	0.398
NDF	461	446	482	19.2	0.528
ADF	213 <sup>a</sup>	215 <sup>a</sup>	225 <sup>b</sup>	0.4	0.003
ADL	30 <sup>b</sup>	34 <sup>c</sup>	25 <sup>a</sup>	0.6	0.013
<i>Nutritive value</i>					
OM digestibility (g/g) <sup>2</sup>	0.803	0.820	0.802	0.0127	0.589
PDIN (g/kg DM) <sup>3</sup>	135	140	140	2.3	0.442
PDIE (g/kg DM) <sup>3</sup>	104	105	104	0.4	0.151
UFL (/kg DM) <sup>4</sup>	1.00	1.02	0.99	0.022	0.607

616 Access time to pasture (AT):7 h/d without dehydrated lucerne (AT7); 7 h/d with dehydrated lucerne (AT7D);  
617 and 11 h/d without dehydrated lucerne (AT11). SEM = Standard Error of the Mean.

618 <sup>1</sup> Difference between extended tiller height and extended sheath height.

619 <sup>2</sup> Calculated from pepsin-cellulase digestibility (Aufrère and Michalet-Doreau, 1988)

620 <sup>3</sup> Metabolisable Protein when Nitrogen (PDIN) or Energy (PDIE) is limiting for microbial synthesis in the rumen  
621 (INRA, 2010)

622 <sup>4</sup> UFL = Unité Fourragère Lait (1 UFL = 7.115 MJ of Net Energy; INRA, 2010).

623 <sup>a,b</sup> For each variable, mean values with different superscript letters are significantly different (P < 0.05)

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626 **Table 4** *Effect of daily access time to pasture and of dehydrated lucerne supplementation on*  
 627 *milk production, milk composition and body weight of strip-grazing dairy goats.*

Variables	Treatment			SEM	P-value
	AT7	AT7D	AT11		
Milk production (kg/d)	3.56 <sup>a</sup>	3.92 <sup>b</sup>	3.68 <sup>a</sup>	0.060	0.001
Milk fat concentration (g/kg)	35.8	35.2	34.2	0.63	0.221
Milk protein concentration (g/kg)	29.7	29.6	30.1	0.26	0.409
3.5% fat-corrected milk production (kg/d)	3.55 <sup>a</sup>	3.86 <sup>b</sup>	3.61 <sup>a</sup>	0.064	0.005
Milk fat production (g/d)	127 <sup>a</sup>	137 <sup>b</sup>	125 <sup>a</sup>	2.8	0.010
Milk protein production (g/d)	105 <sup>a</sup>	115 <sup>b</sup>	110 <sup>ab</sup>	2.1	0.008
Body weight (kg)	51.6	52.0	52.6	0.32	0.102

628 Access time to pasture (AT): 7 h/d without dehydrated lucerne (AT7); 7 h/d with dehydrated lucerne (AT7D);  
 629 and 11 h/d without dehydrated lucerne (AT11). SEM = Standard Error of the Mean.

630 <sup>a,b</sup> For each variable, mean values with different superscript letters are significantly different (P <0.05)

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634 **Table 5** *Effect of daily access time to pasture and of dehydrated lucerne supplementation on*  
 635 *intake and blood metabolites of strip-grazing dairy goats.*

Variables	Treatment			SEM	P-value
	AT7	AT7D	AT11		
<b>Feed intake</b>					
Faecal OM output (g OM/d)	409 <sup>a</sup>	498 <sup>b</sup>	475 <sup>b</sup>	13.7	0.001
Diet OM digestibility (g/g) <sup>1</sup>	0.823 <sup>b</sup>	0.791 <sup>a</sup>	0.823 <sup>b</sup>	0.0017	0.001
Pasture intake (g DM/d)	1893 <sup>b</sup>	1634 <sup>a</sup>	2326 <sup>c</sup>	82.1	0.001
Total intake (g DM/d) <sup>2</sup>	2521 <sup>a</sup>	2623 <sup>a</sup>	2955 <sup>b</sup>	82.4	0.003
UFL supply (% of requirements) <sup>3</sup>	102 <sup>a</sup>	99 <sup>a</sup>	120 <sup>b</sup>	2.7	0.001
PDI supply (% of requirements) <sup>4</sup>	133 <sup>a</sup>	125 <sup>a</sup>	155 <sup>b</sup>	3.5	0.001
<b>Blood metabolites</b>					
Urea (mg/dl)	53.2 <sup>a</sup>	59.4 <sup>b</sup>	56.7 <sup>ab</sup>	1.59	0.034
Glucose (mg/dl)	60.4	61.6	61.2	1.38	0.824
NEFA (μmol/l) <sup>5</sup>	358	497	387	49.3	0.139

636 Access time to pasture (AT): 7 h/d without dehydrated lucerne (AT7); 7 h/d with dehydrated lucerne (AT7D);  
 637 and 11 h/d without dehydrated lucerne (AT11). SEM = Standard Error of the Mean.

