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Effects of post-grazing herbage height and concentrate feeding on milk production and major milk fatty acids of dairy cows in mid lactation

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Abstract

Milk fatty acids (FA) were compared in mid-Lactation dairy cows in four feeding systems combining grazing management and supplementation. The four treatments were factorial combinations of compressed herbage grazed to 3.7 cm or 4.6 cm post-grazing height, with or without concentrate feeding (3.6 kg cow^{-1} day^{-1}). Milk yield and composition were measured for four groups of 8 Friesian × Jersey dairy cows

over 3 weeks in mid lactation for cows that had grazed treatments for 64 days from early spring. Milk yield was higher in cows fed concentrate plus herbage (23.9 kg d^{-1} cow^{-1}) than herbage only (20.3 kg d^{-1} cow^{-1}). Milk fat percentage was higher in cows fed herbage only (5.5%) than herbage plus concentrate (5.1%). Milk protein percentage was higher in cows fed herbage plus concentrate (4.0%) than herbage only (3.7%). The concentrations of CLA c9, t11, C18:0, C18:1 t11, and C18:2 t9, c12 FA were lower where concentrate was fed. The concentrations of C18:1 t10, C18:1 t5, t8 and C18:2 c9, c12 FA were higher where concentrate was fed. The concentrations of C18:1 c6, C18:1 c9, C18:1 t9 and C18:3 c6,9,15 were unaffected by concentrate feeding. Post-grazing herbage height had no significant effect on milk yield or concentration of milk FA. Provided dairy cows are harvesting leafy material of similar nutrient and FA concentration, post-grazing herbage height does not appear to alter milk FA and the supply of high energy concentrates is more influential on milk FA profiles.

***Keywords*:** herbage, concentrate, milk, fatty acids, grazing height.

Introduction

There has been considerable interest in the fatty acid (FA) profile of ruminant milk and meat, particularly the levels of polyunsaturated fatty acids (PUFA) and conjugated linoleic acids (CLA). In addition to effects of dietary fatty acids on human health (Shingfield *et al*., 2013), FA profiles also have important effects on the processing and storage characteristics of milk and milk products, such as the spreadability of butter (Bobe *et al*., 2003). On the other hand, biohydrogenation intermediates t10 18:1, and t10, c12 CLA are associated with milk fat depression in dairy cows (He *et al*., 2012), whereas the medium-chain saturated fatty acids (SFA), for example C12:0, C14:0 and C16:0, which account for the majority of SFA in milk fat, have been associated with cardio-vascular disease (Department of Health, 1994) and cancers in humans (Willett, 1997).

Thus, to improve ruminant milk quality, diets are sought that promote a high concentration of PUFA and a lower concentration of SFA, specifically C14:0 and C16:0, and trans-fatty acids (TFA). Forage plants such as perennial grass and white clover have high concentrations of n-3 fatty acids, particularly α-linolenic acid in their

lipid fraction (Dewhurst *et al*., 2001; Elgersma *et al*., 2003). A number of studies indicate that offering lactating dairy cows herbage as their main diet is associated with increased concentrations of PUFA (Kelly *et al*., 1998; Dewhurst *et al*., 2001; Shingfield *et al*., 2013; Elgersma, 2015) compared to cows fed conserved forage.

Due to the key role that grazed herbage plays in determining FA composition, approaches are sought to examine how herbage management may affect FA concentrations in the herbage and milk. Dewhurst *et al*. (2001) showed that the concentrations of total FA and α-linolenic acid were affected by the maturity stage of the herbage. Fatty acid concentration in herbage, particularly C18:2 and C18:3, declined when the regrowth interval was extended from 20 to 38 days (Dewhurst *et al*., 2001). Furthermore, regrowth that contains a high proportion of stem compared to leaf is associated with a low concentration of FA in herbage (Elgersma *et al*., 2003) and in the milk of cows grazing the herbage (Bauchart *et al*., 1984; Elgersma *et al*., 2003). As stem and dead material accumulates at the base of the sward with less-intensive grazing (Hoogendoorn *et al*., 1992), grazing height may therefore be expected to influence milk FA concentration in harvested herbage.

