Fattening heifers on continuous pasture in mountainous regions – implications for productivity and meat quality

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ABSTRACT: Economical and ecological issues as well as consumer demand for sustainably produced agricultural food rise the trends to fatten beef cattle on pasture during the grazing season. However, particularly for mountainous regions, implications of turning beef cattle on pasture remain unclear concerning animal performance and product quality. Therefore, the present study was conducted to compare short grass grazing with a semi-intensive indoor fattening system in the Alps. Charolais × Simmental heifers of about 300 kg live weight were either fattened on continuous pasture (3–5 cm sward height) and finished in barn (Pasture group) or solely raised in barn on a grass silage-based diet with 2 kg concentrates (Indoor group). Animals were slaughtered at 550 kg live weight. Results showed that continuous pasture with a finishing period in barn allowed as good growth and carcass performance as fattening in barn. Over the whole experiment, average daily gain was 993 g/day in the Pasture group and 1026 g/day in the Indoor group. During the growing period, daily gain was numerically lower in the Pasture group than in the Indoor group (767 g and 936 g, respectively). Carcass fatness of pasture fed animals was lower but within the desirable threshold. Water holding capacity, meat colour, and shear force, an indicator for beef tenderness, were unaffected by feeding practices, but fat colour was more yellow in the Pasture group. Furthermore, meat from animals fattened on pasture had lower intramuscular fat contents and enhanced proportions of nutritionally valuable omega-3 fatty acids and conjugated linoleic acids.

Keywords: beef cattle; Alpine pasture; daily gain; product quality; fatty acid

In the Alps, like in other mountainous regions, low input systems which include grazing of cattle, become more attractive. Advantages of low input systems are lower food and energy costs as well as decreased labour demand, which is particularly important for part time farmers (Durgiai, 1996; Steinwidder et al., 2010). Other arguments for the use of grassland as pasture refer to summer tourism, maintenance of cultivated landscape, and biodiversity matters (Crook and Jones, 1999; Maurer et al., 2006). Furthermore, consumer demand for products of extensive agriculture is rising and quality programs, which specify the use of pastures, are successful (organic production, quality labels). Typical pasture systems are extensive permanent pastures, strip grazing, rotational grazing, and continuous grazing. Continuous grazing on short grass is an intensive permanent pasture system, in which stocking density and fertilization should be optimally adapted to the grazing area. Sward height should be between 5 and 7 cm throughout the whole grazing season, which allows a high and relatively constant feed quality.

Beef cattle fattening in Central Europe is mainly done with bulls due to their higher daily gain and slaughter performance compared to steers and heifers. Within the last decade, several studies have examined the suitability of heifers and steers for low input grassland-based fattening systems and have found contradictory results concerning animal performance and product quality (French et al., 2000b; Steen et al., 2003; Realini et al., 2004; Sami et al., 2004; Noci et al., 2005; Nürnberg et al., 2005; Razminowicz et al., 2006; Keane and

Moloney, 2009). Yet, the literature reporting experiments in less favoured agricultural areas such as mountainous regions is limited. The purpose of the present paper was to enlighten possible opportunities and threats of fattening heifers on continuous pasture in the Austrian Alps concerning growth performance, slaughter characteristics, and meat quality traits.

