Performance and meat quality of suckling calves grazing cultivated pasture or free range in mountain.

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Abstract

The purpose of this study was to compare the effect of grazing on mountain (M) versus cultivated lowland pasture (C) on the performance and meat quality of suckling calves (Experiment 1 and 2). In addition, the effect of finishing on C after M on growth and meat quality was assessed (Experiment 2). Animals on C and M had on average similar live weight gain and carcass weight in the first experiment. However, the performance depended on year as gain and carcass weight was higher on C than on M in the first year and *vice versa* in the second year. In the second experiment the calves on M had lower gain and carcass weight than on C. Three week finishing on C after M compensated to some extent for the lower growth rate on M. Overall, the results indicate that mountain grazing may yield similar growth rates and slaughter weights as improved lowland pasture depending on year. There were only small effects of pasture type on carcass and meat quality traits like conformation, fatness, intramuscular fat and protein content, and fatty acid (FA) composition. The variation in FA composition could to a large extent be explained by difference in fatness with increase in monounsaturated and decrease in polyunsaturated FA with increasing intramuscular fat content, in turn varying between pasture type, experiment and year. There was a tendency that M led to higher proportion of C18:1n-9 and lower proportion of C18:1n-7 than C, which may be due to difference in milk and forage intake. Both pasture types resulted in meat with intramuscular fat with high nutritional value since the n-6/n-3 ratio was low.

Keywords: beef, suckling calves, fatty acids, growth, pasture

1. Introduction

Historically, cattle was the most important domestic animal species, in terms of feed intake and production, used for free-ranging forest and mountain grazing in Norway (Lunden, 2002). However, during the second half of the 20^{th} century, cattle's share of total free range grazing livestock, calculated as metabolic biomass, dropped from 56 % (61.2 kg/km^2) in 1949 to 20 % (9.4 kg/km^2) in 1999 (Austrheim et al., 2008). The contribution of sheep to the grazing biomass increased from 35 % to 77 % during the same period. Locally, cattle-grazing in forests and mountains is still practised, and the interest in more specialized beef production and niche marketing is increasing. Forest and mountain grazing may be economically attractive due to low feed costs and public support. These subsidies intend to stimulate the utilization of forests and mountains as pasture resources and maintain the valued aesthetics of cultural landscapes (Stortingsmelding nr.19, 1999). Previous research with steers and bulls in Norway has shown on average 56% less live weight gain on mountain than on lowland pastures (Gravir, 1962). Grazing cattle on forest and mountain pastures was still common when Gravir (1962) conducted his study, and the stocking rate of domestic animals in mountains was generally much higher than today. Little is known about the performance of cattle in mountain areas nowadays.

Production of pasture-based calf meat has no tradition in Norway. In areas with access to forests or mountains suitable for grazing, lowland grassland can to some extent be spared from summer grazing and used for winter forage production. The winter forage supply and the number of cows can thereby be increased to produce more offspring if the calves are slaughtered at the end or shortly after the end of mountain grazing period. Another advantage of slaughtering the calves in autumn after one season on pasture is that the cost of housing is significantly lowered compared with the traditional Norwegian system of indoor feeding for one (bulls) or two winters (steers). If meat from calves produced on mountain pasture is of a different quality (e.g. better nutritional value) than meat from calves grazing on lowland pasture, niche marketing may be possible; this in turn may generate a higher price. Meat fatty acid (FA) composition is a specific quality characteristic that is affected by diet and has been extensively studied due to its implication for human health (Scollan et al. 2006). Compared to feeding concentrates, grazing results in higher proportions of n-3 polyunsaturated fatty acids (PUFA), particularly C18:3n-3, and conjugated linoleic acid (CLA), increased PUFA:saturated fatty acid (SFA) ratio (P:S ratio) and decreased n-6:n-3 FA ratio in intramuscular fat (French et al., 2000; Poulson et al., 2004; Nuernberg et al., 2005). This is because fresh pasture is a rich source of C18:3n-3 (Dewhurst et al., 2001; Boufaied et al., 2003). Grazing also enhances the contents of other compounds regarded as beneficial in meat, like carotene and tocopherol, which may improve the shelf life of meat (Simonne et al., 1996; Daly et al., 1999; Yang et al., 2002). However, little is known about the effect of pasture type, e.g. botanical composition, on meat quality. It has been found that cow's milk produced on high altitude grassland has higher content of C18:3n-3 than milk produced on lowland pastures; this has been explained by reduced ruminal biohydrogenation of feed 18:3n-3 (Leiber et al., 2005), likely caused by properties of certain plant species (Collomb et al., 2002). Lambs finished on mountain pasture in Norway had more PUFA than comparable lambs grazing on cultivated lowland pastures (Adnoy et al., 2005). Steers grazing semi-natural grassland in UK had a lower proportion of C16:0 and a higher proportion of PUFA than steers grazing improved permanent pasture (Fraser et al., 2009). These studies indicate that there could be a pasture type effect on meat quality. It is known that both diet forage proportion (French et al., 2000) and length of time on pasture (Noci et al., 2005) affect the composition of fatty acids. Finishing on improved grassland after mountain grazing could also alter meat quality as there is change in forage composition, but the effects need to be studied and quantified.

The objectives of this study were to investigate 1) the effect of forest and mountain free-range grazing on growth, and on carcass and meat quality of suckling calves and 2) whether finishing on lowland pasture after mountain grazing affects the meat quality.

2. Materials and methods

2.1. Animals and pastures, experiment 1

On each of seven commercial farms, four in 2006 and five in 2007 (two participating both years), 10-12 suckling calves with their dams were raised on either on-farm permanent cultivated pasture in the lowland (C) or free range pasture in mountain/forest (M) in the municipalities Gausdal, Lillehammer and Øyer of Oppland County in S-E Norway (Table 1). Within farm and year, the calves were grouped according to sex and birth date and randomly assigned to the two experimental groups (C or M). All calves were weighed at birth, the day of turnout to mountain grazing, a few days after the gathering from mountain grazing, and at the abattoir. The calves were born in late February and early March. Average age at turn out to mountain grazing was 111 (SD ± 30) and 105 (SD ± 19) days, average duration of mountain pasture was 92 (SD ± 30) and 88 (SD ± 30) days, and average age at slaughter was 203 (SD ± 31) and 193 (SD ± 25) days in 2006 and 2007, respectively (Table 1). The M and C grazing animals were turned out on the same day, irrespective of temperature or other weather conditions. On all farms crosses of cattle breeds were used with high proportion of

Aberdeen Angus (AA) on one farm, Charolais (CH) on one farm, Norwegian Red (NR) on one farm and Simmental (SI) on the other farms (Table 1).

During winter, from birth to start of grazing, the calves and their dams were fed according to the practice on each farm. Generally, the animals were fed grass silage *ad libitum* and restricted amounts of concentrate.