Supplementation of cows grazing herbage is a further factor that has been reported to affect FA concentration in milk. Supplements are used during spring and summer to increase milk production in grazing systems when herbage quality or quantity is low (Penno, 2006). In a recent study (Rugoho *et al*., 2014) of irrigated perennial ryegrass-white clover herbage, there was reduction in the concentration of CLA and C18:3 c9, c12, c15 when higher levels of supplements were fed to cows offered high quality herbage. However, it is not clear how supplementation may interact with grazing height in determining the milk FA profile.

The objective of this study was to investigate the effects of grazing to low and high herbage heights and of concentrate supplementation on milk FA and milk production of dairy cows grazing perennial ryegrass-white clover herbage in late spring.

Materials and methods

Experimental design

The study was conducted on the Lincoln University Research Dairy Farm (43°38′S, 172°27′E) in Canterbury, New Zealand. The soil type is Paparua sandy loam soil. All procedures were approved by the Lincoln University Animal Ethics committee and licensed in accordance with the Animal Welfare Act, 1999, section 100 (AEC no.

482). Milk yield, composition and FA profiles were measured for mid-lactation mixed-age dairy cows that were part of a two-year farmlet study, which commenced in August 2012. The purpose of the farmlet study was to investigate the effects of supplementation and grazing height on milk production (see Bryant *et al*., 2013 for details). Measurements in the current study took place when all herbage had been exposed to treatment conditions for 64 days so the effect of grazing height on milk composition could be tested (16 October and 9 November 2012). The cows were allocated to represent a typical herd age structure for a herbage-based grazing system.

The farmlet study comprised 32 mixed parity, spring-calving, Friesian × Jersey crossbred dairy cows which were grazed within a 2 × 2 factorial design. At the start of lactation in spring (14 August 2012), cows were blocked into 8 groups of four according to their previous seasons milk solid production (389 ± 7 kg MS cow^{-1} $year^{-1}$; mean ± SD), liveweight (427 ± 13 kg; mean ± SD), breeding worth (121.5 ± 7.5 BW; mean ± SD) and age (4.8 ± 0.2 years; mean ± SD). The first seven groups included multiparous cows whereas the eighth group was primiparous cows. One group was assigned at random to each treatment resulting in 8 cows per treatment group. The four treatments were a factorial combination of two post-grazing herbage heights measured with a rising plate meter (RPM; Jenquip, Fielding, New Zealand), with (+) and without concentrate feeding. Cows were allocated to one of four treatments soon after calving at the start of lactation (14 August 2012):

High: cows grazed to 5.0 cm herbage height without concentrate;
High+: cows grazed to 5.0 cm herbage height and fed 4 kg DM of concentrate;
Low: cows grazed to 3.5 cm herbage height without concentrate;
Low+: cows grazed to 3.5 cm herbage height and fed 4 kg DM of concentrate.

The farmlet area consisted of 6.9 ha which was divided into 72 paddocks each of 0.096 ha using permanent and temporary fencing materials. The 18-month-old herbage consisted of *Lolium perenne* (cv. Trojan, NEA2 endophyte) and *Trifolium repens* (cv. Weka). Nitrogen was applied in the form of urea at 30 kg N ha^{-1} to each paddock following grazing during the first and second grazing rotations, with a total application of 60 kg N ha^{-1} during the first 12 weeks. Gibberellins (Progibb, Nufarm, Auckland, New Zealand) were applied at a rate of 8 g active ingredient ha^{-1} to all paddocks after grazing during the first rotation.

Water was available in all paddocks. The 72 paddocks were allocated to four farmlets representing the four treatments. Nineteen paddocks were allocated to each of the two non-concentrate groups, and 17 paddocks to the two concentrate groups, reflecting potential substitution of herbage by cows receiving concentrate. The resultant respective stocking rates for non-concentrate and concentrate supplemented groups were 4.4 and 5.0 cows ha^{-1}. Paddocks were grazed in order of highest pre-grazing herbage mass from 14 August to start of measurement period on the 25 October. Movement of cows to each new paddock occurred on the basis of target post-grazing herbage height (3.5 cm ± 0.5 cm and 5 cm ± 0.5 cm for low and high post-grazing height) being met, thus cows were moved at different times of the day. On average cows were moved to a new paddock every 40 hours, though time spent in each paddock ranged between 24 and 70 hours.

Cows receiving concentrate received half of their 4 kg daily ration at each milking using an automatic feeder. The concentrate composition on a fresh weight basis was: wheat, 60%; maize 22%; canola 11%; peas 7%; molasses 1%; minerals, vitamins and additives, 3%.