MATERIAL AND METHODS

Experimental design and feeding regime

At AREC Raumberg-Gumpenstein (673 m a.s.l., average annual temperature 6.7°C, precipitation 969 mm/year, province Styria, Austria) twenty crossbred Charolais × Simmental heifers of 298 kg live weight (SD = 37.4 kg) and 7.5 months old (SD = 1.07 months) were purchased from suckler cow farms at the beginning of April 2009. Ten heifers were assigned to pasture rearing (Pasture group) and ten heifers were assigned to barn rearing (Indoor group). The Indoor group was kept in a loose barn with straw bedding and was fed grass silage (700 g/kg dry matter (DM)) and hay (300 g/kg DM) based upon *ad libitum* allowance. Additionally, each animal received 2 kg of concentrates (coarse mixture of 30% wheat, 30% barley, 25% maize, and 15% rapeseed meal), 30 g of a commercial mineral and vitamin mixture, and 30 g of salt per day. The Pasture group was not supplemented during the entire grazing season, but was offered minerals, vitamins, and salt. Continuous grazing on short grass was chosen as pasture management, and the grazing period started at the end of April. Two heifers of the Pasture group were housed for the finishing period in barn at the end of September because they had reached a target live weight of 500 kg. The eight heifers which remained on pasture were housed from mid-October onwards due to harsh weather conditions. Throughout the period in barn, the Pasture group was fed the same diet as the Indoor group. All heifers were slaughtered at 550 kg live weight. The experiment lasted from April 2009 to April 2010.

Data collection and measurements

Representative feed samples were analyzed according to VDLUFA (1976) procedures. Animals were weighed weekly and individual daily feed intake was recorded in barn using electronic Calan gates. Carcass conformation and degree of fat cover were determined according to the EUROP beef carcass classification system (conformation score E = excellent, P = poor; fatness score 1 = low, 5 = very high) (Council Regulation, 1981). Meat quality characteristics were assessed from the *m. longissimus* between the 8th and 11th ribs. Carcasses were cut 7 days *post mortem* (*p.m.*), and the first meat quality analyses immediately followed. Part of the meat samples were vacuum packed until 14 and 21 days *p.m.* when analyses of meat and fat colour, grill loss, and shear force were repeated. For drip loss, the cut was left in a plastic box at 2°C for 48 h. For cooking loss, the meat was cooked in a 70°C-warm water bath for 50 min and cooled down in cold water. For grill loss, cuts were grilled to an internal temperature of 60°C in a Silex grill. Shear force was measured on grilled meat using an Instron 3365 (Instron, Grove City, USA) testing system equipped with a Warner-Bratzler shearing device. A luminometer Codec 400 (Phyma, Gaaden, Austria) was used to measure colour of fat and meat. Meat dry matter, crude fat, crude protein, and ash content were assessed according to Acker et al. (1968). Extraction of intramuscular fat (IMF) for fatty acid analyses was carried out according to Folch et al. (1957) with slight modifications. The concentration of individual fatty acids was determined by gas liquid chromatography as described by Deutsche Gesellshaft für Fettwissenschaft (2006). Each individual fatty acid was expressed as g per 100 g of total fatty acids.

Statistical analysis

Statistical analysis was performed using SAS software (Statistical Analysis System, Version 9.2, 2009). Slaughter characteristics were analyzed with the GLM Procedure of SAS with treatment group (Pasture, Indoor) as fixed effect, and correcting for the effect of individual animal live weight at the experiment's start. Carcass classification data were analyzed by the Wilcoxon test. All single measurements of meat quality were analyzed using the GLM Procedure. Growth characteristics, meat colour, fat colour, grill loss, and shear force were analyzed with the Mixed Procedure for repeated measurements and animals were nested within treatment group. For growth characteristics, repeated statements were week (1–53) (results in Table 2) or live weight class (300–350 kg, 350–400 kg, 450–500 kg, 500–550 kg) (results in Figure 2). Grouping according to live weight class was chosen because the individual animals markedly differed in live weight in the course of the experiment. For repeatedly measured meat quality traits, repeated statement was ageing (7, 14, 21 days). In the mixed models, compound symmetry and autoregressive covariance structures were tested. Interactions between treatment group and repeated statement were tested but did not significantly contribute to the model. Correction for the small sample size was made as described by Kenward and Roger (1997). For all statistical models the Tukey's procedure was used.