The animals in M grazed free-range together with other herds in vegetation types that varied from open, grass-dominated meadows to forests with patches of grasses, herbs and shrubs between the trees (mainly *Betula spp*. and *Picea abies* L.) and alpine vegetation with dwarf shrub heath, lichen heath and tall forbs meadows. The altitude range was from 600 to 1300 m above sea level (Table 1, tree limit is at ≈ 1050 m). The stocking rate ranged from 0.5 to 11.5 cattle heads, including cows, calves, steers and heifers, and 0 to 53 sheep per km^2. The lowland pastures (C) were fertilized continuously grazed permanent grasslands located close to the farm within the altitude range of 250 to 500 m. The stocking rate ranged from 1.3 to 2.8 cattle heads per ha, and the N fertilization rate from 0 to 180 kg N per ha applied as compound fertilizers and animal manure (Table 1). The pastures were grass-dominated, and quantitatively important species were *Poa pratense* L., *Agrostis capillaris* L., *Deschampsia cespitosa* L., *Acillea millefolium* L., *Rumex acetosa* L., *Ranunculus acris* L. On all farms in 2006 and on two farms in 2007, the animals in the C-treatment grazed on cultivated pastures dominated by *Lolium multiflorum* Lam. (5 farms) or *Dactylis glomerata* L. (1 farm in 2006) for at least three weeks before slaughtering. On two farms, the animals on C were fed on farm produced round bale grass silage in periods with pasture shortage.

The weather conditions showed considerable between-year variations, but were similar in the lowlands and in the mountains (Figure 1). Average mean daily temperature was lower (3.5 °C in July) in 2007 than in 2006. Precipitation in June and July, critical for grass growth, was between 129 and 159 % higher in 2007 than in 2006.

2.2. Animals and pastures, experiment 2

Thirty-two winter-born (5 March ± 25 days) calves (local Norwegian breed "Sided Trønder and Nordlandsfe", hereafter termed STN) were used in 2008. The calves were grouped according to sex and date of birth. On turn-out to mountain pasture (19 June), the animals were randomly divided into four treatment groups: CE; lowland cultivated pasture for 68 days (age at slaughter 176 ± SD 19 days), CF; same as CE but for 95 days (age at slaughter 198 ± SD 30 days), ME; mountain pasture for 68 days (age at slaughter 174 ± SD 25 days), and MF; mountain pasture for 68 days with ME and thereafter 27 days finishing on lowland cultivated pasture with CF (age at slaughter 200 ± SD 31 days). The cultivated lowland pasture was located on the experimental farm of the Norwegian University of Life Sciences (59.7°N, 10.8°E, 95 m above sea level). Fertiliser was applied to the lowland cultivated pasture at a total rate of 149 kg N ha^{-1}, 28 kg P ha^{-1} and 71 kg K ha^{-1} at two approximately equal dressings. Animals in the M groups grazed in a mountain area of Folldal municipality in Hedmark County (62.2°N, 10.1°E, 850 m above sea level) for 7 days, before they were moved approximately 20 km to Grimsdalen, Dovre municipality in Oppland county (62.1°N, 9.8°E, 1000 m.a.s.l.) for the rest of the period. The lowland cultivated pasture was rotationally grazed, while the animals grazed free-range in the mountains. The grazing area in Folldal consisted of *Betula spp*. dominated sub-alpine forest of varying grazing quality, some parts were poor with little grass and herbs whilst other areas offered forage of very high quality

(Rekdal, pers.comm.). The grazing areas along the river in the valley floor in Grimsdalen (treatment M) consisted of 1) alpine ridge vegetation dominated by *Arcotastaphylos uva-uris*, *Festuca rubra ssp rubra* and *Festuca ovina ssp.ovina*, 2) graminoid ridge with high proportion of *Agrostis capillaries* and *Deschampsia cespitosa* and 3) patches of extremely to moderately rich lawn fen. The valley sides were dominated by 4) dwarf birch heath and 5) tufted hair-grass grassland (*Deschampsia cespitosa* grassland) at now abandoned out-farms (Rekdal 1998; Grenne and Bele pers. comm.). The improved lowland pasture at Ås (treatment L) was dominated by *Poa pratensis*, *Phleum pratense* and *Festuca paratensis.*

The calves followed their mothers and could suckle freely from birth to slaughter. From calving until turn-out, the cows and their calves were offered baled grass silage *ad libitum*. No concentrates were offered, but the animals had free access to a standard mineral and vitamin premix (PLUSS Multitilskudd Appetitt storfe og geit, Felleskjøpet Fôrutvikling, Trondheim Norway).

Three times (June 23-24, July 22-23 and August 11-12) during the summer grazing period, activity budgets of both the free range and the lowland flocks were collected. On each occasion, observers followed the herds continuously for 48 hours and used a time-sampling method with scanning (Martin and Bateson 1993) of all visible animals every 15 minutes. For each of five behaviour categories (foraging, walking/running, lying, suckling and “others”), the number of animals performing the activity was registered, for cows and calves separately. The observations within each category were summed and proportions of animals performing the different activities were calculated for each period.

All animals, cows and progeny, were individually weighed at birth, at turn out to pasture in spring (9 May), at the time of turn-out to mountain pasture (19 Jun), at the end of the mountain grazing period (27 Aug, CE and CF, only calves), four days after collection from mountain grazing (1 Sep, CF and MF calves and all cows), the day before transport to the abattoir (23 Sep, CF and MF calves) and before slaughtering at the abattoir (28 Aug, CE and ME; 24 Sep, CF and MF).

2.3. Slaughter procedure

The calves were transported to a commercial slaughterhouse. All calves within-farm were slaughtered on the same date within one week after having been gathered from M (experiment 1), and on the same day they arrived at the slaughterhouse. Carcasses were electrically stimulated after exsanguinations, hanged (pelvic suspension), visually graded and placed in a room where the temperature was lowered by 1°C per hour from room temperature to 4°C within 24h. Carcasses were visually graded according to the EUROP system, and the EUROP classes were transformed to a numerical scale; conformation ranging from 15 (E+, very good conformation) to 1 (P -, very poor conformation) and fatness (ranging from 1 = 1- leanest to 15 = 5+, fattest). Temperature and pH were monitored in the left *M. Longissimus dorsi* at 1, 3, 8 and 24 h after slaughtering. After 24 hours, the left *M. longissimus dorsi* was removed from the carcasses. The whole muscle was then wrapped in plastic and brought to Nortura, Oslo. Adipose tissue was dissected from the muscle and samples of the tissue were taken and kept at – 20°C until analysis. The muscle samples were packed in oxygen barrier polyamide bags (in vacuum) and conditioned for 21 days at 4°C. Thereafter the samples were frozen and kept at – 20°C until chemical (all samples) and sensory analysis (experiment 2) could be conducted.

2.4. Chemical analysis

Samples of muscle and subcutaneous fat were analysed three to four months after sampling. Ash, moisture, fat and protein (nitrogen × 6.25) contents were determined according to NMKL (Nordic Committee on Food Analysis (NMKL), 1989; Nordic Committee on Food Analysis (NMKL), 1991; Nordic Committee on Food Analysis (NMKL), 2003; Nordic Committee on Food Analysis (NMKL), 2005).

Meat colour was measured instrumentally as L*a*b values of lightness, redness and yellowness using a MINOLTA CM 2002 recording spectrocolorimeter (illuminant D65, observer angle 108). The colour was measured directly on the meat surface within 1 min of opening the samples.

