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# Effect of calving period on herbage intake and nutrient turnover of Simmental and Angus suckler cows with Angus sired calves grazing subalpine and alpine pastures

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## Abstract

Herbage intake and utilisation were measured in 12 Simmental and 12 Angus suckler cows with Angus sired calves grazing one subalpine (1000 m o.d. (ordinance datium)) and two alpine pastures (first and secondary growth; 2000 m). Calving periods were late autumn and late winter for both breeds. Herbage dry matter intake of cows and calves, determined with slow-release alkane capsules, increased from subalpine to alpine pastures from 11.9 to 15.8 and 1.1 to 3.5 kg/day, respectively. Nitrogen (N) intake was highest on regrowth pasture. Simmental cows consumed more herbage than Angus cows, even when corrected for metabolic body weight. Their calves did not differ in herbage consumption although crossbred calves had significantly higher daily gains (+16%) than Angus calves. Dam breed effects on N and phosphorous (P) excretion and N utilisation were small when corrected for differences in intake (higher in the Simmental groups). Compared to winter-calving, autumn-calving resulted in cows gaining weight but also resulted in lower daily gains of the calves despite higher herbage intake. This increased N and P losses per unit of weight gain even when calculated for cows and calves together. Accordingly, late-winter calving is advantageous for this type of alpine grazing system.


*Keywords:* Beef cattle; Herbage intake; Nitrogen; Phosphorus; Pasture; Alpine environments

## 1. Introduction

Livestock systems utilising high altitude alpine pastures typically consist of a three-step procedure in altitude in order to optionally utilise the natural feed resources available. Animals are kept at lowland facilities during winter, then first graze on subalpine pastures around 1000 m o.d. (ordinance datium) in spring, and then spend the summer season of about 3 months duration on alpine pastures which range up to 2500 m o.d. before returning to the lowland again. Until recently, subalpine and alpine pastures were traditionally used to graze dairy cows and heifers. However, suckler beef systems have now gained a comparative advantage because of their current

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support by agricultural policy, the general trend to declining numbers of dairy cows and the lower work load. Identification of the most efficient way to utilise these alpine feed resources will decide on the sustainability of this livestock system. However, data on feed intake and nutrient utilisation of suckler beef on subalpine and highly diverse alpine pastures (Schubiger et al., 1998) are still very scarce. At high altitude, early-lactating dairy cows were found to be unable to consume sufficient amounts of herbage, even from well-managed high altitude pastures, to cover requirements (Christen et al., 1996; Berry et al., 2001a) but, because of the much lower milk yield level, these pastures could be sufficient for suckler beef systems. This has been confirmed only for a slow-growing extensive beef breed (Berry et al., 2002). A suboptimum herbage use efficiency is often associated with an elevated release of environmentally harmful emissions such as N, P and methane which are already unfavourably high both in suckler beef (Estermann et al., 2001) and in specialised pure beef populations (Martin and Seeland, 1999). Measures effectively reducing such emissions include supplementary feeding (Gruber et al., 1999). This is occasionally practised in alpine grazing of dairy cows (Berry et al., 2001b), but is uncommon in suckler systems. Other measures consist of a sophisticated adaptation of the animal system to seasonal growth of alpine feed resources including rotational grazing (Berry et al., 2001b). Accordingly, it can be assumed that the efficiency of alpine pasture use by suckler beef is very sensitive to a variation in production traits such as calving season and breed since it is necessary to closely match feed supply (determined by location) with feed requirements (determined by genetic potential, stage of lactation and altitude) to achieve efficiency. In this respect, the proportion of nutrients derived by the calf from milk and from forage is very important (Estermann et al., 2002) although it is unclear whether a high or a low proportion of nutrients coming from milk is advantageous in the overall production system.

The objective of the present study was to compare nutrient intake, excretion and utilisation on subalpine and alpine pasture of four suckler beef production options, namely, two common calving seasons in two dam breeds. Genotypes were either a dual purpose breed, which might be directly available in dairy farms, or a beef breed. Rotational grazing was simulated by small and frequently changed paddocks as well as by second grazing of the high altitude site previously grazed at the start of the alpine period.

## 2. Materials and methods

### 2.1. Animals

In each of two years 12 cows with their calves were selected from a herd of 40 cows with 40 calves in the first year and 38 calves in the second year; thus there was a total of 24 different suckler cows. Half of the cows were Simmental and the other half Angus (with an average of 81% Aberdeen Angus blood obtained from grading up of Swiss dairy breeds). Cows were mated with 12 different Angus sires (91% Aberdeen Angus blood on average). Half of the cows of each breed calved in late autumn (9 November–7 January, with a 10 December average) and the other half in late winter (23 February–1 April, with a 12 March average). This resulted in four treatment groups. The mean lactation number was 1.6 ($\pm$0.7) and 1.8 ($\pm$0.9) for Simmental and Angus suckler cows, and 1.1 ($\pm$0.3) and 2.3 ($\pm$0.6) for the first and the second year, respectively. The number of primiparous and multiparous cows as well as of female and male calves was balanced in the four groups. At the start of the first experimental measurement period on the first pasture, the age of the autumn-born calves was 187 ($\pm$12) days and 150 ($\pm$25) days for the Angus $\times$ Simmental and the Angus groups, respectively. The corresponding ages of the calves born in late winter were 73 ($\pm$8) days and 80 ($\pm$18) days.