RESULTS AND DISCUSSION

The present study examined growth performance as well as carcass and meat quality of beef cattle grazing short grass in the Alps. Nutrient composition and energy content of feedstuffs fed in barn are summarized in Table 1. Nutrient content of the grass on pasture was not analyzed in the present experiment, but Steinwidder et al. (2010) found an average of 16% dry matter (DM), 10.5 MJ metabolizable energy (ME), 21% crude protein (CP), 3% crude fat (CF), 22% crude fibre (CF), 44% neutral detergent fibre (NDF), and 26% acid detergent fibre (ADF) for continuous pastures in Alpine regions. Starz et al. (2011) carried out a three-year field trial on continuously grazed swards in the Eastern Alps between the first week of May and the last week of October. ME varied within the range of 10%, while CP, CF, NDF, and ADF varied within a range of 25%. Figure 1 describes stocking rate and sward height of the present experiment.

Growth performance

Details on live weight and age at the beginning of the experiment, at the end of the growing period, and at slaughter are given in Table 2. Average length of the growing period on pasture was 167 days (SD = 9 days) and average finishing period in barn was 118 days (SD = 41 days). Throughout the whole experiment, the average daily gain (ADG) of the Pasture and Indoor heifers was 1000 g/day (Table 2). The ADG was high and in accordance with the results of Schwarz et al. (1998), Steen et al. (2003), Noci et al. (2005), Keane and Moloney (2009), and Velik et al. (2013) for semi-intensive beef fattening systems. Noci et al. (2005) fed Charolais crossbred heifers on a perennial ryegrass sward without concentrates for five months prior to slaughter and found an ADG of 996 g/day. Steen et al. (2003) finished heifers and steers of late maturing breed types on a ryegrass pasture for four months before slaughter and found an ADG of 969 g/day for heifers and 1100 g/day for steers. In the present study, the ADG of the Pasture group over the growing period was by 18% lower than that of the Indoor group over the same period (Table 2). The lack of statistical differences might be due to the small and heterogeneous herd size. Moreover, the Pasture group had a less stable growth rate than the Indoor group (Figure 2). An explanation for this could be that animals on pasture are exposed to changing climatic conditions influencing grass supply and maintenance requirements (National Reasearch Council, 2001; Legrand et al., 2009). Further reasons could be worm infections, weather

Table 1. Chemical composition of feeds fed indoor (means ± SD; g/kg DM unless otherwise stated)

	Hay	Grass silage	Concentrates
DM (%)	89 ± 1.9	34 ± 4.3	89 ± 0.8
ME (MJ/kg DM)	9.2 ± 0.3	10.0 ± 0.2	13.3 ± 0.1
Crude protein	116 ± 14.0	144 ± 8.7	145 ± 14.8
Crude fat	22 ± 4.9	34 ± 3.6	27 ± 1.9
Crude fibre	271 ± 14.1	268 ± 19.7	54 ± 8.9
Neutral detergent fibre	522 ± 19.2	500 ± 14.9	174 ± 12.1
Acid detergent fibre	290 ± 38.3	312 ± 28.2	71 ± 5.7

DM = dry matter, ME = metabolizable energy

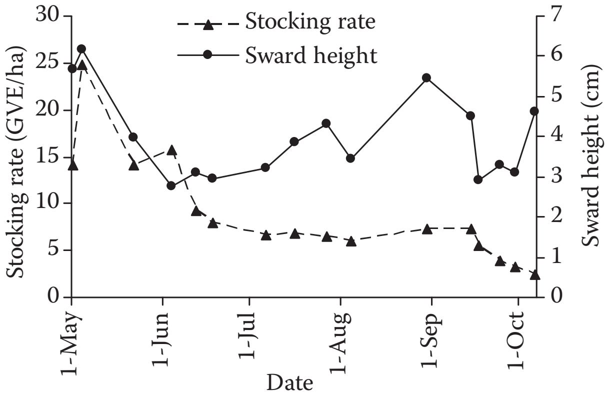

Figure 1. Stocking rate and sward height of the pasture grazed by the Pasture group (GVE = livestock unit, 0.6 GVE = bovine between 6 and 24 months, 1 GVE = 500 kg live weight (bovine above 24 months)) (ÖPUL, 2007)