Analysis of fatty acid methyl esters

The fatty acid (FA) composition was determined using the modified method of (Aasoldsen, 1998). Lipids from *M. longissmus dorsi* were extracted by adding and mixing 15 g homogenizate with 10mL HCl solution (ρ = 1.25)/10mL ethanol. The fat was extracted with 30 mL diethyleter and 30 mL light petroleum in a separation funnel. Lipids from the subcutaneous fat were isolated by melting (60 ºC) and filtration. About 20 mg of isolated lipids were dissolved in 1.5 mL toluene. Sodium methylate in methanol (1.5 mL 3%) was added and the mixture heated to 50 ºC for 3-5 minutes. After cooling, 3 mL water and 5 mL isooctane (with 0.1 % butylated hydroxytoluene (BHT)) were added. After mixing, the upper phase was isolated and dried over sodium sulphate. Twenty µL of the remaining extract was transferred to a 1.8 mL GC vial which was filled up with isooctane (1% BHT). Vials were transferred to GC for analysis.

All meat samples were analyzed for individual fatty acid methyl esters (FAME) on a Perkin Elmer gas chromatograph Autosys XL (Perkin Elmer Instruments, USA), equipped with a flame ionization detector and a WCOT Fused Silica/CP-Wax 52 CB capillary column (25 m × 0.25 mm, 0.2 µm film thickness). An amount of 1 µl was injected by split injection (1:30, split temperature 260 °C). Hydrogen was used as a carrier gas at a flow rate of 2.2 ml/min and a pressure of 55.8 kPa. The initial oven temperature was 90 °C for 2.0 min. The temperature program was as follows; increase of 40.0 °C/min up to 170 °C; increase of 3.0 °C/min up to 225 °C; isotherm at 225°C for 12.0 min. The detector temperature was 270 °C. Individual fatty acids were identified by retention time with reference to fatty acids standards Nu Check 68D (Nucheckprep, Elysian. Minnesota, US) and Larodan 6263 (Larodan Fine Chemicals, Malmø, Sweden) and fat sources (lard and cod liver oil) with known FA composition.

2.5. Sensory analysis (experiment 2)

The sensory analysis was carried out at Nofima Food (Ås, Norway), using a panel of 12 trained members. The frozen meat samples were thawed over-night under cool conditions. Then the samples were cut into 1.5 cm thick slices, put in plastic bags, vacuum packed and kept chilled for one more night. The following day, the meat was steamed in bags in a combi-steamer at 70°C for 30 min, kept warm and served. The meat was evaluated on a scale from 1 (none) to 9 (much) on odour (sour, sweet, metallic, liver, rancid), taste (sour, sweet, metallic, liver, bitter, rancid), and texture (hardness, tenderness, coarseness, greasiness, juiciness).

2.6. Statistical analysis

Data from experiment 1 were analysed using the Mixed Procedure of (SAS, 2004) where pasture type, sex, age at turn-out to mountain pasture (covariate) and live weight gain from birth to turn-out to mountain pasture (covariate) were included as fixed effects and year, farm within year and their interaction with the fixed effects were regarded as random effects. In addition, the data from the two farms that participated both years were subjected to a separate analysis where the effect of year was included as fixed effect in addition to pasture type, sex, age at turn out to mountain pasture and live weight gain, whilst effect of farm and its interaction with the fixed effect was included as random effects. In experiment 2, treatment (CE, CF, ME, MF), sex, age at turn-out to mountain pasture (covariate) and live weight gain from birth to turn-out to mountain pasture (covariate) were included as fixed effects and animal within treatment as a random effect. The following planned orthogonal contrasts were used: 1) Lowland improved pasture (C) vs. mountain pasture (M) $(\mu_{CE}+\mu_{CF})-(\mu_{ME}+\mu_{MF})$, 2) Early slaughtering (E) vs. finishing on cultivated pasture before slaughtering (F) $(\mu_{CE}+\mu_{ME})-(\mu_{CF}+\mu_{MF})$, and 3) the effect of finishing on lowland pasture after mountain grazing was tested by comparing the difference in response between mountain and lowland pasture treatment at early and late slaughter time $(\mu_{CF}+\mu_{ME})-(\mu_{CE}+\mu_{MF})$, where μ_{CE}, μ_{CF}, μ_{ME}, μ_{MF} is the expected response to treatment CE, CL, ME and ML, respectively. The last contrast (3) was tested only for response variables that included observations for all treatments at the date of slaughtering and for meat quality parameters.

In experiment 1, some of the data from two calves had to be omitted from the analysis; one calf was arrested by the Norwegian food safety authority at the abattoir (incorrect cleaving of the carcass) before we could take sample of the meat, and one because of weight measurement error at the start of the mountain grazing period. Two other calves from one farm were born during the mountain grazing period and therefore regarded as so different from the other experimental animals that we decided not to record data from them. One calf in experiment 2 drowned in a river while on mountain pasture.

Least square means and standard error of means are reported. Differences were regarded as significant when $P<0.05$ and as a tendency when $P<0.10$.

3. Results

3.1 Experiment 1: Mountain grazing vs. grazing on cultivated pasture

3.1.1 Animal performance and carcass quality

Live weight gain during the mountain grazing period, live weight gain from birth to slaughter, live weight at slaughter, carcass weight and carcass conformation was not affected by pasture type (Table 2). The carcasses from the M group had higher ($P<0.05$) fatness score than those from the C. The separate statistical analysis, using data only from the two farms participating both years, showed that there was a pasture type effect on calf performance but it depended on year indicated by a significant pasture type by year interaction for live weight gain ($P<0.01$), live weight at slaughter ($P<0.01$) and conformation ($P<0.1$). These traits were greater on C than on M in 2006 and lower on C than on M in 2007 (figures not shown). The variation was too great to prove any significant differences in carcass weight, but numerically the effect of year was similar; higher performance on C than on M in 2006 and vice versa in 2007.

3.1.2 Meat quality

The muscle of calves from C contained less fat ($P<0.05$) and its colour was darker (less lightness, $P<0.05$) and less yellow ($P<0.05$) than that from M-grazed animals (Table 3). These quality traits seemed not to be affected by year (figures not shown).

LSMEANS of fatty acid (FA) proportions by weight of total identified FA in intramuscular lipids are shown in Table 4. Generally, the FA composition was little affected by pasture type. However, the proportions of C18:0 and C18:1n-9 were higher ($P<0.001$) whilst C15:0 ($P<0.01$), C17:0 ($P<0.01$), C18:1n-7 ($P<0.001$) and C18:2n-6 ($P<0.01$) were lower in M- than in C-grazing animals. The fatty acid ratios used as health indicators, i.e. the P:S and the n-6:n-3 ratios, were also affected by treatment. P:S ratio tended to be larger ($P<0.10$) on C and the n-6:n-3 ratio was lower ($P<0.01$) on M (Table 4). The effect of pasture type seemed to be consistent across years. Although statistical significant for only C18:1n-9 ($P<0.001$), the effect of pasture type was similar in the data set with the two farms present both years as for the dataset with all farms, and there was no significant pasture type by year effects (figures not shown).

3.2 Experiment 2: Effect of finishing on cultivated pasture after mountain grazing

3.2.1 Animal activity

In the first two periods, June and July, the mountain flock spent more time walking than the lowland flock (Figure 2), whilst for the other activities differences were quite small. Still, there were indications of the animals spending less time grazing and standing on mountain pasture than on lowland pasture (Figure 2).