638 <sup>1</sup> From faecal indicators

639 <sup>2</sup> Total intake = Pasture + concentrate + Yb-concentrate + dehydrated lucerne intake

640 <sup>3</sup> UFL = Unité Fourragère Lait (1 UFL = 7.115 MJ of Net Energy; INRA, 2010)

641 <sup>4</sup> PDI = Metabolisable Protein (INRA, 2010)

642 <sup>5</sup> NEFA = Non esterified fatty acids

643 <sup>a,b</sup> For each variable, mean values with different superscript letters are significantly different (P < 0.05)

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647 **Table 6** *Effect of daily access time to pasture and of dehydrated lucerne supplementation on*  
 648 *grazing behaviour of strip-grazing dairy goats.*

Variables	Treatment			SEM	P-value
	AT7	AT7D	AT11		
Grazing time (min/d)	385 <sup>a</sup>	379 <sup>a</sup>	536 <sup>b</sup>	7.8	0.001
Proportion of time spent grazing	0.90 <sup>b</sup>	0.90 <sup>b</sup>	0.81 <sup>a</sup>	0.014	0.001
Number of grazing meals (meals/d)	3.7 <sup>a</sup>	3.4 <sup>a</sup>	6.6 <sup>b</sup>	0.31	0.001
Mean grazing meal duration (min)	113 <sup>ab</sup>	129 <sup>b</sup>	84 <sup>a</sup>	11.5	0.029
First grazing meal duration (min)	241	257	243	13.7	0.667
Pasture intake rate (g DM/h)	295	260	261	12.2	0.075

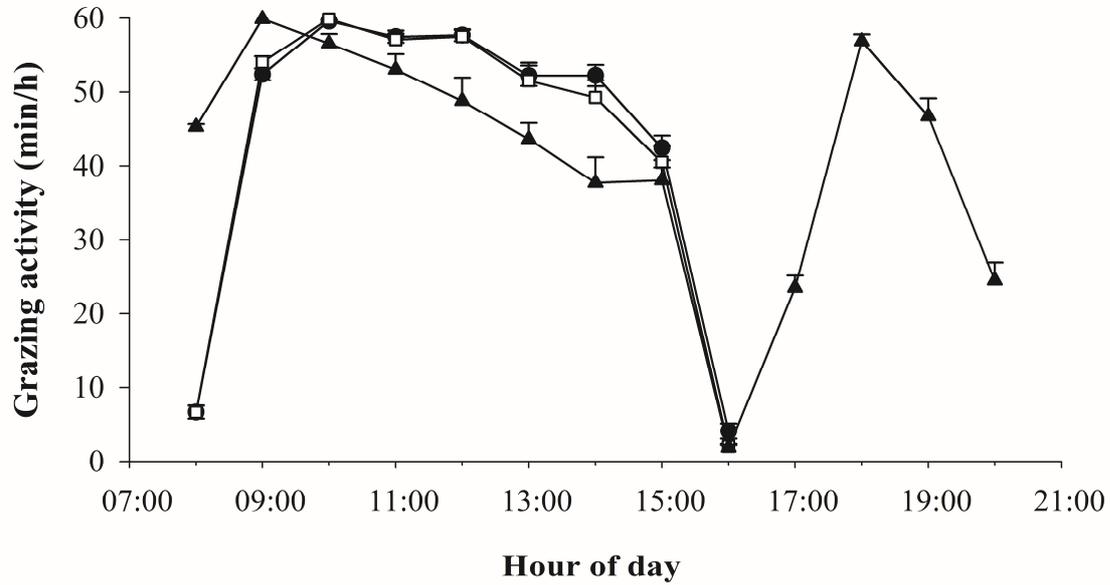
649 Access time to pasture (AT): 7 h/d without dehydrated lucerne (AT7); 7 h/d with dehydrated lucerne (AT7D);  
 650 and 11 h/d without dehydrated lucerne (AT11). SEM = Standard Error of the Mean.

651 <sup>a,b</sup> For each variable, mean values with different superscript letters are significantly different (P < 0.05)

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**Figure captions**



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**Figure 1** Daily pattern of grazing activity of strip-grazing dairy goats according to access time to pasture (AT) and dehydrated lucerne (D) supplementation (● AT7, □ AT7D, ▲ AT11, positive SE bars). AT7: 7 h/d of AT without D; AT7D: 7 h/d of AT with D; AT11: 11 h/d of AT without D.