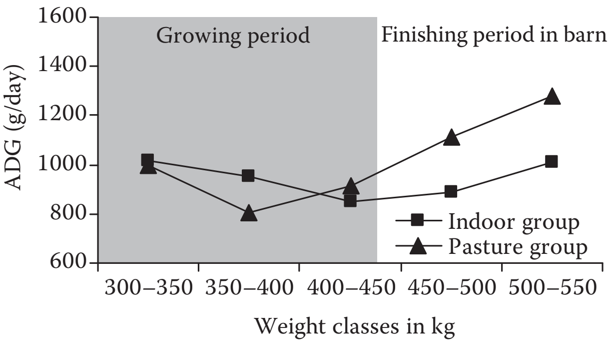

Figure 2. Average daily gain (ADG) for each weight class

conditions, low pasture allowance, and low sward height (Figure 1). Inversely, the ADG over the barn period was slightly higher in the Pasture group than in the Indoor group, which might have been due to the compensatory growth potential of the animals.

Feed intake and feed conversion efficiency during the finishing period in barn were similar in both groups (Table 2). Feed conversion efficiency was within the range observed by Velik et al. (2013) with heifers, but above the results of Dufey et al. (2002) with steers and Sami et al. (2004) with bulls, most likely because of different feed energy content and effects of sex.

Slaughter characteristics

Carcass traits are presented in Table 3. In terms of slaughter age, a large variability was observed ranging from 13.8 to 20.8 months old, which was due to different rearing systems before purchase.

Table 2. Effects of pasture versus indoor feeding on fattening performance of beef heifers

Item	Pasture group	Indoor group	SEM	Significance
Initial live weight (kg)	292	312	12.7	ns
Initial age (days)	230	230	10.6	ns
Live weight (kg), end of growing period[1]	438	462	6.4	ns
Age (days), end of growing period[1]	397	397	11.0	ns
Slaughter weight (kg)	550	548	3.40	ns
Slaughter age (days)	515	506	13.0	ns
ADG (g/day), whole experiment	993	1026	119	ns
ADG (g/day), growing period[1]	767	936	95	ns
ADG (g/day), finishing period[1]	1190	1075	111	ns
Finishing period[1]				
Total feed intake (kg DM/day)	8.9	9.1	0.39	ns
ME intake (MJ/day)	92.7	94.1	3.75	ns
Crude protein intake (g/day)	1228	1252	54	ns
DM efficiency (kg/kg gain)	9.2	9.4	0.96	ns
ME efficiency (MJ/kg gain)	95	97	10.5	ns

ME = metabolizable energy, ADG = average daily gain, DM = dry matter, ns = not significant ($P > 0.05$)

[1]pasture group was on pasture (growing period) from April until October and in barn during the finishing period (October until slaughter)

Table 3. Effects of pasture versus indoor feeding on selected carcass traits of beef heifers

Item	Pasture group	Indoor group	SEM	Significance
Carcass weight (kg)	302	303	3.1	ns
Dressing percentage (%)	55.0	55.3	0.43	ns
EUROP conformation score (E = 5)	3.9	4.1	–	ns
EUROP fatness score (1 = lean)	2.8	3.3	–	*
Valuable sections (% of carcass)	23.0	22.9	0.19	ns
Kidney fat (kg)	7.8	10.9	1.04	ns

*$P < 0.05$, ns = non significant ($P > 0.05$)

Carcass weight and dressing percentage did not differ between groups, which is in accordance with the results of Keane and Moloney (2009) and Velik et al. (2013). While carcass conformation score was similar in both groups, fatness score was significantly lower in the Pasture group. This observation is in accordance with Realini et al. (2004), Sami et al. (2004), and Keane and Moloney (2009), comparing extensive and intensive beef cattle fattening. Although there was no significant difference between groups ($P = 0.06$), kidney fat showed the same trend as carcass fatness score. Regarding cuts, only the flank and sirloin were significantly heavier (by 6%) in the Indoor group compared to the Pasture group; however, this might have hardly any practical relevance.