3.2.2 Animal performance and carcass quality

The calves grazing on lowland pastures (C) had higher ($P < 0.01$) live weight gain both during the grazing period and in total from birth to slaughter (Table 5). Finishing on cultivated pasture resulted in compensatory growth ($P < 0.10$) in the M-grazing animals (MF), but not enough to reach the live weight obtained by calves that spent the whole grazing season on C (CF). Thus, finishing on lowland pasture did not alter the difference in performance between mountain and lowland grazing calves.

The dams on mountain pasture lost weight (on average - 45 kg), while those grazing in the lowlands gained weight (on average 13 kg) (Table 6).

3.2.3 Meat quality

Calves slaughtered early had higher ultimate pH in the muscle ($P < 0.001$) than the animals that were slaughtered late (Table 7). There was a trend ($P < 0.10$) that muscles from C-calves contained more fat than those from M-calves. The muscle colour of animals slaughtered early had similar yellowness, but finishing on cultivated pasture decreased muscle yellowness in CF and increased it in MF, increasing the difference between M and C grazing animals ($P < 0.05$). There was a tendency that the muscle from calves that were slaughtered after finishing on C (CF and MF) was darker (less lightness, $P < 0.10$) than from calves slaughtered early (CE and ME) (Table 7).

The intramuscular fat of the M-grazing calves had on average a lower proportion of C14:0 ($P<0.01$), C16:0 ($P<0.05$) and total sum of SFA ($P<0.05$), and a higher proportion of the PUFA C18:2n-6 ($P<0.01$) and C18:3n-3 ($P<0.05$) than the C-grazing animals (Table 8). The sum of PUFA and the P:S ratio was higher ($P<0.05$) and the n-6:n-3 FA ratio tended ($P<0.10$) to be higher on M than on C. Finishing on cultivated pasture reduced or tended to reduce the difference between M and C grazing calves in the meat proportion of C18:2n-6 ($P<0.05$), C18:3n-3 ($P<0.10$), total SFA, total PUFA ($P<0.05$), P:S ratio ($P<0.10$) and total SFA ($P<0.10$) (Table 8).

Sensory attributes of steaks from the two pasture types were similar, except for a tendency ($P<0.10$) that steaks from M-grazing calves had less greasy texture than steaks from L-calves (Table 9). The test panel deemed the texture of the steaks from early slaughtered calves to be less hard ($P<0.05$), more tender ($P<0.05$) and tending towards being more juicy ($p<0.10$) and less greasy ($P<0.10$) than steaks from calves slaughtered late. Steaks from the early slaughtered calves had more sweet ($P<0.001$), less sour ($P<0.001$), less metallic ($P<0.01$) and more rancid ($P<0.05$) odour than meat from Late slaughtered animals. The taste was judged similarly as the odour except for no difference in metallic taste. In addition, the early slaughter treatment had a higher ($P<0.001$) score for bitter taste than late slaughter. Finishing on lowland pasture after mountain grazing tended ($P<0.1$) to alter the difference in some few sensory attributes (Table 9). Steaks from M-calves were tenderer than meat from C-calves at early slaughtering whereas finishing on cultivated pasture made the meat from C-calves tenderer than from the M-calves. Similarly, metallic odour of the meat was stronger from M- than C-calves at early slaughtering whereas after finishing on cultivated pasture the meat had less metallic odour from M- than C-grazing animals.

Several of the judges remarked that the samples had unpalatable taste and odour. The unattractive characteristics were further described as fermented taste and odour, and manure odour. As these characteristics were not included in the pre-planned analysis protocol, their intensity was not quantified further. Both pasture types had similar remarks and the frequency of remarks was not different between pasture types.

4. Discussion

4.1. Animal performance

The present study shows that mountain grazing may yield similar live weight gain and carcass weight in suckling calves as grazing on improved pastures in the lowland. The differences were modest, as live weight gain on mountain grazing was 17 % lower in experiment 2, and similar in experiment 1. This is in contrast to Gravir (1962), who found that steers and bulls that grazed on lowland pastures had on average 56 % (0.33 kg/day) greater live weight gain than those grazing in the mountains. Fraser et al (2009) also found higher live weight gain of steers (38 %, 0.36 kg/day) on improved permanent pasture than on semi-natural pastures. Due to a higher stocking rate in the mountains when Gravir (1962) conducted his study, herbage allowance was probably more limiting than in our study. The estimated metabolic body weight of all domestic livestock grazing free range in forest and mountains in south-eastern Norway in 1999 was 40 % of that in 1949, and the reduction in cattle grazing was even greater (Austrheim et al. 2008). Still, although not measured in our study, herbage mass per area was probably lower on mountain than on lowland improved pastures, and animals grazing in lowland had access to silage in periods with low pasture growth. The mountain flock walking more than the lowland flock was as expected. On the mountain rangelands, the preferred forage vegetation was heterogeneously distributed, with areas of less attractive vegetation between feeding patches (Rekdal 1998; Rekdal, pers.comm.). More walking indicates an increase in energy expenditure for these free-ranging animals, and, consequently, a lower live weight gain was to be expected. The observed tendency towards less grazing by cows on mountain pastures may reflect the increased allocation of time to locomotion; it could also result from more time needed for rumination due to the likely lower quality of the rangeland forage. However, the mountain animals did not spend more time lying down and they tended to stand still less frequently than the lowland animals.

Gravir (1962) wrote that the observed differences in gain in his study were probably over-estimated because of great differences in rumen fill due to long transport time before the animals were weighed after the collection from mountain grazing. We believe this to be of minor importance in our study, as duration of transport was similar for the two groups. Animals from both groups were weighed at the same time at the abattoir, and the pasture effect on live weight gain was also found for carcass weight. An important difference between our study and that of Fraser (2009) and Gravir (1962) is that we used pre-weaned animals. The calves were still suckling, and in situations with low forage allowance or herbage quality, as can occur on mountain, forest or semi-natural grasslands, the cows may have directed more resources towards milk production rather than body reserve deposits and thereby lessened the adverse impact of feed restriction (Petit et al., 1995). The difference in live weight gain between pasture types in experiment 2 was on average ≈ 0.2 kg/day during the mountain period, but still the calves on mountain grazing grew reasonably well (0.9 kg/day). The difference would likely have been greater if the calves had been weaned. The difference in weight loss between cows grazing in the mountain and those grazing in the lowland indicate that the rangeland cows indeed supported their progeny with considerable amounts of milk.

The contrasting results for live weight gain in the two years in experiment 1 were likely due to differences between years in forage quantity and quality in the mountains. Cool summers delay plant maturity and prolong the access to high quality forage, and higher precipitation may improve plant production in areas where water is a limiting factor for plant growth. Thus, the year 2007 may have provided more forage of higher quality than 2006 during the mountain grazing period (Figure 1). Carcass weight of moose grazing in forests in regions with a dry climate is higher after a summer with high precipitation and low temperatures than vice versa (Saether, 1985), and weights of lambs finishing on mountain pasture were positively correlated with precipitation and negatively with temperature in July in areas in Norway with inland, continental climate (Steinheim et al., 2004).