### 2.2. Pasture management

Animals of all experimental groups subsequently grazed three pastures and all animals were kept together on the same paddocks. The first experimental pasture (P1) facing north-west with a slight incline was located at 1000 m o.d. (subalpine). The paddock grazed during the main collection period on P1 had an area of 0.9 hectares. At the grazing time, herbage was first growth in late vegetative stage. The herbage on offer consisted of six grass species, three legume species and 12 herb species with grasses, legumes and herbs covering 86, 2 and 12% of surface, respectively. Both the second and the third experimental pasture (P2 and P3) facing south-west were located at 2000 m o.d. (alpine) with a medium incline. The paddocks on P2 and P3 grazed during the main collection periods had areas of 1.2 and 3.5 hectares, respectively, allocated in size according to estimated herbage mass. Pasture P2 was with first growth in its medium to late vegetative stage, P3 was regrowth in an early vegetative stage on a previously grazed site. Herbage on offer on P2 and P3 was composed of 12 grass species, eight legume species and 46 herb species covering 45, 25 and 30% of surface according to a previous assessment. Prior to grazing the composition of the standing sward was determined by taking random samples ($n = 50$ per paddock) of $20 \times 20$ cm$^2$ quadrats every 10 m along a diagonal line. Within the quadrats all vegetation was cut to 3 cm height and all samples of one paddock were mixed and frozen at $-20$ °C. The pasture of the subalpine site (P1) was fertilised twice per year with liquid cattle manure in early spring time and after the second grazing in summer, while the alpine pastures had not been fertilised for 15 years when for the last time superphosphate was applied. The animals had permanent access to fresh water and to a mixture (1:1) of NaCl and minerals containing per kg: 120 g Ca, 60 g P, 40 g Na, 30 g Mg, 600 000 IU vitamin A, 60 000 IU vitamin $D_3$, 1500 IU vitamin E, 500 mg Cu, 30 mg Se, 20 mg J, 10 mg Co, according to producer's statement (Kroni AG, Altstätten, Switzerland). Mineral supplement was offered to the cows and calves as a powder in a bowl. Intake of phosphorus (P) from the minerals was estimated from the total consumption of the complete groups assuming a constant ingestion rate per kg body weight (BW). As this calculated P intake from the premix proportionately only contributed to some 10% of total P intake, this simplification seems justified. The experiment was conducted in accordance with the Swiss guidelines for animal welfare.

### 2.3. Climatic conditions

Climatic conditions were measured during the grazing period with an automatic data recording station (Markasub, Olten, Switzerland) equipped with a data-logger (CR 10, Campbell Scientific Inc., Utah, USA). Measurements were air temperature, air humidity, wind speed and solar radiation as means over 10 min periods, and cumulation of precipitation data.

### 2.4. Sample collection regimen

The experimental periods were subdivided into 10 days of adaptation and 7 days of main data and sample collection on the experimental paddocks adjacent to the paddocks grazed during adaptation. Controlled release capsules (CRC, Captec® Ltd. Auckland, New Zealand) exuding $C_{32}$ (and $C_{36}$) alkanes at a stated steady batch release rate were orally introduced into the rumen 7 days prior to the respective collection periods (Berry et al., 2000). Cows received type MCM capsules (designed for 300 to 650 kg BW) and calves either type YC (designed for 100 to 300 kg BW) or type SP (designed for 50 to 100 kg BW; only six out of 72 capsules administered in the calves; this in the winter-born calves in period 1). Over the 7 days of measurement, which fell into the recommended sampling window for CRC's, spot faeces samples were collected at dawn from fresh dungpats of known individual animals or obtained rectally. Measurements on pasture P2 were 5.5 weeks after measurements on P1 (with the animals transferred to high altitude after 3 weeks) and P3 measurements were 3 weeks after those on P2; the animals grazed other areas in the time between measurements to ensure that previously dosed alkane capsules were empty (Berry et al., 2001a). Hand-plucked herbage samples to imitate the feeding pattern of cows and calves were obtained daily separately for each experimental group for 12 h per day by two people as suggested by Berry et al. (2000), when starting and ending 1 day prior to the faeces collection to account for delay in excretion. After collection, faeces and herbage samples were frozen at $-20$ °C and then thawed and pooled either for each animal or experimental group, respectively. Subsamples of faeces were refrozen for nitrogen (N) analysis performed in the samples thawed at 4 °C for 24 h. Herbage and faeces samples assigned to the other analyses were dried at 60 °C in a ventilated oven for 48 h. For calculation of herbage intake and digestibility, using the equations of Mayes et al. (1986), the $C_{31}$:$C_{32}$ ratio was applied as previously described by Berry et al. (2001a); in grass-only rations the latter ratio led to more accurate estimates of feed intake than those with $C_{33}$:$C_{32}$ (Estermann et al., 2001). Briefly, digestibility was calculated from the data on $C_{31}$ alkane concentrations in feed and faeces, faecal dry matter (DM) excretion was computed from dosed and excreted $C_{32}$ alkane, DM intake was calculated from DM excretion with faeces and DM digestibility, and faecal excretions of nitrogen and phosphorus were determined by faecal DM excretion and the respective contents in faecal DM. Body weight was recorded in all sampling periods every morning at about 06:00 h and, additionally, every second week throughout the total grazing period. Body weight data used for statistical evaluation refer to the average within the 7-day period of collection while daily BW change was calculated from the difference over a 21-day period including the 17-day experimental periods. Since no urine was collected, body N retention and urine N excretion were estimated by assuming 26 g N/kg of BW change in cows and calves (Anderson et al., 1988; Gibb et al., 1992). The latter estimate was confirmed by results of Gibb and Ivings (1993) in cows gaining or loosing BW. Urine P excretion was not considered.