Meat quality

Meat quality is influenced by animal-intrinsic factors (e.g. breed, sex, age, and weight), dietary factors (e.g. feedstuffs, energy, and nutrient composition), and environmental factors (e.g. housing conditions, slaughter procedures, and meat ageing) (Priolo et al., 2001; Ender and Augustini, 2007). These confounding factors make it difficult to evaluate whether meat quality differences are due to dietary composition or dietary effects on growth performance and carcass quality. Moreover, comparing grazing systems with indoor systems often implies comparing extensive and intensive production methods, which complicates the comparison of experiments.

Water holding capacity, meat composition, and fatty acid profile. For water holding capacity, an important trait for meat processing and home cooking, no significant group or ageing effect was observed (Table 5), which was confirmed by the results of Frickh et al. (2002), Razminowicz et al. (2006), and Velik et al. (2013). Water holding capacity was within the range advised by Frickh et al. (2005).

In accordance with the results of French et al. (2000a, b) and Velik et al. (2013), crude protein and ash content were similar in both groups. Intramuscular fat (IMF) content was lower in the Pasture group (Table 4), which is in agreement with the literature (Sami et al., 2004; Nürnberg et al., 2005; Dannenberger et al., 2006; Ender and Augustini, 2007). Moreover, the average IMF in the Pasture group was below the threshold of 2.5% recommended by Frickh et al. (2005), but above the 1.5% threshold for acceptable tenderness mentioned in Razminowicz et al. (2006). In line with the present results and the literature review of Muir et al. (1998), IMF tended to be positively correlated to carcass fatness. Yet, other studies comparing pasture fattening and more intensive indoor feeding did not find any significant differences in carcass fatness traits and IMF (French et al., 2000a; Steen et al., 2003; Velik et al., 2013).

In the study at hand, omega-6 (n-6) fatty acids were significantly higher in the Pasture group, which is in line with Realini et al. (2004). To the opposite, Steen et al. (2003) found higher n-6 for the high concentrate diet, while French et al. (2000b), Descalzo et al. (2005), Noci et al. (2005), and Nürnberg et al. (2005) observed no differences. However, differences in pasture systems and feeding intensities complicate the comparison of experiments. Conjugated linoleic acids (CLA) and omega-3 (n-3) fatty acids were found in significantly higher concentrations in the meat of the Pasture group (Table 4). The increase in CLA and n-3 when feeding grass-based diets compared to concentrate-based diets was observed in several other studies. In the latters, either the pasture group was slaughtered directly from pasture (French et al., 2000b; Steen et al., 2003; Realini et al., 2004; Descalzo et al., 2005; Noci et al., 2005; Garcia et al., 2008) or the finishing diet was different from

Table 4. Effects of pasture versus indoor feeding on meat composition and selected fatty acids in meat of beef heifers