4.2. Meat quality

Meat levels of PUFA (4.4-9.8 g/100g FAME) and P:S ratio (0.09-0.24) were high and the n-6:n-3 FA ratio (1.5-2.5) low compared to many other studies, but in accordance with beef production systems based on pasture and young and lean animals with low fat content (De Smet et al., 2004; Scollan et al., 2006; Moreno et al., 2006; Alfaia et al. 2007; Moreno et al. 2007). The intramuscular fat content of SFA and MUFA increases faster with increasing fatness than the content of PUFA, and therefore the relative proportion of PUFA decreases (Figure 3). Cattle deposit more fat subcutaneously and intramuscularly when fed rations high in energy and during maturation. This extra fat is primarily neutral lipids with a rather low proportion of PUFA, whilst the amount of high PUFA containing phospholipids in muscle cell membranes remains fairly constant with increasing fatness (Warren et al., 2008). The relationship between the muscle fat content and PUFA, MUFA and SFA in the present study

(Figure 3a) is in accordance with De Smet et al.'s (2004) findings for double-muscled bulls fed different diets. At similar intramuscular fat content, there is a variation in sum of PUFA and MUFA (Figure 3) and in individual fatty acids (figures not shown). However, as can be seen in Figure 3b, this variation was not influenced by pasture type. Thus, the small apparent effect of pasture type in this study is likely an effect of dietary energy intake and fat deposition rather than an effect of forage botanical composition *per se*. It has been hypothesized that mountain pasture or botanically diverse pastures may contain plant metabolites that inhibit the rumen biohydrogenation of PUFA, thus explaining higher proportions of e.g. C18:3n-3, CLA and PUFA in meat and milk from alpine or botanically diverse pastures (Collomb et al., 2002; Lourenço et al., 2008). We did not find evidence for such an effect in the present study, as the higher proportion of PUFA and C18:3n-3 in the meat from mountain grazing calves in experiment 2 was probably due to lower fat content.

The composition of FA in the meat further supports that milk was a more important and fresh forage a less import part of the diet for calves on mountain than on lowland pastures, as suggested in the discussion of animal performance above. Muscle fat from the mountain grazing calves had a lower proportion of C18:1n-7 and a greater proportion of C18:1n-9 than the lowland calves. This is in accordance with Moreno et al (2006) who found higher content of oleic acid in intramuscular fat from un-weaned than from weaned calves, which was explained by difference in intake from milk. Apart from palmitic acid (C16:0) and stearic acid (C18:0), oleic acid (C18:1n-9) is quantitatively the most important FA in cow's milk. As other unsaturated C18 FA, oleic acid is also biohydrogenated to stearic acid in the rumen, but stearic acid is to a large extent desaturated to oleic acid again in the tissue (Smith et al., 2006). Thus, lowland calves had probably a relatively higher intake of trans-vaccenic acid precursors (C18:3n-3 and C18:2n-6) from forage and less intake of fat from milk and C18:0 and C18:1n-

9 than mountain grazing calves. Finishing on lowland pasture probably evened out dietary differences, explaining that fatty acid composition of MF meat was more similar to meat from C-grazing animals than meat from ME, in addition to the effect of increased muscle fat content. Thus, even a relatively short period of finishing on a different pasture type may alter the chemical composition of the meat also in pre-weaning calves. This is in accordance with Moreno et al (2007) who found that 50 days concentrate feeding to pre-weaning calves altered the meat FA composition considerably relative to pasture fed pre-weaning calves.

The lack of an effect of pasture type on the odour, taste and texture of the *M. longissimus dorsi* of the suckling calves in our study stands partly in contrast to Adnoy et al. (2005), who observed that lambs grazing mountain pastures had somewhat more tender meat and less fat texture than lambs grazing in the lowlands. Otherwise, Adnoy et al. (2005) observed no great differences between pasture types for lamb meat sensory characteristics.

The remarks from the judges that the prepared meat from both pasture types had unappetizing odour (fermented and manure) and taste (fermented) are surprising. However, it is clear that if the sensory panel is trained on other types of meat, this may influence the results, as earlier experiences and preferences by the individual members of the panel may influence the outcome of the sensory analysis (Sañudo et al., 2000; Moloney et al., 2001). Meat produced on pasture usually gets higher scores for greasy taste and ”barn” taste compared with meat from animals receiving a high proportion of concentrates in their feed (Melton, 1990; Sañudo et al., 2000; Priolo et al., 2001).

5. Conclusions

Suckling calves grazing cultivated lowland pastures or mountain pastures may have similar growth rates, carcass weights and conformation. However, the relative effect of pasture type may vary between years due to weather conditions. There were only small differences in fatty acid composition between meats produced from different pasture types, and they were mainly dependent on meat fat content. Finishing on lowland pasture after mountain grazing tended to even out differences in meat fatty acid composition. Both pasture types gave lean meat with a high proportion of PUFA, a high P:S ratio and a low n-6:n-3 FA ratio, all of which are regarded to be dietary beneficial from a nutritional point of view.

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Figure 1. Average monthly temperature (lines) and monthly rainfall (bars) at Lillehammer and Venabu meteorological stations, close to the study area, from May to September in 2006 and 2007.

Figure 2. Proportion of time spent grazing, lying, walking, standing and “other activities” (including suckling and social interactions) by cows and their progeny (calves) in two flocks of suckler cows with calves on mountain pasture (Mountain, n=16) or cultivated lowland pasture (Lowland, n=16) on three occasions (June, July and August) in 2008 (Experiment 2). The flocks were followed continuously for 48 hours each month and their behaviors were assigned to one of five categories every 15 minutes. Proportion of animals translates into estimated proportion of time. Bars indicate standard errors of the mean.

Figure 3. a) Relationship between the intramuscular fat content (%) and the proportion of SFA (□), MUFA (▲) and PUFA (♦) (g/100 g FAME) and b) Relationship between intramuscular fat content (%) and the proportion of PUFA (○●) and MUFA (∆▲) (g/100 g FAME) on lowland (○∆) pastures or in mountains (●▲). Data from both experiments (n = 133).

Table 1. General characteristics of the farms(A-G, SFH); breed, date and calf age at turn out to mountain pasture, days on mountain pasture, altitude and position of pasture and stocking density in experiment 1 and 2

	Farms in experiment 1							Experiment 2
	A	B	C	D	E	F	G	SFH
Year	2006 / 2007	2006 / 2007	2006	2006	2007	2007	2007	2008
Animals	12	12	10	10	12	12	12	32
Breed[1]	AA	SI	SI	SI	SI	CH	NR	STN
Date start mountain grazing	June 15 / 12	June 16 / 6	June 27	June 17	June 30	June 26	June 23	June 19
Age at turn out, days	121 / 109	120 / 119	120	81	113	93	90	105
Days on mountain pasture	90 / 88	103 / 109	78	95	78	82	85	68
Mountain pasture								
Area, km^2	81	27	81	126	31	381	381	250
Sheep, heads/km^2	23.5 / 22.3	43.3 / 53.3	13.6	23.0	0	20.0	20.0	8.0
Cattle, heads/km^2	3.5 / 4.1	4.0 / 4.0	3.8	0.5	11.5	1.0	1.0	1.6
Altitude, m	850 – 1300	600 - 800	850 - 1300	700 – 900	800 - 1000	700 - 900	700 - 900	850-1000
Latitude/Longitude	62.3°N/9.48°E	61.3°/N10.1°E	62.3°N/9.5°E	61.2°N/10.6°E	61.2°N/9.8°E	61.3°N/10.8°E	61.3°N/10.8°E	62.1°N/9.8°E
Cultivated pasture								
Altitude, m	200	500	250	300	500	500	350	100
N fertilization rate, kg/ha	36 / 36	0 / 0	148	36	0	180	108	149
Grass silage supplementation	Yes	No	Yes	No	No	No	No	No
Cattle, heads/ha	1.9	1.7	2.8	1.4	2.4	1.3	2.4	3.0