### 2.5. Sample analysis

Dried feed and faeces samples were milled through a 0.75 mm screen. In these samples, contents of DM and organic matter (OM) were analysed by heating samples in an automatic muffle furnace (TGA 500, Leco Instruments, St. Joseph, MI, USA). Neutral detergent fibre (NDF) and crude fibre (CF) contents were determined as outlined by Van Soest et al. (1991) and Naumann and Bassler (1997). Nitrogen contents were assessed by an automatic C/N analyser (Leco-Analyzer Type FP-2000, Leco Instruments, St. Joseph, MI, USA), with crude protein (CP) calculated as $6.25 \times N$. Phosphorus concentrations were analysed using the AOAC method (AOAC, 1995) on an autoanalyser (SKALAR SANplus, Procon AG, Burgdorf, Switzerland). Contents of *n*-alkanes ($C_{31}$ and $C_{32}$) were determined on a gas chromatograph (HP-6890, Hewlett Packard, Waldbronn, Germany) equipped with a SPB-1 column (Supelco, Buchs, Switzerland) by duplicate extraction applying direct saponification (Berry et al., 2000). Herbage contents of metabolisable energy, net energy for lactation (NEL) and absorbable protein (PDI) were calculated from nutrient analyses by using the equations given by RAP (1999).

### 2.6. Statistical analyses

The experimental procedures allowed individual data on cows and calves to be obtained despite herding the animals in one group; this excluded the otherwise inevitable bias arising through differences between paddocks on diverse alpine vegetation. In some cases, data for individual cow–calf groups were analysed. Because of the malfunction of alkane capsules in three calves and in one cow, the four datasets of cows with calves from different experimental groups were omitted in the statistical analyses. All statistical analyses were performed with SAS (1996), applying a mixed model procedure (method = ml) which accounted for the repeated measurements character of the data. With attention to Schwarz's Bayesian criterion the optimum covariance structure was determined as described by Littell et al. (1998). As fixed effects dam breed ($B$), calving season ($C$), pasture ($P$), year ($Y$) and all possible interactions were analysed by the following model ($n = 68$ observations):

$$\begin{aligned} y_{ijklmn} = {} & \mu + B_i + C_j + P_k + Y_l + (B \times C)_{ij} \\ & + (B \times P)_{ik} + (B \times Y)_{il} + (C \times P)_{jk} \\ & + (C \times Y)_{jl} + (P \times Y)_{kl} + (B \times C \times P)_{ijk} \\ & + (B \times C \times Y)_{ijl} + (B \times P \times Y)_{ikl} \\ & + (C \times P \times Y)_{jkl} + (B \times C \times P \times Y)_{ijkl} \\ & + V(d_{ijm}) + cov(e_{ijklmn}). \end{aligned}$$

In a preliminary data analysis calf gender was found to have no significant influence on either intake or excretion of nutrients of suckler cows together with calves, and, therefore, was not included in the final analysis. Experimental year was inseparably confounded with lactation numbers of the cows, which always were selected from the same herd; therefore, year effects are not given in the tables. The Tukey procedure was used for multiple comparisons among means, provided effects were significant. $P$-values $<0.05$ were considered significant. In the tables, only interactions of breed and calving season are given whereas with the other interactions footnotes explain significance if any.

## 3. Results

### 3.1. Climate

Average climatic data during the two main experimental periods on each of the three pastures are presented in Table 1. There were only slight differences in average temperatures (11–13 °C) between periods, but within experimental periods mean daily temperature varied by up to 10 °C. Compared to P1, the daily average wind speed was twice greater on both P2 and P3. A high precipitation and a high percentage of rainy days occurred on P1 and P3 compared to P2; these were associated with corresponding differences in air humidity and solar radiation. The climatic conditions recorded can be considered as quite moderate but nevertheless typical (Christen et al., 1996; Berry et al., 2001a) for the respective altitudes and the stages of the seasons when the measurement periods took place.

### 3.2. Body weight change, herbage intake and digestibility of selected herbage

Body weight of cows on all pastures did not significantly differ between groups although the BW was numerically lower in the Angus cows than in the Simmental cows by an average of 23 kg (Table 2). Most cows calving in late winter lost weight (−156 g/day on average) whereas there were weight gains in autumn-calving cows (+114 g/day; significantly different from the group of winter-calving cows irrespective of breed). Body weight of the winter-born calves increased during subalpine and alpine grazings from 114 to 187 kg and the corresponding increase in the autumn-born calves was from 208 to 272 kg. The Angus×Simmental calves started at a significantly higher BW and had a higher BW gain than the Angus calves (1124 vs. 971 g/calf/day; $P<0.01$), but the effect of the calving season was similarly high and in favour of the winter-born calves (+146 g/calf/day). Interactions between calving season and dam breed were found only in BW of the calves and not in weight gain or loss of cows and calves.

The herbage selected by cows and calves did not differ much in nutrient composition from that offered on the three pastures and no clear pattern of selection for or against a compositional trait was obvious (Table 3). The estimated dry matter intake (DMI) of the cows depended on measurement period (pasture) and breed (Table 4). The average DMI was similar on the two alpine pastures (P2 and P3) and was lower on the subalpine pastures P1, but there was a large variation between groups even on the alpine pastures. The Simmental cows consumed 22% more DM than the Angus cows. There was no effect of calving season on cow DMI with an average of 14.3 and 14.5 kg/day for autumn and winter calving cows, respectively. When related to metabolic BW ($BW^{0.75}$), DMI of cows was still affected by pasture and dam breed (139 vs. 117 g/kg $BW^{0.75}$ in Simmental and Angus cows, respectively). Digestibilities of OM and of NDF were not influenced by breed and calving season; but alpine pastures had an average of

Table 1
Climatic conditions (24 h averages) recorded at subalpine (P1) and alpine regions (P2, P3) during the respective measurement periods (average of two grazings)

| | P1 (1000 m o.d.) | P2 (2000 m o.d.) | P3 (2000 m o.d.) |
|---|---|---|---|
| Temperature (°C) | 12.0±3.2 (7.8–17.0) | 10.8±2.9 (5.4–16.3) | 13.3±5.5 (8.2–18.5) |
| Wind speed (km/h) | 3.1±1.1 (0.2–9.2) | 6.5±1.1 (0.5–15.9) | 6.4±1.3 (0.6–16.6) |
| Precipitation (mm/day) | 8.6±0.8 (0.0–32.2) | 1.5±0.3 (0.0–13.4) | 6.6±0.5 (0.0–23.2) |
| Days without rain (%) | 31±27 | 69±35 | 47±24 |
| Air humidity (%) | 79.3±8.4 | 68.9±12.7 | 73.5±12.6 |
| Solar radiation (W/m$^2$) | 203±73 | 268±64 | 198±78 |