Herbage and concentrate measurements

Pre-grazing herbage height and post-grazing herbage height were determined daily by taking 30 RPM measurements per paddock. Separate RPM calibrations were derived for the high and low post-grazing herbage height groups. Before and after grazing, compressed herbage height within a 0.2 m^2 quadrat was measured with the RPM. All herbage within the quadrat was then harvested to ground level, washed and oven-dried to a constant weight. Regression of herbage mass (kg DM ha^{-1}) against RPM height (0.5 cm units) for low (n=35) and high (n=48) post-grazing treatments revealed a logarithmic relationship resulting in the following coefficients:

High post-grazing herbage mass (kg DM ha^{-1}) = 1981 × LN (RPM 0.5 cm unit) - 2848 (R^2 = 0.88, SE of estimate = 356),

Low post-grazing herbage mass (kg DM ha^{-1}) = 1585 × LN (RPM 0.5 cm) - 2104 (R^2 = 0.88 SE of estimate = 322).

The mean estimated herbage group DM intake was calculated as the product of the difference between pre- and post-grazing herbage mass, and the area grazed. Group estimated herbage DM intake was divided by number of cows to determine average apparent DM intake (kg DM cow^{-1} day^{-1}).

To determine the nutritive and botanical composition of the herbage, two herbage samples were collected twice weekly before the new herbage was offered. The herbage samples were cut to grazing height of the respective treatment (3.5 cm above ground level for Low and Low+ groups and 5 cm for High and High+ groups). The first subsample of approximately 100-200 g was separated into botanical components (perennial ryegrass, white clover, dead material and weed). The botanical components were dried in an oven at 65 ^{o}C for 48 h and weighed, before determination of percentage botanical composition on a dry weight basis. The second sample of approximately 100-200 g taken from each of the herbage samples was bulked and frozen at -20 ^{o}C for later analysis of the nutritive composition of herbage. Concentrate refusals per cow per day were collected to calculate apparent DM intake of concentrates and twice-weekly samples were taken for nutritive composition.

Four herbage samples cut to grazing height were collected each day per treatment group and one bulk sample was prepared over the experimental period per treatment group. Two concentrate samples were collected each day and one bulk sample prepared over experimental period per treatment group. Both samples were stored at -20^{o}C until analysis of herbage and concentrate FA concentrations.

Milk sampling

Milk yield was measured daily with an automated system (DeLaval Alpro Management System, DeLaval, Tumba, Sweden). Milk samples were collected from all eight cows from each treatment group over consecutive morning and evening milkings (16-17 October 2012 and 8-9 November 2012) to determine milk composition. Additional milk samples were collected during morning and afternoon milkings (25 mL from each milking). This was done by using inline milk meters (DeLaval International AB) to collect representative milk samples from consecutive afternoon and morning milkings and one bulk sample was prepared per cow per sampling day then frozen and stored at -20 °C without preservative until analysis of milk FA. Bulked frozen milk samples were then freeze dried for subsequent milk FA analysis.

Nutritive composition of herbage

A subsample was taken from the frozen weekly bulked herbage samples and concentrate samples per treatment. The subsample was weighed to obtain fresh

weight, oven dried at 100 °C, and then reweighed to determine percentage dry matter (% DM). The second subsample of herbage was freeze dried for a period of 5 days at 0.5 mbar (Cuddon Limited, New Zealand Model E. D. 5.3). After freeze drying, the samples of herbage were ground to pass through a 1 mm sieve (ZM200, Retsch). Nutritive composition analysis has been described in detail by Bryant *et al*. (2012). Briefly, nutritive composition was estimated using near infrared spectrophotometry (NIRS; Model: FOSS NIRSystems 5000, Maryland, USA). Near infrared spectrophotometry calibrations for water soluble carbohydrates (WSC; MAFF, 1986), neutral detergent fibre (NDF; van Soest, 1991), acid detergent fibre (ADF; Procedure 973.18 from AOAC, 1990) and *in vitro* organic matter digestibility, (DMD; Jones and Hayward, 1975) were previously derived on perennial ryegrass samples and R-squares for predictions were 0.98, 0.99, 0.98 and 0.97, respectively. Standard error of the cross validation for WSC, NDF, ADF and DMD calibrations were 2.38, 2.54, 1.69 and 2.57 respectively. All spectra from samples in the current study fell within the calibration range with Global (GH) and Neighbourhood (NH) matrix averaging 0.36 and 0.27 respectively. The maximum was 0.63 for GH and 0.39 for NH which is below the accepted maximum of 3.0 and 0.80 (Shenk *et al*., 2001). Metabolizable energy (ME) concentration for herbage was estimated from the equation: Herbage ME (MJ/kg DM) = (0.17 × DMD%) – 2.0 (CSIRO, 2007). Samples of concentrate were also ground and scanned by NIRS using a separate calibration for cereal feeds and metabolizable energy (ME) calculated from fat concentration and DM digestibility (CSIRO, 2007).