[1]AA=Arberdeen Angus, SI=Simmental, CH=Charolais, NR=Norwegian Red, STN=Sided Trønder and Nordlandsfe

Table 2. Effect of pasture type on live weight at slaughter, daily live weight gain during the mountain grazing period (LWGp) and from birth to slaughter (LWGt), carcass weight, dressing, and carcass conformation and fatness of suckler calves grazing on lowland cultivated pastures (C) or in mountain (M), experiment 1

	C	M	SEM[1]	P-value
N	51	53		
Live weight, kg	225	226	6.5	0.664
LWGp, g/day	1012	1028	38.0	0.632
LWGt, g/day	927	938	17.9	0.494
Carcass weight, kg	118	119	3.1	0.556
Dressing, %	52.4	52.6	5.4	0.656
Conformation[2]	5.9	6.1	0.24	0.567
Fatness[3]	4.0	4.5	0.48	0.037

[1]SEM = standard error of the mean

[2]EUROP system: P- = 1, P = 2, P+ = 3, O- = 4, O = 5, O+ = 6, R- = 7, R = 8, R+ = 9

[3]EUROP system: 1- = 1, 1 = 2, 1+ =3, 2- = 4, 2 = 5, 2+ = 6, 3- = 7 … 5+ = 15

Table 3. Effect of pasture type on meat quality traits in m. *longissimus dorsi* of suckler calves grazing on lowland cultivated pastures (C) or in mountain (M), experiment 1

	C	M	SEM[1]	P-value
N	51	53		
pH 24h	5.62	5.60	0.027	0.306
Fat, %	1.08	1.25	0.152	0.019
Protein, %	23.0	22.8	0.19	0.150
Meat colour				
L*, lightness	41.4	42.1	1.10	0.049
a*, redness	18.0	18.2	0.30	0.505
b*, yellowness	4.9	5.3	0.23	0.046

[1]SEM = standard error of the mean

Table 4. Effect of pasture type on fatty acid proportions (g/100g FAME) of intramuscular fat in m. *longissimus dorsi* muscle of suckler calves grazing on lowland cultivated pastures (C) or in mountain (M), experiment 1

	C	M	SEM[1]	P-value
N	51	53		
C 14:0	3.8	4.1	0.21	0.103
C 14:1	0.75	0.71	0.066	0.359
C 15:0	1.3	1.0	0.25	0.036
C 16:0	22.9	22.7	0.56	0.581
C 16:1	2.8	2.7	0.24	0.116
C 17:0	1.3	1.2	0.12	0.009
C 18:0	15.4	16.6	0.37	< 0.001
C 18:1n-7	4.6	3.5	0.13	< 0.001
C 18:1n-9	29.0	31.1	1.27	< 0.001
C 18:2n-6	5.8	4.7	0.51	0.008
C 18:3n-3	2.1	1.9	0.16	0.110
C 20:3n-6	0.4	0.4	0.05	0.423
C 20:4n-6	1.7	1.7	0.238	0.962
C 20:5n-3	1.1	1.1	0.11	0.875
C 22:5n-3	1.1	1.3	0.187	0.628
SFA[2]	44.6	45.6	1.40	0.064
MUFA[3]	38.7	39.5	1.68	0.204
PUFA[4]	12.6	11.3	1.09	0.103
P:S[5]	0.29	0.25	0.028	0.078
n-6:n-3[6]	1.9	1.7	0.09	0.009

[1]SEM = standard error of the mean

[2]SFA = Sum of saturated fatty acids

[3]MUFA = Sum of mono unstaurated fatty acids

[4]PUFA = Sum of polyunsaturated fatty acids

[5]P:S = PUFA/SFA

[6]n-6:n-3 = (18:2n-6+C20:3n-6+C20:4n-6)/(C18:3n-3+C 20:5n-3+C 22:5n-3)

Table 5. Effect of pasture type (C=Lowland cultivated pasture and M=Mountain free range) and finishing (E = early slaughtering directly after the mountain grazing period and F = late slaughtering after finishing on C) on live weight gain during mountain grazing period (LWG_p), live weight gain from birth to slaughter (LWG_t), live weight gain during finishing on lowland pasture (LWG_f), live weight at collection date from mountain pasture (Live $weight_c$), after finishing on cultivated pasture live weight at late slaughter (Live $weight_f$), carcass weight, dressing percentage, conformation and fatness of suckler calves, experiment 2

	Treatment					P-value		
	CE	ME	CF	MF	SEM[1]	C vs. M[2]	E vs. F[3]	CE-ME vs. CF-MF[4]
N	8	7	8	8				
LWG_p, g/day	998	866	1193	934	61.1	0.004	-	-
LWG_t, g/day	911	858	922	842	23.4	0.008	0.923	0.578
LWG_f, g/day	-	-	460	609	53.5	0.076	-	-
Live $weight_c$, kg	193	183	206	181	4.4	< 0.001	0.217	-
Live $weight_f$, kg	-	-	216	194	4.7	0.006	-	-
Carcass weight, kg	99	94	108	96	2.7	0.007	0.058	0.224
Dressing, %	51.6	51.8	50.1	49.3	0.76	0.685	0.013	0.498
Conformation[5]	3.9	3.6	3.6	3.6	0.22	0.470	0.705	0.482
Fatness[6]	5.3	4.5	4.5	3.9	0.32	0.033	0.042	0.764

[1]SEM = standard error of the mean

[2] Contrast C vs. M = lowland cultivate pasture vs. mountain free range

[3]Contrast E vs. F = Early slaughtering vs. slaughtering after finishing on lowland cultivated pasture

[4] Contrast CE-ME vs. CF-MF = Effect of finishing on lowland cultivated pasture after mountain grazing, i.e. difference in response between C and M at early slaughtering vs. difference in response between C and M after finishing on lowland cultivated pasture

[5]EUROP system: P- = 1, P = 2, P+ = 3, O- = 4, O = 5, O+ = 6, R- = 7, R = 8, R+ = 9

[6]EUROP system: 1- = 1, 1 = 2, 1+ =3, 2- = 4, 2 = 5, 2+ = 6, 3- = 7 … 5+ = 15

Table 6. Suckler cow live weight (kg) at turn out to grazing, end of mountain grazing and end of experiment and live weight change during mountain grazing period (kg/day), experiment 2

	Lowland	Mountain	SEM[1]	P-value
N	16	16		
Turn out to mountain grazing	462	455	5.8	0.370
End of mountain grazing	475	410	6.5	< 0.001
End of experiment (n=8)	478	418	10.3	< 0.01
Live weight change during mountain grazing period	0.17	- 0.63	0.055	< 0.001