Table 2
Body weight and daily weight change of suckler cows and calves on subalpine (P1) and alpine pastures (P2, P3)

| Dam breed (B) Calving season (C) | | Simmental Autumn | Simmental Winter | Angus Autumn | Angus Winter | Mean | S.E. | Fixed effects and interactions B | C | P | B×C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cows | | | | | | | | | | | |
| Body weight (kg) | P1 | 565 | 551 | 536 | 540 | 548 | 16.9 | ns | ns | ns | ns |
| | P2 | 572 | 542 | 533 | 536 | 546 | | | | | |
| | P3 | 572 | 533 | 531 | 523 | 540 | | | | | |
| | Mean | 570 | 542 | 533 | 533 | | | | | | |
| Weight change (g/day) | P1 | 23 | −10 | −298 | −408 | −173 | 176.7 | ns | * | ns | ns |
| | P2 | 353 | 37 | 411 | −208 | 148 | | | | | |
| | P3 | 37 | −151 | 158 | −198 | −38 | | | | | |
| | Mean | 138 | −41 | 90 | −271 | | | | | | |
| Calves | | | | | | | | | | | |
| Body weight (kg) | P1 | 226 | 119 | 190 | 109 | 161[c] | 4.6 | *** | *** | *** | ** |
| | P2 | 267 | 163 | 230 | 148 | 202[b] | | | | | |
| | P3 | 291 | 198 | 253 | 176 | 229[a] | | | | | |
| | Mean | 261[w] | 160[y] | 224[x] | 144[z] | | | | | | |
| Weight gain (g/day) | P1 | 1071 | 1248 | 986 | 987 | 1073 | 58.1 | ** | ** | ns | ns |
| | P2 | 1070 | 1167 | 815 | 1001 | 1013 | | | | | |
| | P3 | 966 | 1219 | 936 | 1097 | 1055 | | | | | |
| | Mean | 1036 | 1211 | 913 | 1029 | | | | | | |

[a–c]Means within the same column and within variable not sharing a common superscript are significantly different ($P<0.05$).
[w–z]Means within the same row not sharing a common superscript are significantly different ($P<0.05$).
$P$-value: *$P<0.05$, **$P<0.01$, ***$P<0.001$, ns = non significant.

Table 3
Nutrient composition (per kg DM) over two grazings of herbage on offer at the start of the respective measurement periods ($n=2$ per pasture) and of herbage actually selected by the animal groups ($n=8$ per pasture)

| Pasture (P) | DM (g)[a] | OM (g) | CP (g) | P (g) | NDF (g) | CF (g) | ME[b] (MJ) | NEL[b] (MJ) | PDI[b] (g) |
|---|---|---|---|---|---|---|---|---|---|
| P1, 1000 m o.d. | | | | | | | | | |
| Offered | 197 | 918 | 139 | 3.5 | 565 | 273 | 10.02 | 5.81 | 95 |
| Selected by cows | 239 | 926 | 131 | 3.1 | 586 | 280 | 10.01 | 5.79 | 94 |
| Selected by calves | 206 | 913 | 135 | 3.3 | 560 | 271 | 9.95 | 5.76 | 94 |
| P2, 2000 m o.d. | | | | | | | | | |
| Offered | 212 | 927 | 127 | 2.3 | 491 | 226 | 10.71 | 6.29 | 99 |
| Selected by cows | 236 | 926 | 129 | 2.2 | 483 | 233 | 10.61 | 6.22 | 97 |
| Selected by calves | 252 | 928 | 125 | 2.1 | 488 | 231 | 10.65 | 6.25 | 96 |
| P3, 2000 m o.d., regrowth | | | | | | | | | |
| Offered | 216 | 897 | 172 | 2.1 | 476 | 199 | 10.75 | 6.34 | 105 |
| Selected by cows | 215 | 894 | 171 | 2.0 | 452 | 186 | 10.83 | 6.40 | 105 |
| Selected by calves | 235 | 899 | 169 | 1.8 | 463 | 188 | 10.87 | 6.42 | 105 |

[a] Per kg of fresh weight.
[b] Calculated by RAP (1999) method.

4% higher digestiblity of OM and a 4% lower digestibility of NDF compared to the subalpine pasture.

DMI of the calves was influenced by their age (calving season and measurement period). Average herbage DMI of the calves increased almost linearly

Table 4
Herbage dry matter intake and digestibility of suckler cows and calves on subalpine (P1) and alpine pastures (P2, P3)