Herbage, concentrate, and milk fatty acids and milk composition analysis

The FA composition of herbage, concentrate (g kg^{-1} DM) and milk (g $100g^{-1}$ total FA) were determined using a method described by Sukhija and Palmquist (1988). The collected representative milk samples from consecutive afternoon and morning milkings were analysed separately for milk composition and then calculated using a weighted average in proportion to the yield at each milking. Milk composition was analysed by the laboratory of the Livestock Improvement Corporation Ltd. (Christchurch, New Zealand) to determine milk fat and protein.

Statistical analysis

Milk FA were analysed by ANOVA for a 2×2 factorial design GenStat (v14, VSL, Hempstead, UK) with post-grazing height and concentrate as treatment factors and individual FA as variables. Herbage height, mass and intake data were averaged across sampling days prior to analysis. Individual cows were used as experimental units in analysis of milk and FA composition. Grazing height, concentrate feeding and their interaction were used as fixed terms in the model and cow was included as random effect. No statistical analysis of nutritive composition, botanical composition of herbage and FA profile of herbage was performed as they were bulked samples collected from paddocks within each farmlet.

Results

Diets

The nutritive composition of herbage and concentrate and FA concentration in herbage and concentrate are presented in Table 1. The difference in the mean concentration of total FA (g kg^{-1} DM of freeze dried sample) in herbage in the four grazing treatments was small (i.e., 22 g kg^{-1} DM for cows grazing to low and 20 g kg^{-1} for cows grazing to high post-grazing height) (Table 1).

[Insert Table 1 about here]

Grazing height, herbage mass, estimated intake and botanical composition

Pre- and post-grazing heights over the experimental period are shown in Table 2. The differences in herbage mass between cows grazing to low grazing herbage height and cows grazing to high grazing herbage height was 463 kg DM ha^{-1}. Average estimated herbage DM intake was 13.3 kg DM cow^{-1} day^{-1} and 15.9 kg DM cow^{-1} day^{-1} for cows grazing low and high height respectively (Table 2). Both supplementation groups consumed 3.6 kg DM cow^{-1} day^{-1} of concentrate, giving total DMI of 14.6, 15.7, 15.7, and 19.8 kg DM cow^{-1} day^{-1} for Low, Low+, High, and High+ groups. Averaged over the study period, the respective average percentage of perennial ryegrass and white clover was 90.3%% and 8.5%, with little difference between treatments (Table 2).

[Insert Table 2 about here]

Milk yield

There was no significant effect ($P > 0.05$) of post-grazing herbage height or the interaction between post-grazing herbage height and concentrate feeding on milk yield or milk composition (Table 3). Milk, fat and protein yield per cow were higher in cows supplemented with concentrate than cows fed herbage only (Table 3). Milk fat percentage was lower and milk protein percentage higher for cows supplemented with concentrate than cows fed herbage only (Table 3).

[Insert Table 3 about here]

Major fatty acid concentration of milk

There was no effect ($P > 0.05$) of post-grazing herbage height or the interaction between post-grazing herbage height and concentrate feeding on milk FA acid profile. The concentrations of C4:0, C6:0 and C16:1 t9 were lower in cows supplemented with concentrate than cows fed herbage only (Table 4).

[Insert Table 4 about here]

The concentrations of C18:1 c11, C18:1 c12, C18:2 c9, c12 (C18:2n-6), C18:1 t5, t8 and C18:1 t10 were higher in cows supplemented with concentrate than cows fed herbage only (Table 4). Concentrations of C18:1 trans-11, C18:2 t9, c12 ($P<0.001$), C18:0 ($P=0.026$) and CLA c9 t11 (0.032) were lower in cows supplemented with concentrate than cows fed herbage only. The concentrations of C18:1 c6, C18:1 c9, C18:1 t9 and C18:3 c6,9,15 (C18:3n-3) milk FA were not significantly affected by concentrate (Table 4).