[1]SEM = standard error of the mean

Table 7. Effect of pasture type (C= Lowland cultivated pasture and M=Mountain free range) and finishing (E = early slaughtering directly after end of mountain grazing and F = late slaughtering after finishing on C) on meat quality traits in m *longissimus dorsi* of suckler calves grazing on cultivated pastures, experiment 2

	Treatment					P-value		
	CE	ME	CF	MF	SEM[1]	C vs. M[2]	E vs. F[3]	CE-ME vs. CF-MF[4]
n	8	7	8	8				
pH24	6.2	6.1	5.5	5.6	0.10	0.887	< 0.001	0.522
Fat, %	2.3	1.7	2.2	2.1	0.20	0.055	0.511	0.227
Protein, %	22.7	22.6	22.8	22.9	0.16	0.963	0.316	0.410
Meat colour								
L*, lightness	41.7	41.5	38.9	41.3	0.74	0.145	0.064	0.112
a*, redness	20.0	19.7	19.1	20.1	0.47	0.408	0.591	0.204
b*, yellowness	5.2	5.1	4.6	5.9	0.27	0.030	0.655	0.018

[1]SEM = standard error of the mean

[2] Contrast C vs. M = lowland cultivate pasture vs. mountain free range

[3] Contrast E vs. F = Early slaughtering vs. slaughtering after finishing on lowland cultivated pasture

[4] Contrast CE-ME vs. CF-MF = Effect of finishing on lowland cultivated pasture after mountain grazing, i.e. difference in response between C and M at early slaughtering vs. difference in response between C and M after finishing on lowland cultivated pasture

Table 8. Effect of pasture type (C= Lowland cultivated pasture and M=Mountain free range) and finishing (E = early slaughtering directly after end of mountain grazing and F = late slaughtering after finishing on C) on fatty acid proportions (g/100g FAME) of intramuscular fat in *longissimus* muscle of suckling calves, experiment 2

	Treatment					P-value		
	CE	ME	CF	MF	SEM[1]	C vs. M[2]	E vs. F[3]	CE-ME vs. CF-MF[4]
n	8	7	8	8				
C 10:0	0.41	0.26	0.14	0.38	0.096	0.684	0.480	0.080
C 12:0	0.48	0.30	0.25	0.25	0.054	0.113	0.018	0.135
C 14:0	6.78	4.59	5.62	4.72	0.441	0.002	0.261	0.175
C 14:1n-5	1.57	1.16	1.22	1.04	0.150	0.054	0.136	0.471
C 15:0	1.01	1.11	0.73	0.85	0.073	0.138	0.001	0.832
C 16:0	25.9	22.4	24.6	23.6	0.085	0.012	0.910	0.164
C 16:1n-7	4.25	3.72	4.00	3.67	0.215	0.054	0.492	0.634
C 17:0	0.89	0.95	0.86	0.95	0.040	0.072	0.703	0.802
C 18:0	12.1	12.9	12.7	13.1	0.52	0.210	0.393	0.773
C 18:1n-7	4.26	3.78	4.11	4.16	0.130	0.103	0.412	0.060
C 18:1n-9	33.7	33.6	35.5	36.6	0.96	0.589	0.018	0.571
C 18:2n-6	2.41	6.13	2.70	3.04	0.717	0.008	0.064	0.032
C 18:3n-3	0.89	1.55	1.20	1.24	0.147	0.025	0.976	0.052
C 20:0	0.26	0.38	0.15	0.21	0.047	0.060	0.006	0.448
C 20:1n-9	0.16	0.19	0.17	0.17	0.012	0.208	0.609	0.198
C 20:4n-6	0.42	0.94	0.93	0.85	0.240	0.377	0.395	0.248
C 20:5n-3	0.27	0.56	0.74	0.65	0.168	0.566	0.111	0.288
C 22:5n-3	0.36	0.62	0.74	0.63	0.164	0.641	0.261	0.298
SFA[5]	47.9	42.8	45.0	44.4	1.11	0.018	0.560	0.068
MUFA[6]	45.5	45.4	45.7	46.6	1.00	0.675	0.498	0.487
PUFA[7]	4.4	9.8	6.3	6.4	1.27	0.037	0.576	0.054
P:S[8]	0.10	0.24	0.14	0.15	0.035	0.047	0.529	0.074
n-6:n-3[9]	1.7	2.5	1.5	1.6	0.23	0.062	0.018	0.213

[1]SEM = standard error of the mean

[2] Contrast C vs. M = lowland cultivate pasture vs. mountain free range

[3] Contrast E vs. F = Early slaughtering vs. slaughtering after finishing on lowland cultivated pasture

[4] Contrast CE-ME vs. CF-MF = Effect of finishing on lowland cultivated pasture after mountain grazing, i.e. difference in response between C and M at early slaughtering vs. difference in response between C and M after finishing on lowland cultivated pasture

[5]SFA = Sum saturated fatty acids

[6]MUFA = Sum mono unstaurated fatty acids

[7]PUFA = Sum polyunsaturated fatty acids

[8]P:S = PUFA/SFA

[9]n-6:n-3 = (18:2n-6+C20:3n-6+C20:4n-6)/(C18:3n-3+C18:4n-3+C 20:5n-3+C 22:5n-3)

Table 9. Effect of pasture type (C= Lowland cultivated pasture and M=Mountain free range) and finishing (E = early slaughtering directly after end of mountain grazing and F = late slaughtering after finishing on C) on sensory qualities of meat (*longissimus dorsi*) from suckler calves (hedonic scale 1-9), experiment 2

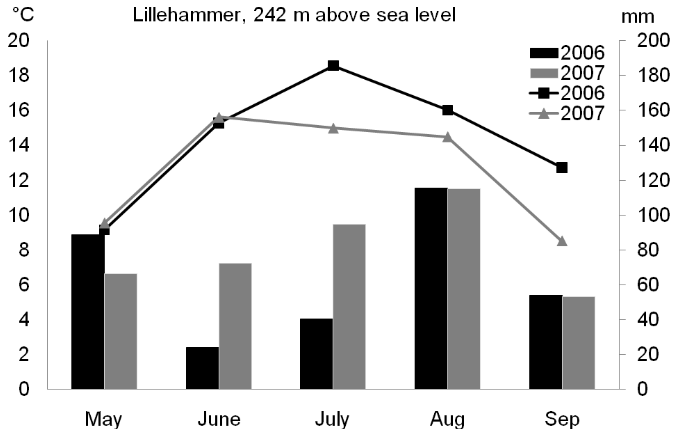
	Treatment				SEM[1]	P-value		
	CE	ME	CF	MF		C vs. M[2]	E vs. F[3]	CE-ME vs. CF-MF[4]
n	8	7	8	8				
Texture								
Hardness	4.1	3.7	4.2	4.3	0.16	0.434	0.027	0.138
Tenderness	6.0	6.4	5.9	5.6	0.18	0.637	0.014	0.061
Coarseness	3.9	3.8	4.1	3.9	0.10	0.154	0.150	0.723
Greasiness	2.5	2.4	2.6	2.5	0.06	0.075	0.070	0.764
Juiciness	3.9	4.1	4.3	4.1	0.11	0.692	0.052	0.108
Odour								
Sweet	4.6	4.7	3.3	3.3	0.34	0.925	< 0.001	0.890
Sour	2.7	2.4	3.6	3.5	0.26	0.502	< 0.001	0.910
Metallic	4.7	4.9	5.3	5.0	0.12	0.900	0.008	0.054
Liver	3.1	3.4	3.5	3.4	0.16	0.671	0.320	0.443
Rancid	1.3	1.5	1.1	1.1	0.12	0.502	0.029	0.322
Taste								
Sweet	4.7	4.6	2.9	3.0	0.33	0.880	< 0.001	0.690
Sour	2.7	2.8	4.0	3.7	0.30	0.636	0.001	0.596
Metallic	4.6	4.9	4.7	4.8	0.10	0.090	0.848	0.455
Liver	3.0	3.3	3.2	3.1	0.16	0.545	0.924	0.183
Bitter	4.2	4.4	3.8	3.8	0.16	0.737	0.004	0.644
Rancid	1.4	1.5	1.3	1.1	0.13	0.837	0.042	0.322