| Dam breed (B) Calving season (C) | | Simmental Autumn | Simmental Winter | Angus Autumn | Angus Winter | Mean | S.E. | B | C | P | B×C |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cows** | | | | | | | | | | | |
| Herbage DM intake (kg/day) | P1 | 11.7 | 13.4 | 10.7 | 11.9 | 11.9[b] | 0.80 | *** | ns | *** | ns |
| | P2 | 17.8 | 17.3 | 14.5 | 13.1 | 15.7[a] | | | | | |
| | P3 | 17.1 | 17.9 | 14.2 | 13.9 | 15.8[a] | | | | | |
| | Mean | 15.5 | 16.2 | 13.1 | 12.9 | | | | | | |
| Herbage DM intake[†] (g/kg $BW^{0.75}$) | P1 | 101 | 118 | 96 | 107 | 106[b] | 5.9 | *** | ns | *** | ns |
| | P2 | 151 | 153 | 130 | 116 | 138[a] | | | | | |
| | P3 | 146 | 161 | 127 | 125 | 140[a] | | | | | |
| | Mean | 133 | 144 | 118 | 116 | | | | | | |
| Digestibility of OM[†,‡] (%) | P1 | 69.1 | 72.6 | 71.9 | 73.7 | 71.8[c] | 0.77 | ns | ns | *** | ns |
| | P2 | 77.1 | 76.2 | 75.1 | 74.8 | 75.8[a] | | | | | |
| | P3 | 74.3 | 74.9 | 73.0 | 73.9 | 74.0[b] | | | | | |
| | Mean | 73.5 | 74.6 | 73.3 | 74.1 | | | | | | |
| Digestibility of NDF[†,‡] (%) | P1 | 66.2 | 71.2 | 72.1 | 72.8 | 70.6[a] | 1.18 | ns | ns | ** | ns |
| | P2 | 71.2 | 68.9 | 68.5 | 66.5 | 68.8[b] | | | | | |
| | P3 | 67.4 | 69.0 | 67.1 | 67.1 | 67.7[b] | | | | | |
| | Mean | 68.3 | 69.7 | 69.2 | 68.8 | | | | | | |
| **Calves** | | | | | | | | | | | |
| Herbage DM intake[‡] (kg/day) | P1 | 1.8 | 0.4 | 1.6 | 0.6 | 1.1[c] | 0.17 | ns | *** | *** | ** |
| | P2 | 3.7 | 1.3 | 2.8 | 1.7 | 2.4[b] | | | | | |
| | P3 | 5.0 | 2.3 | 4.2 | 2.6 | 3.5[a] | | | | | |
| | Mean | 3.5[x] | 1.3[z] | 2.9[y] | 1.6[z] | | | | | | |
| Herbage DM intake (g/kg $BW^{0.75}$) | P1 | 30 | 10 | 30 | 16 | 22[c] | 2.6 | ns | *** | *** | ** |
| | P2 | 55 | 28 | 47 | 41 | 43[b] | | | | | |
| | P3 | 70 | 44 | 66 | 53 | 58[a] | | | | | |
| | Mean | 52[x] | 27[z] | 48[x] | 37[y] | | | | | | |
| Digestibility of NDF (%) | P1 | 67.7 | 58.2 | 63.5 | 62.4 | 62.9[b] | 1.26 | ns | *** | *** | ** |
| | P2 | 65.3 | 59.6 | 62.9 | 62.1 | 62.5[b] | | | | | |
| | P3 | 70.9 | 67.7 | 69.5 | 68.0 | 69.0[a] | | | | | |
| | Mean | 67.9[x] | 61.9[z] | 65.3[y] | 64.1[y] | | | | | | |

Columns B, C, P and B×C: Fixed effects and interactions.

[a–c] Means within the same column and within variable not sharing a common superscript are significantly different ($P<0.05$).
[x–z] Means within the same row not sharing a common superscript are significantly different ($P<0.05$).
$P$-value: * $P<0.05$, ** $P<0.01$, *** $P<0.001$, ns = non significant.
[†]Significant ($P<0.05$) interaction of dam breed × pasture.
[‡]Significant ($P<0.05$) interaction of calving season × pasture.

with advancing pasture season from 1.1 to 3.5 kg/day; this was not an effect of the increasing BW alone since intake relative to metabolic BW increased from 22 to 58 g/kg ($P<0.001$). Calves born in late winter consumed significantly less herbage DM than autumn-born calves, particularly when this was expressed on an absolute basis (−1.8 kg/d) but also as a proportion of metabolic BW (−18 g/$kg^{0.75}$). Dam breed had little influence on herbage intake of the calves. In the calves, digestibility of NDF was about 9% lower on pastures with first growth (P1 and P2) than on secondary growth (P3). Furthermore, the winter-born calves digested NDF to a significantly lower proportion (63.0%) than the autumn-born calves (66.6%), irrespective of dam breed. Nevertheless, the interaction of dam breed and calving season was generally significant for herbage intake and NDF digestibility of the calves; the effects of the calving season were greater with Simmental dams than with Angus dams.

The potential stocking density on given pastures differed between the different experimental groups as the joint DMI of cows and calves (data not shown) was higher in Simmental (18.7 kg/day) than in Angus groups (15.5 kg/day) and higher in autumn calving (17.7 kg/day) than in winter calving groups (16.2 kg/day). Furthermore, average total DMI increased as the pasture season advanced from 13.5 to 18.0 and 19.3 kg/day in P1, P2 and P3, respectively.

### 3.3. N and P turnover

Dam breed had a significant effect on most variables of the system (cow with calf) N turnover. The Simmental groups had a higher N intake (+70 g/day) and excretion than the Angus groups, even when expressed per kg of weight gain (Table 5). However, this did not affect either the urinary N as a proportion of total N excretion or the estimated N utilisation expressed as N retention as a percentage of N intake. The winter calving groups consumed and excreted less N (not significant in faecal N) than

Table 5
Nitrogen excretion of suckler beef (cows together with calves) on subalpine (P1) and alpine pastures (P2, P3)