Discussion

Biohydrogenation intermediates C18:1 t10, and t10, c12 CLA are associated with milk fat depression (He *et al*., 2012). Although t10, c12 CLA was not found in the present study, the concentration of C18:1 t10 in milk fat was 0.83 g $100g^{-1}$ FA higher for cows fed concentrate than no concentrate at low post-grazing height and 0.33g $100g^{-1}$ FA higher for cows fed concentrate at high post-grazing height. In the present study, milk fat percentage was lower when herbage was supplemented with concentrate. This was despite the fact that concentrate feeding level (4 kg DM cow^{-1} day^{-1}) was up to 46% less than in other studies [e.g. 8.7 kg DM cow^{-1} day^{-1} (Pulido and Leaver, 2001); 6 kg DM cow^{-1} day^{-1} (Bargo *et al*., 2002)] that have recorded

lower milk fat percentage when herbage was supplemented with concentrates. Cows grazing high-quality herbage often have low rumen pH (Gibbs *et al*., 2007) and herbage attributes affect rumen biohydrogenation through reduced rumen pH (Harfoot and Hazlewood, 1997). Furthermore, low rumen pH was associated with reduced rates of biohydrogenation in the herbage-based study by Kolver and de Veth (2002). It seems likely that the reduced milk-fat percentage values in the present study, despite relatively low levels of concentrate feeding, were the result of high-quality herbage contributing to the low pH needed to produce t10 C18:1.

Bauchart *et al*. (1984) and Elgersma *et al*. (2003) reported high concentrations of FA in herbage during the leafy stage in comparison to stem regrowth stage. Low grazing height is typically associated with high herbage quality as this prevents the build-up of stem and dead material (Hoogendoorn *et al*., 1988). High grazing height may results in reduction in herbage quality as it is associated with accumulation of stem and dead material at the base of the sward (Hoogendoorn *et al*., 1992). As a result, it was anticipated that allowing stem to accumulate at a higher herbage grazing height would cause dairy cows to consume relatively more stem, which, in turn, would cause consumption of herbage with low PUFA concentration and could influence major milk FA profiles. However, in the present study, grazing height had no effect on the concentration of milk FA. The difference in the concentration of total FA (g kg^{-1} DM of freeze dried sample) in herbage in the four grazing treatments was small i.e. 22 g kg^{-1} DM for cows grazing to low and 20 g kg^{-1} for cows grazing to high post-grazing height. Also, grazing height had no significant effect on the percentage of grass, clover and dead material in harvested sample. Although, the 1.5 cm intended difference between high and low post-grazing height treatments was not achieved, the difference in post-grazing height was noticeably visible. The differences in herbage post-grazing height was ~0.9 cm between high and low post-grazing height treatments, which is equivalent to 463 kg DM ha^{-1}. Further, post-grazing herbage heights stayed relatively constant within grazing height treatments over successive grazing rotations, with little stem accumulating above grazing height. Consequently, dairy cows were always harvesting leafy material of similar FA concentration and botanical composition above grazing height for the high herbage height and low herbage height treatments. A review by Dewhurst *et al*. (2006) also found no effect of herbage allowance on milk FA. Moreover, a review by Elgersma *et al*. (2006) showed that without supplementation, variation in FA intake was more associated with

differences in FA composition of the herbage than differences in DM intake. Further, the difference in estimated herbage DM intake between cows grazing to high post-grazing herbage height and cows grazing to low grazing herbage height was only 2.6 kg DM cow^{-1} day^{-1} in this study.