Item	Pasture group	Indoor group	SEM	Significance
Dry matter (g/kg)	248	256	2.8	*
Crude protein (g/kg)	219	218	1.1	ns
Intramuscular fat (g/kg)	17.9	28.6	2.95	*
Ash (g/kg)	11.3	10.5	0.37	ns
Fatty acid profile (% of total fatty acids)				
C14:0 (myristic acid)	2.64	3.45	0.190	**
C16:0 (palmitic)	26.01	29.47	0.530	***
C18:0 (stearic)	16.01	15.37	0.550	ns
ΣC18:1 *trans*	4.76	4.67	0.444	ns
C18:1 *cis*9 (oleic)	31.99	31.36	0.890	ns
C18:2 *cis*9,12 (linoleic)	4.00	2.41	0.334	**
C18:3 *cis*9,12,15 (ALA)	1.35	0.97	0.078	**
CLA *cis*9,*t*11	0.65	0.53	0.026	**
C20:5 (EPA)	0.39	0.18	0.039	**
C22:5 *cis*7,10,13,16,19 (DPA)	0.91	0.54	0.093	*
C22:6 (DHA)	0.066	0.048	0.0060	*
Total fatty acids				
SFA[a]	47.1	50.9	0.80	**
MUFA[b]	43.7	43.2	0.84	ns
PUFA[c]	9.21	5.88	0.658	**
CLA[d]	0.73	0.60	0.028	**
n-3[e]	2.76	1.75	0.212	**
n-6[f]	5.73	3.53	0.467	**
n-6 : n-3	2.08	2.00	0.096	ns

[a]C8:0 + C10:0 + C11:0 + C12:0 + C13:0 + C14:0 + C15:0 + C16:0 + C17:0 + C18:0 + C20:0 + C21:0 + C22:0 + C23:0 + C24:0

[b]C14:1 + C15:1 + C16:1 + C17:1 + C18:1*t* +C18:1*c*9 + C18:1*c*11 + C20:1 + C22:1-6 + C24:1

[c]sum of CLA, n-3, and n-6 fatty acids

[d]CLA*c*9*t*11 + CLA*t*10*c*12 + CLA*c*9*c*11

[e]C18:3*c*9,12,15 + C18:4 + C20:3*c*11,14,17 + C20:5 + C22:3 + C22:5*c*7,10,13,16,19

[f]C18:2*t*9,12 + C18:2*c*9,12 + C18:3*c*6,9,12 + C20:2 + C20:3*c*8,11,14 + C20:4 + C22:2 + C22:4 + C22:5*c*4,7,10,13,16

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ns = not significant ($P > 0.05$)

that of the indoor fed group (Nürnberg et al., 2005), which is a limitation to the comparison with the present study. It could have been speculated with the results presented here that the effect of grazing was overcome by the indoor finishing period ranging from 1.9 to 6.6 months. Velik et al. (2013) finished pasture fed heifers on a ration based on grass silage, maize silage, and concentrates for 3.3 months (finishing period ranging from 0 to 5.1 months). The results showed a slight tendency for higher CLA and n-3 in the Pasture group compared to the Indoor group, fed on the same ration during the whole experiment. According to De Smet et al. (2004), meat fatty acid composition is correlated with carcass fatness. Hence, significant differences in n-6, CLA, n-3, and SFA observed in the present experiment might have been biased by the significantly lower fatness score and intramuscular fat content of the Pasture group as well as by the differences in the ratio of neutral and polar lipids (De Smet et al., 2004). However, with the data at hand, no definitive statement can be made. The n-6 : n-3 ratio did not differ between groups, which is in contrast to most studies which showed a lower n-6 : n-3 ratio in the meat of pasture fed animals (French et al., 2000b; Steen et al., 2003; Realini et al., 2004; Descalzo et al., 2005; Noci et al., 2005; Nürnberg et al., 2005).

Table 5. Effects of pasture versus indoor feeding on meat and fat colour of beef heifers

Item	Group				Ageing (in days)				
	Pasture	Indoor	SEM	significance	7	14	21	SEM	significance
Drip loss (%)	3.3	3.2	0.24	ns					
Cooking loss (%)	26.8	26.6	1.03	ns					
Grill loss$_{warm}$ (%)	22.2	19.7	1.12	ns	21.3	19.7	21.9	1.03	ns
Shear force (kg)	3.15	3.28	0.228	ns	4.06^a	2.96^b	2.61^b	0.189	***
Meat colour									
Lightness L*	38.6	39.3	0.84	ns	37.4^b	39.5^a	39.9^a	0.66	**
Redness a*	11.3	10.3	0.39	ns	10.7	10.9	10.9	0.33	ns
Yellowness b*	7.5	6.8	0.37	ns	7.1	7.3	7.2	0.33	ns
Fat colour									
Yellowness b*	8.8	7.2	0.44	*	6.8^c	8.2^b	8.9^a	0.33	***