| Dam breed (B) Calving season (C) | | Simmental | | Angus | | Mean | S.E. | Fixed effects and interactions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Autumn | Winter | Autumn | Winter | | | B | C | P | B×C |
| N intake[†] (g/day) | P1 | 291 | 304 | 289 | 280 | 291[c] | 18.7 | *** | * | *** | ns |
| | P2 | 431 | 382 | 356 | 310 | 370[b] | | | | | |
| | P3 | 595 | 551 | 488 | 436 | 517[a] | | | | | |
| | Mean | 439 | 412 | 378 | 342 | | | | | | |
| Total N excretion[†] (g/day) | P1 | 263 | 271 | 269 | 258 | 265[c] | 17.9 | *** | * | *** | ns |
| | P2 | 394 | 351 | 324 | 289 | 340[b] | | | | | |
| | P3 | 568 | 523 | 459 | 412 | 491[a] | | | | | |
| | Mean | 409 | 382 | 351 | 320 | | | | | | |
| Faecal N (g/day) | P1 | 138 | 130 | 107 | 125 | 125[c] | 7.7 | ** | ns | *** | ns |
| | P2 | 164 | 156 | 153 | 128 | 150[b] | | | | | |
| | P3 | 206 | 197 | 180 | 149 | 183[a] | | | | | |
| | Mean | 169 | 161 | 146 | 134 | | | | | | |
| Urinary N[†,‡] (g/day) | P1 | 124 | 140 | 161 | 135 | 140[c] | 13.1 | ** | * | *** | ns |
| | P2 | 230 | 195 | 172 | 161 | 189[b] | | | | | |
| | P3 | 363 | 326 | 280 | 263 | 308[a] | | | | | |
| | Mean | 239 | 221 | 204 | 186 | | | | | | |
| Urinary N[†] (% of total excretion) | P1 | 44.0 | 49.6 | 60.8 | 50.5 | 51.2[c] | 2.24 | ns | ns | *** | ns |
| | P2 | 57.3 | 55.3 | 51.4 | 53.6 | 54.4[b] | | | | | |
| | P3 | 63.7 | 62.5 | 60.8 | 63.7 | 62.7[a] | | | | | |
| | Mean | 55.0 | 55.8 | 57.7 | 56.0 | | | | | | |
| Total N excretion[†] (g/kg weight gain) | P1 | 311 | 220 | 300 | 272 | 276[c] | 35.9 | * | ** | *** | ns |
| | P2 | 518 | 330 | 334 | 285 | 366[a] | | | | | |
| | P3 | 626 | 433 | 507 | 377 | 486[a] | | | | | |
| | Mean | 484 | 328 | 380 | 311 | | | | | | |
| N retention[‡] (% of N intake) | P1 | 10.2 | 10.9 | 9.0 | 9.5 | 9.9[a] | 0.57 | ns | ** | *** | ns |
| | P2 | 7.4 | 8.3 | 6.8 | 9.4 | 8.0[b] | | | | | |
| | P3 | 4.3 | 5.8 | 5.1 | 6.6 | 5.5[c] | | | | | |
| | Mean | 7.3 | 8.3 | 7.0 | 8.5 | | | | | | |

[a–c] Means within the same column and within variable not sharing a common superscript are significantly different ($P<0.05$).
$P$-value: * $P<0.05$, ** $P<0.01$, *** $P<0.001$, ns = non significant.
[†]Significant ($P<0.05$) interaction of dam breed × pasture.
[‡]Estimated from N balance assuming ±26 g N/kg body weight change (Anderson et al., 1988; Gibb et al., 1992).

the autumn calving groups, particularly when related to units of weight gain (432 vs. 320 g N excretion/kg weight gain in the autumn and winter calving groups, respectively). Accordingly, N utilisation was higher by 17% in the groups calving in late winter. No significant interactions of dam breed and calving season were noted, suggesting that these effects, when occurring, were additive. Intakes of N increased significantly from P1 to P2 to P3. The increase from P1 to P2 was mainly due to the higher herbage DM intake, whereas in P3 the much higher N content of the grass was the overriding factor. Interactions of dam breed and pasture occurred for several traits; this is partially explained by the similar N intake of breed groups on P1 and the higher intakes of the Simmental groups on P2 and P3.

Phosphorus intake and faecal excretion were lower ($P<0.001$) on P2 and P3 than on P1 (41.5 vs. 48.2 g/day and 27.2 vs. 39.2 g/day, respectively) (Table 6). Intake of P by the Angus groups was about 14% lower than that of the Simmental groups. Faecal P correspondingly differed between breed groups. However, dam breed effects were no longer significant when P excretion was related to system BW gain. The winter calving groups, with only slightly lower P intake, excreted significantly less P through faeces both in absolute terms and relative to BW gain. Urine P was likely to be so low that it could be ignored. No significant interactions between the main effects were found in P intake and faecal excretion.

## 4. Discussion

This study compared herbage intake, performance and nutrient turnover of suckler beef animals of different dam breed and calving season, which grazed three pastures differing in altitude and in growth number of herbage thus simulating typical alpine farming systems. Alpine grazing assists to maintain nutrient quality and biodiversity of these areas and helps to prevent potential natural hazards such as avalanches (Cernusca et al., 1997); therefore it is publicly considered valuable and is subsidised. Troxler and Jans (2000) claimed that an appropriate alpine pasture and animal management ensures favourable performance of beef cattle and sustainable pasture utilisation. In this study, some of these decisive management options were investigated under controlled experimental conditions.

### 4.1. Herbage intake and performance

Alkane-based techniques to estimate herbage intake on alpine pasture were repeatedly and successfully applied in dairy cows (Malossini et al., 1996; Berry et al., 2001a,b), and the applicability of slow-