The increase in the concentration of CLA c9 t11 in herbage only fed cows in the present study is consistent with other grazing studies (Kelly *et al*., 1998; Lahlou *et al*., 2014; Elgersma, 2015). The average concentration (g $100g^{-1}$ total milk FA) of C18:3n-3 (0.78) and CLA (1.35) in the present study are higher than reported in literature for cows fed grass silage (0.48, C18:3n-3 and 0.37, CLA) (Dewhurst *et al*., 2003), grass silage plus concentrate (0.4, C18:3n-3 and 0.36, CLA) (Dewhurst *et al*., 2003) and maize and legume silages (0.25, C18:3n-3 and 0.46, CLA (Kelly *et al*., 1998). The difference in total milk FA concentration between herbage and silages most likely reflects the loss of PUFA during field wilting (Dewhurst *et al*., 2006). The concentration (g $100g^{-1}$ total milk FA) of 0.78 for C18:3n-3 is consistent with the concentration of 0.75 g $100g^{-1}$ total milk FA found in the New Zealand (Mackle *et al*., 1999) for cows grazing non-irrigated perennial ryegrass based herbage in summer. However, the concentration (g $100g^{-1}$ total) in milk FA of C18:3n-3 and CLA in the present study are lower compared with reported values (e.g. 1.57, C18:3n-3 and 1.63, CLA) for cows fed high-quality irrigated perennial ryegrass based herbage in summer from farms in Canterbury, New Zealand (Rugoho *et al*., 2014). Fatty acid synthesis in plants mainly occurs in the chloroplast and much of the lipid (33-36% of DM) of whole leaf is concentrated in the chloroplasts (Hawke, 1973). Also, the plant chloroplast contains more than half of the plant's proteins (Hawke, 1973) and therefore the greater the number of chloroplast the greater the plant protein and lipid content of plants. The relatively low DMD and CP (g kg^{-1} DM) of the herbage used in the current study (130-180) compared to Rugoho *et al*. (2014) (210-240) suggests that herbage lipids would not be as high as is often the case in Canterbury, as a result reducing the concentration of milk PUFA.

The concentration of C18:2n-6 in milk FA in the current study increased by 33% for cows fed herbage plus concentrate. This likely reflects the higher concentration of C18:2n-6 in concentrate herbage (3.94 vs. 2.84 g kg^{-1} DM).

Conclusion

Herbage grazing height in a farm system where cows maintained similar herbage DM intakes and grazed herbage having similar nutritive composition and botanical attributes above the set target height had no effect on major milk FA. In contrast, the effects of concentrates on C18:2n-6 was large and this was due to high concentration of C18:2n-6 in the concentrate.

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Tables

Table 1 Nutritive composition (g kg^{-1} DM) and C4-C18 fatty acid (FA) (g kg^{-1} DM) of concentrate and herbage offered to dairy cows grazing pasture to low and high post-grazing herbage height with (+) or without supplementary concentrate feeding.

	Low	Low+	High	High+	Concentrate
DMD (g kg^{-1} DM)	800	805	802	801	904
WSC (g kg^{-1} DM)	168	281	351	245	406
CP (g kg^{-1} DM)	176	168	123	158	173
ADF (g kg^{-1} DM)	215	207	211	212	62
NDF (g kg^{-1} DM)	393	377	383	39	14
ME (MJ/kg DM)	11.7	12.2	12.1	11.7	13.7
C6:0	0.00	0.00	0.00	0.00	0.27
C8:0	0.00	0.00	0.00	0.00	0.07
C10:0	0.00	0.00	0.00	0.00	0.03
C12:0	0.03	0.03	0.03	0.03	0.43

C14:0	0.08	0.08	0.07	0.07	0.16
C16:0	4.00	3.26	2.72	3.70	3.23
C16:1 c7	0.02	0.01	0.00	0.01	0.12
C16:1 c9	0.41	0.38	0.25	0.39	0.02
C18:0	0.33	0.26	0.22	0.30	0.41
C18:1 c9	0.50	0.40	0.35	0.49	5.58
C18:1 c11	0.07	0.05	0.04	0.05	0.53
C18:2 c9,12	3.04	2.74	2.36	3.23	3.94
C18:3 c9,12,15	13.6	12.1	9.74	13.5	0.29
Total fatty acids (g kg^{-1} DM)†	23.5	20.7	16.9	23.1	16.3

DMD: dry matter digestibility; WSC: water soluble carbohydrates; CP: Crude protein; ME: metabolisable energy and NDF: neutral detergent fibre; For nutritive composition data n=6.

†Total fatty acid (g kg^{-1} DM) = Include fatty acids (g kg^{-1} DM) listed in Table 1 plus all the remaining analysed fatty acids (g kg^{-1} DM).

Table 2 Pre-and post-grazing height and mass, apparent herbage intake, botanical composition of herbage offered to dairy cows grazing herbage to low and high post-grazing herbage height with (+) or without supplementary concentrate feeding.