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, ns = non significant ($P > 0.05$)
^{a,b}significant differences within a row ($P < 0.05$)

Shear force, meat and fat colour. IMF was often found to be positively correlated to beef tenderness, juiciness, and taste (Ender and Augustini, 2007; Warriss, 2010) although some studies have found no or only a weak correlation (reviewed by Muir et al., 1998). In the present study, no difference in shear force, an objective measurement for beef tenderness, was observed (Table 5) although carcass fatness and IMF were significantly lower in the Pasture group. These findings were confirmed by the results of Sami et al. (2004) who fed Simmental bulls with maize silage and concentrates on an *ad libitum* or a restricted basis. However, literature is contradictory concerning the influence of the fattening system on beef tenderness. While Nürnberg et al. (2005) and Dannenberger et al. (2006) found higher shear force values for meat from extensively fattened bulls in comparison to intensively produced bulls, Realini et al. (2004) found the opposite for steers. Sex, breed, age, live weight, dietary energy density, and carcass fatness are claimed as main factors influencing beef tenderness (Ender and Augustini, 2007). Deviations in these parameters might be an explanation for the contradictory results of different studies. It has been widely acknowledged that ageing lowered shear force values of cooked meat (Gruber et al., 2006; Marino et al., 2006). In the present study, the grilled meat had significantly lower shear force values after 14 days of ageing compared to 7 days; prolonging meat ageing up to 21 days did not have any marked influence on shear force (Table 5).

In the present paper, values for meat lightness and redness were within the range advised by Ender and Augustini (2007). Meat colour is generally darker in grass-based feeding systems, compared to intensive systems (Schwarz et al., 1998; Priolo et al., 2001; Realini et al., 2004; Nürnberg et al., 2005). According to the literature, meat colour is related to slaughter age, live weight, IMF, animal physical activity, and ultimate meat pH (reviewed by Priolo et al., 2001). In the present study, lightness was not statistically different in the meat originating from the Pasture or the Indoor group (Table 5), which was also observed by French et al. (2000a) and Velik et al. (2013). In the study at hand, similar slaughter ages and slaughter weights as well as the indoor finishing period of all the animals on the same diet (of the Indoor group) might be an explanation for missing colour differences.

The effect of grazing on fat yellowness due to carotenoids in grass is well known (Noziere et al., 2006), and the present study confirmed the observations of Muir et al. (1998), Schwarz et al. (1998), French et al. (2000a), Realini et al. (2004), and Velik et al. (2013) (Table 5). Yellowness of the fat can impair the acceptance of the meat by consumers. It has to be evaluated whether these numerically low differences found with a luminometer are visible to the unaided human eye. The significant increase in fat yellowness with prolonged ageing might be the result of accumulated meat juice in the vacuum bag (Table 5).

CONCLUSION

The current study gives an indication that fattening heifers in mountainous regions on short grass with an indoor finishing period provides as good growth performances as fattening in barn. However, growth rate of the animals on pasture is less stable than that of the animals in barn. Meat and processing quality is not impaired if animals are grazing. Allowing the cattle to graze improves the fatty acid profile of the meat in terms of human health recommendations. Fat colour may be inconvenient regarding consumers' preferences but may also help differentiating the meat from grazing animals from that of animals raised in barn. In contrast, the leaner meat of the animals on pasture could be more attractive for consumers concerned by fat in their diet. A finishing period in barn from 450 kg to 550 kg is sufficient in order to obtain desirable carcass fatness and conformation scores.

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Received: 2012–08–10
Accepted after corrections: 2013–01–10

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