Table 6
Phosphorus excretion of suckler beef (cows together with calves) on subalpine (P1) and alpine pastures (P2, P3)

| Dam breed (B) Calving season (C) | | Simmental | | Angus | | Mean | S.E. | Fixed effects and interactions | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Autumn | Winter | Autumn | Winter | | | B | C | P | B×C |
| P intake (g/day) | P1 | 48.5 | 51.3 | 46.6 | 46.5 | 48.2[a] | 1.83 | *** | ns | *** | ns |
| | P2 | 47.2 | 43.8 | 41.5 | 37.1 | 42.4[b] | | | | | |
| | P3 | 45.7 | 43.9 | 37.8 | 34.7 | 40.5[b] | | | | | |
| | Mean | 47.1 | 46.3 | 41.9 | 39.4 | | | | | | |
| Faecal P (g/day) | P1 | 44.0 | 38.6 | 40.1 | 34.1 | 39.2[a] | 1.39 | ** | ** | *** | ns |
| | P2 | 30.9 | 26.7 | 28.6 | 24.0 | 27.6[b] | | | | | |
| | P3 | 29.6 | 28.4 | 25.6 | 23.2 | 26.7[b] | | | | | |
| | Mean | 34.8 | 31.2 | 31.5 | 27.1 | | | | | | |
| Faecal P excretion (g/kg weight gain) | P1 | 49.7 | 31.3 | 44.7 | 35.5 | 40.3[a] | 2.75 | ns | *** | *** | ns |
| | P2 | 40.1 | 25.0 | 29.4 | 23.5 | 29.5[b] | | | | | |
| | P3 | 32.3 | 23.3 | 28.3 | 21.1 | 26.3[b] | | | | | |
| | Mean | 40.7 | 26.5 | 34.1 | 26.7 | | | | | | |

[a–b] Means within the same column and within variable not sharing a common superscript are significantly different ($P<0.05$).
$P$-value: * $P<0.05$, ** $P<0.01$, *** $P<0.001$, ns = non significant.

release capsules for this purpose was demonstrated by Berry et al. (2000) and Estermann et al. (2001). As these capsules are also available in sizes suitable for calves, this technique was applied in the present study and provided reasonable figures and effects on herbage intake.

DMI of Simmental and of Angus suckler cows on P1 at 1000 m o.d. was slightly lower than values found by Estermann et al. (2002) in suckler cows of the same breeds fed indoors with a forage mix consisting of grass silage, hay and straw and was also lower than that of grass- and maize-silage fed Simmental and Angus cows (Teichmann et al., 1999). DMI of cow-calf pairs on P1 was about 1 kg/day lower than values found by Marshall et al. (1998) with beef cows and calves grazing a grass-legume lowland pasture. However, a similar DMI was found by McCaughey et al. (1999) on alfalfa-grass pastures with primiparous Hereford× Simmental suckler cows. Therefore, the high proportion of primiparous cows in the present study explains the relatively low herbage intake.

When animals were moved to the high altitude pasture intake in all cows increased, as was also found in early-lactating dairy cows transferred from lowland to 2000 m o.d. (Christen et al., 1996); presumably this was a response to the high additional energy demand to cope with low oxygen pressure, steep slopes and other constraints (Christen et al., 1996; Coulon and Pradel, 1997; Kreuzer et al., 1998; Berry et al., 2001a). Feed intake on P2/P3 compared to P1 was also enhanced by the higher OM digestibility measured in the cows (Gruber and Steinwender, 1996). The differences in OM digestibility which were corroborating with NDF content but not with NDF digestibility, may have resulted from the retarded growth development of alpine grass (Christen et al., 1996; Schubiger et al., 1998) while the variation in NDF digestibility might be attributed to shifts in the mass proportions of grasses, legumes and herbs with vegetative stage (Schubiger et al., 1998). In the present study there was, unexpectedly, no clear selection for or against nutrient or energy content of herbage by cows or calves, although the highly diverse alpine pastures, in particular, would have offered sufficient opportunity for selection. This finding is to some extent different from Berry et al. (2002) who noted that Scottish Highland calves actively select for a higher fibre content of herbage, presumably in order to counterbalance the high nutrient density in milk.

Similar to observations of Teichmann et al. (1999) and Estermann et al. (2002), Simmental cows showed a higher herbage DMI than Angus cows. Breed group differences in DMI increased from P1 (11%) to P2 and P3 (25%). Assuming this additional net energy from herbage (corrected for differences in maintenance requirements) was utilised for milk production (RAP, 1999), the Simmental cows would have produced 2 and 6 kg more milk than the Angus cows on P1 and P2/P3, respectively. Cows of both breeds managed to maintain or even increase their body weight when early calving (late-autumn calving) and showed a slight weight loss when cows were in early lactation (late-winter calving). A slight weight loss is a physiological reaction at this stage of lactation and the weight loss was far smaller than that found in early-lactating dairy cows producing about 30 kg/day milk and transported to high altitude (Christen et al., 1996; Berry et al., 2001a). This indicates that all suckler cows were able to cover their energy and nutrient requirements from the highly digestible herbage alone. Dam breed effects on herbage intake of the calves were minor; this suggests that differences in weight gain were mainly covered by a corresponding variation of milk intake (Fiss and Wilton, 1993). Angus×Simmental calves were clearly superior in growth to the Angus calves as was expected from the higher genetic growth potential of Simmental compared to Angus (e.g. Jenkins et al., 1991). This was also true over the complete fattening-period including the 3 months of alpine grazing; BW gains of 1120 and 1017 g/day were measured for Angus×Simmental and purebred Angus calves, respectively (Erdin et al., 2000). The calves in the above study were in the herd which also included the calves selected for the present study. Similarly, McGee et al. (1998) and Manninen et al. (1998) found high daily BW gains in suckler beef systems when milk supply from the dams was high. These studies suggest that herbage intake did not seriously limit growth particularly in the winter-born calves; therefore, the subalpine and alpine pastures of the quality investigated are generally adequate to match the requirements of cows and calves in both dam breeds. However, Erdin et al. (2000) showed that, after the alpine grazing during summer, calves did not have sufficient fat cover to be slaughtered at

10 months of age as is prescribed in a major Swiss beef label for marketing of suckler beef.