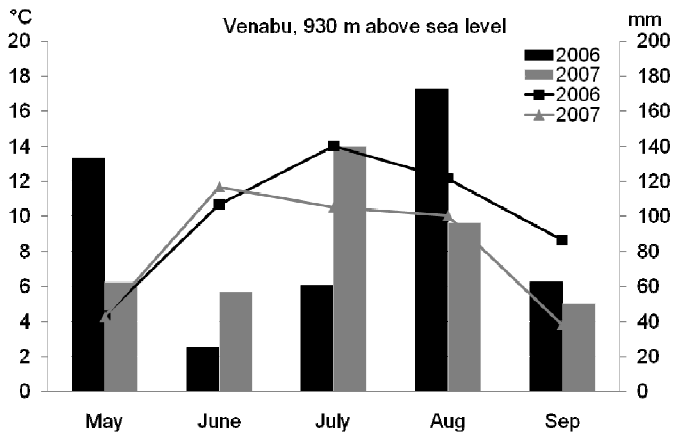
[1]SEM = standard error of the mean

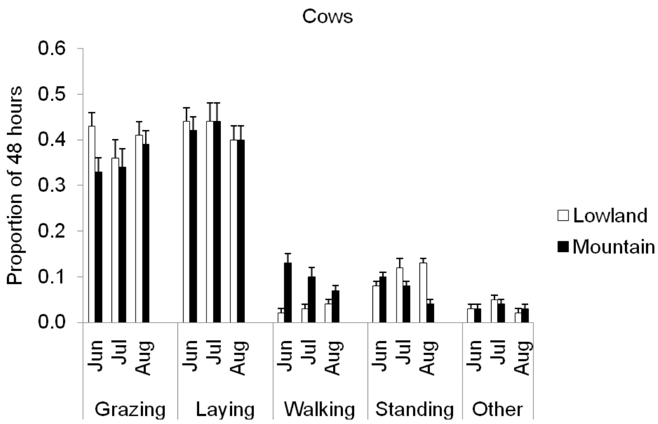
[2] Contrast C vs. M = lowland cultivate pasture vs. mountain free range

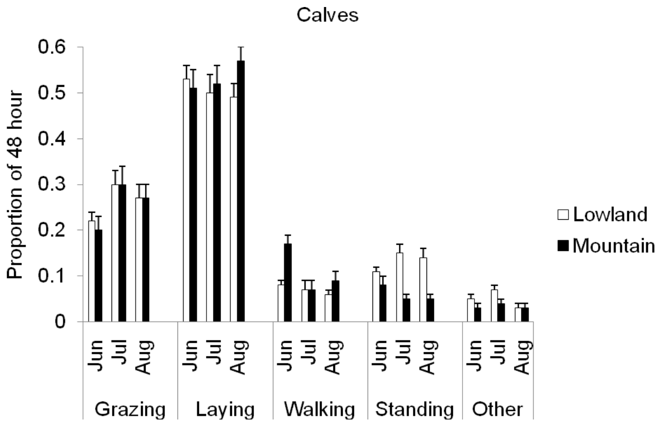
[3] Contrast E vs. F = Early slaughtering vs. slaughtering after finishing on lowland cultivated pasture

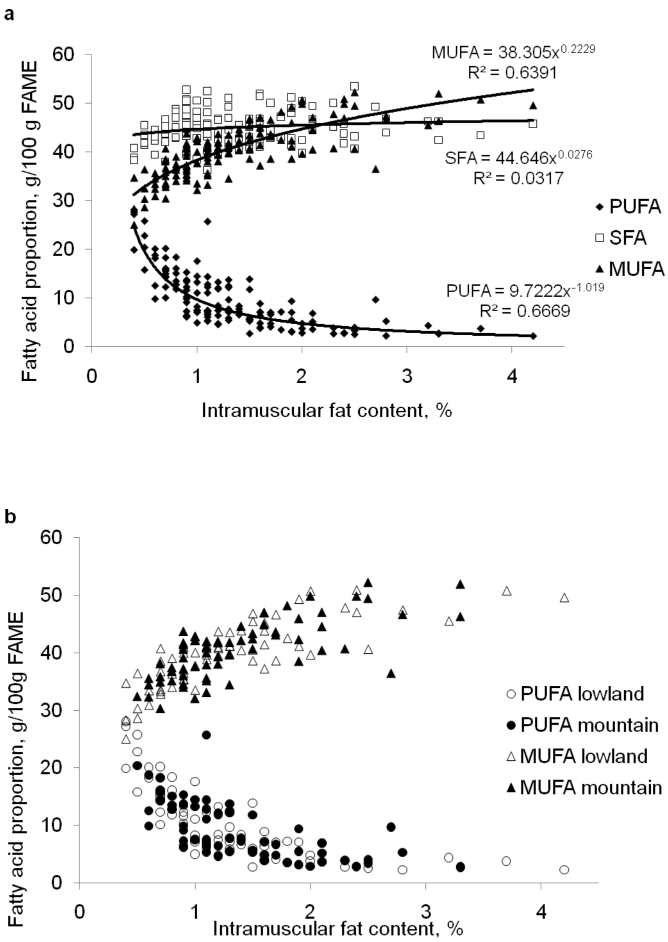
[4] Contrast CE-ME vs. CF-MF = Effect of finishing on lowland cultivated pasture after mountain grazing, i.e. difference in response between C and M at early slaughtering vs. difference in response between C and M after finishing on lowland cultivated pasture.


°C
Lillehammer, 242 m above sea level
mm
2006
2007
2006
2007
May
June
July
Aug
Sep


°C
Venabu, 930 m above sea level
mm
2006
2007
2006
2007
May
June
July
Aug
Sep


Cows
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Proportion of 48 hours
Jun Jul Aug
Grazing
Laying
Walking
Standing
Other
Lowland
Mountain


Calves
0.6
0.5
0.4
0.3
0.2
0.1
0
Proportion of 48 hour
Jun Jul Aug
Grazing
Laying
Walking
Standing
Other
Lowland
Mountain


a
MUFA = 38.305x^0.2229
R² = 0.6391
SFA = 44.646x^0.0276
R² = 0.0317
PUFA = 9.7222x^-1.019
R² = 0.6669
PUFA
SFA
MUFA
Fatty acid proportion, g/100 g FAME
Intramuscular fat content, %
b
PUFA lowland
PUFA mountain
MUFA lowland
MUFA mountain
Fatty acid proportion, g/100g FAME
Intramuscular fat content, %