	Low	Low+	High	High+	SEM†
Pre-grazing height (cm)	9.7	10.0	10.8	9.3	0.28
Post-grazing height (cm)	3.7	3.6	4.5	4.6	0.05
Pre-grazing herbage mass (kg DM ha^{-1})	2578	2662	3232	2930	48.5
Post-grazing herbage mass (kg DM ha^{-1})	1080	1022	1489	1538	23.0
Apparent herbage intake (kg $d^{-1}cow^{-1}$)	14.6	12.1	15.7	16.2	0.73
Dry Matter (%)	18	18	17	18	0.7
Ryegrass (%)	86	90	91	94	3.1
White clover (%)	13	9	7	5	3.3
Dead matter (%)	0	0	0	0	0.0
Weed (%)	1	0	1	1	1.0

†SEM = standard error of means for post-grazing height × concentrate interaction; For pre-and post-grazing height and intake n=18, 14, 18 and 22 (for Low, low+, High and High+ respectively) and for botanical composition, n=6.

Table 3 Milk yield and milk composition from dairy cows grazing herbage to low and high post-grazing herbage height with (+) or without supplementary concentrate feeding. All grazing height and grazing height by concentrate interaction effects were not statistically significant at P=0.05.

	Low	**Low+**	**High**	**High+**	**SED†**	***P* (concentrate)**
Milk yield (kg d^{-1} cow^{-1})	20.9	22.8	19.6	24.9	1.901	0.02
Milk fat (%)	5.45	5.34	5.60	4.78	0.283	0.03
Milk protein (%)	3.69	3.98	3.75	3.85	0.271	0.05
Milk fat (kg $d^{-1}$$cow^{-1}$)	1.17	1.15	1.21	1.03	0.061	0.03
Milk protein (kg $d^{-1}$$cow^{-1}$)	0.79	0.85	0.81	0.83	0.028	0.05

†SED = Standard error of the difference of mean for grazing height × concentrate interaction, n=8.

Table 4 Concentration of C4-C18 milk fatty acids (g $100g^{-1}$ total FA) in milk from dairy cows grazing herbage at low or high post-grazing herbage height with (+) or without supplementary concentrate feeding. All grazing height and grazing height by concentrate interaction effects were not statistically significant at P=0.05.

Fatty acid	Low	Low+	High	High+	SED†	*P* (concentrate)
C4:0	1.91	1.64	1.91	1.68	0.074	<0.001
C6:0	1.97	1.81	1.91	1.80	0.062	0.004
C8:0	1.43	1.42	1.36	1.39	0.046	NS‡
C10:0	3.80	4.00	3.48	3.89	0.154	0.008
C12:0	4.46	4.84	4.10	4.73	0.210	0.001
C14:0	12.5	12.7	12.1	12.7	0.373	NS
C16:0	29.0	28.2	29.3	27.6	1.180	NS
C16:1 c7	0.23	0.26	0.24	0.24	0.015	NS
C16:1 c9	1.09	1.23	1.09	1.16	0.074	NS
C16: 1 t9	0.17	0.15	0.19	0.15	0.011	0.002
C18:0	10.2	8.13	9.30	8.90	0.756	0.026
C18:1 c6	0.29	0.28	0.23	0.30	0.037	NS‡
C18:1 c9	14.2	15.7	15.1	15.8	0.579	NS
C18:1 c11	0.30	0.44	0.31	0.43	0.032	<0.001
C18:1 c12	0.08	0.11	0.07	0.10	0.009	<0.001
C18:1 t9	0.13	0.12	0.12	0.17	0.022	NS

C18:1 t10	0.16	0.99	0.13	0.46	0.358	0.025
C18:1 t11	4.43	3.50	4.72	3.53	0.363	<0.001
C18:1 t5 t8	0.25	0.27	0.22	0.27	0.027	0.053
C18:2 c9 t12	0.11	0.14	0.10	0.13	0.021	0.022
C18:2 c9 c12 (n-6)	0.77	1.51	0.73	1.44	0.118	<0.001
C18:2 c9 t13	0.46	0.64	0.41	0.56	0.111	0.049
C18:2 t9 c12	0.73	0.46	0.61	0.47	0.060	<0.001
C18:3 c6,9,15 (n-3)	0.80	0.79	0.76	0.78	0.036	NS
CLA c9 t11	1.36	1.30	1.52	1.23	0.117	0.032

†SED = Standard error of the difference mean for post-grazing herbage height × concentrate interaction, n=8.

‡NS = not significant at 5% level.