Calving season did not significantly affect herbage intake of the suckler cows but was responsible for the differences in BW change as the early-lactation cows mobilised nutrients and the autumn-calving cows retained nutrients. On the other hand, age had a major effect on herbage intake of the calves as can be seen from the effects of calving season and measurement period; this resulted from the increasing requirements (BW), increasing feed intake capacity and declining proportion of milk. The higher NDF digestibility noted in the autumn-born calves (not obvious in the cows) as well as the increase of this trait on P3 both illustrate the progressive adaptation of the rumen of the calves to roughage. Winter-born calves had a clear advantage over autumn-born calves based on their higher daily gains and efficiency. Astonishingly, herbage utilisation through the cows seems to be more efficient than that directly through the calves despite the twofold transformation losses from feed to milk to BW gain. Reasons for that could be that the herbage intake capacity of the autumn-born calves was still too limited to cope with the lower milk yield and that early-lactation cows contributed body reserves to maintain high calf gains. The first hypthesis is supported by the results of Sowell et al. (1996) who did not find an increase in forage DMI of young (71 days of age) suckler calves when suckling was prevented.

As one of the few significant interactions, Angus × Simmental calves responded in a more pronounced manner in herbage intake to alterations in calving season than the Angus calves. However, this was presumably a result of the initial differences in BW since the interaction was non-significant in BW gain.

### 4.2. N intake, excretion and utilisation

The system (cow with calf) N intake on P2 and P3 was about 1.3 and 1.8 times higher than that on P1 as a consequence of both the higher DMI on alpine pastures and the increased N content in regrowth herbage. A higher system N intake was associated with more than proportionate increases in both urinary N excretion and urine N as a proportion of total N excretion. Urine N is highly susceptible to volatilisation and leaching, particularly on pastures with diverse topography and vegetation communities and large spatial variability in nutrient excretion (Woodmansee et al., 1981). Despite the relatively low N content of herbage on P1 and P2, the urinary N proportion of total excreted N was higher than values found by Estermann et al. (2001) with forage-fed (137 g CP/kg DM) suckler beef and similar to values found with maize silage-hay fed (142 g CP/kg DM) dairy cows (Kirchgessner et al., 1991). Urine N proportion on P3 was slightly lower than that measured in dairy cows grazing lowland pasture with 195 g CP/kg DM (Bussink, 1994) and of suckler beef receiving a forage-concentrate diet with 175 g CP/kg DM (Reynolds and Tyrrell, 2000). These observations seem reasonable, since N utilisation in suckler beef is generally lower than in dairy cows and, consequently, urine N losses are higher at the same dietary CP content. With short rotational grazing, urine N can be directly used for plant growth within the same alpine season resulting in regrowth of high quality; this allows a higher overall seasonal stocking rate (Berry et al., 2001b).

The more than proportionate response in urine N to dietary N intake, together with the limited relationship of herbage N content and intake, shows that DMI of suckler cows and calves was not predominantly regulated by N intake and that herbage crude protein contents of 170 g/kg DM have to be regarded as excessive for suckler beef. The inverse relationship between organic fertiliser N and N utilisation is obvious from comparing P3 data with those of P1 and P2. Generally, N utilisation was high compared to suckler beef based on a slowly growing beef breed but low compared to dairy cows (Berry et al., 2001b).

Dam breed was found to significantly affect N intake and excretion, but urinary N proportion of total N and N utilisation relative to intake were similar with Simmental and with Angus dams. This shows that this was an effect only of the different herbage intakes. Accordingly, it would have been possible to have a higher stocking density with similar N intakes and returns with the Angus systems; this means that outputs of the two dam breeds would then be similar on a per hectare basis. A late calving season decreased system N turnover due to the lower herbage intake of the calves, and estimated overall N utilisation was higher due to the higher system daily weight gains at lower intake. This clearly favours late-winter over late-autumn calving. Interactions found between dam breed and pasture mainly resulted from the higher response in N intake to changes in pasture type by the Simmental groups, whereas interactions between dam breed and calving season were not significant.

### *4.3. P intake and excretion*

Phosphorus content of herbage on P1 almost reached the level of 3.5 g/kg DM recommended to meet P requirements of cattle (Spatz et al., 1981), whereas the alpine pastures were clearly deficient in this respect as noted earlier (Berry et al., 2001b). A low herbage P content is expected on unfertilised pastures or pastures with low crude protein content and legume proportion (Prins et al., 1985). Due to the low herbage P content, P intake from herbage on P2 and P3 was lower by 14% than on P1, although DMI was higher on P2 and P3. Supplementary P, from the mineral offered, helped to increase P supply to recommended levels for growth (Ternouth et al., 1996) and lactation (Ternouth and Coates, 1997) although only moderate amounts of the mineral were consumed and the Ca:P ratio was unfavourably low for P. Faecal P closely reflects P intake since urinary P excretion is usually low, e.g. less than 1 g/day in cows fed diets with P contents $<40$ g/kg DM (Wu et al., 2000). The fact that faecal P excretion was relatively low would suggest a very high P retention in the body of the cows and calves. However, effects and relationships may have been masked by individual variation, since mineral P intake was measured for the complete herd only and consumption of the mineral by wildlife passing by cannot be totally excluded. The subalpine soil and particularly the alpine soil are low in P; therefore, excreta P returns did not pose a great environmental problem in any treatment groups in terms of P run-off, unless faeces distribution was highly uneven.

## 5. Conclusions

The present results showed that suckler beef cattle were able to meet nutrient requirements from herbage alone at all levels of altitude. Calves, particularly those born in late winter, were able to maintain a relatively high level of average daily gains. Calf gains as well as several traits of excretion and utilisation clearly favoured calving taking place shortly before summer feeding starts but not during summer grazing since this would pose great logistical problems with calving particularly on remote pasture sites. Late winter calving additionally opens the opportunity for intensive finishing in autumn, when the target age at slaughter is 10 months. The effects of the dam breed were lower than the effects of date of calving and slightly favoured the Simmental dams. In terms of excretion of nitrogen, particularly through urine, the variables overriding all other effects were pasture type and the N content of the herbage. In spite of the high N content of regrowth, rotational grazing on subalpine and alpine pastures is advisable in terms of fertilisation of nutrient-poor soils by excreta returns.

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