

Lipid content and fatty acid composition of grasses sampled on different dates through the early part of the growing season

P. S. Mir¹, S. Bittman², D. Hunt², T. Entz¹, and B. Yip¹

¹Agriculture and Agri-Food Canada, Research Centre, P.O. Box 3000, Lethbridge, Alberta, Canada T1J 4B1; and ²Agriculture and Agri-Food Canada, Research Centre, Box 1000, Agassiz, British Columbia, Canada V0M 1A0. Lethbridge Research Centre contribution number (387)05037.

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Mir, P. S., Bittman, S., Hunt, D., Entz, T. and Yip, B. 2006. **Lipid content and fatty acid composition of grasses sampled on different dates through the early part of the growing season.** *Can. J. Anim. Sci.* **86**: 279–290. In order to explore the value of herbage for the production of ruminant products with a high content of conjugated linoleic acid (CLA), a study was undertaken to determine the content of fatty acids that can be hydrogenated [hydrogenatable fatty acids (HFA)] in herbage of three cool-season forage grasses, orchardgrass (OG), perennial ryegrass (PRG) and tall fescue (TF). Dry matter (DM) yield, lipid content (ether extract) and fatty acid concentration (weight percent of detected fatty acids) on five sampling dates in the spring of 2004 were determined. HFA is the available substrate for the production and deposition of fatty acid bioconversion products in ruminants that consume the grass. Fatty acid content of the grasses was estimated as the product of fatty acids concentration (weight percent) and lipid content (ether extract), while HFA was estimated as the sum of the content of C18:1, C18:2 and C18:3. The DM yield of the three species of grasses increased ($P < 0.05$) between Mar. 29 and Apr. 28, after which the increase was observed for TF followed by PRG. However, the lipid content decreased in all the grasses over the 140 d of sampling. Although concentration of the saturated fatty acids and C18:1 and C18:2 increased over the sampling period, the content did not alter substantially. In OG samples, C18:2 concentrations were higher ($P < 0.05$) than those in PRG or TF in all samples. The concentration and content of C18:3 was highest ($P < 0.05$) in all the forages, but declined progressively. Results indicate that the availability of HFA is greatest in OG and PRG, especially in the early samples, but DM yields are low; however, later in the season TF produces more DM but with substantially reduced lipid and HFA content.

Key words: Orchard grass, perennial ryegrass, tall fescue, hydrogenatable fatty acids, conjugated linoleic acid, ruminants

Mir, P. S., Bittman, S., Hunt, D., Entz, T. et Yip, B. 2006. **Teneur en lipides et composition des acides gras des graminées échantillonnées à divers moments au début de la période végétative.** *Can. J. Anim. Sci.* **86**: 279–290. Pour mieux connaître la valeur des herbages devant servir à l'obtention de produits animaux riches en acide linoléique conjugué (ALC), les auteurs ont entrepris d'établir la concentration des acides gras qu'on pourrait hydrogéner (acides gras hydrogénables – AGH) dans l'herbage de trois graminées de saison fraîche, en l'occurrence le dactyle pelotonné (DP), le ray-grass vivace (RV) et la fétuque élevée (FE). Ils ont déterminé le rendement en matière sèche (MS), la teneur en lipides (extraits à l'éther) et la concentration d'acides gras (pourcentage en masse des acides gras identifiés) dans les plantes à cinq dates, au printemps 2004. Chez les ruminants mis à l'herbe, les AGH servent de substrat à la synthèse et à l'accumulation des produits de la bioconversion des acides gras. Les auteurs estiment que la teneur en acide gras des graminées correspond au produit de la concentration des acides gras (pourcentage en masse) et de la teneur en lipides (extraits à l'éther), alors qu'ils évaluent la concentration de AGH en additionnant celles de C18:1, de C18:2 et de 18:3. Le rendement en MS des trois espèces augmente ($P < 0,05$) du 29 mars au 28 avril et cette hausse se poursuit chez la FE puis le RV. Toutefois, la teneur en lipides diminue tout au long des 140 jours d'échantillonnage chez les trois espèces. Bien que la concentration d'acides gras saturés, de C18:1 et de C18:2 augmente durant la période d'échantillonnage, leur teneur ne change pas de manière appréciable. La concentration de C18:2 est plus élevée ($P < 0,05$) dans les échantillons de DP que dans ceux de RV et de FE. La concentration et la teneur les plus élevées ($P < 0,05$) dans tous les échantillons sont celles de C18:3, mais elles diminuent graduellement dans le temps. Les résultats indiquent que les AGH sont plus abondants chez le DP et le RV, surtout dans les premiers échantillons, cependant le rendement en MS est faible à ce moment. Plus tard en saison, la FE donne plus de MS mais sensiblement moins de lipides et d'AGH.

Mots clés: Dactyle pelotonné, ray-grass vivace, fétuque élevée, acides gras hydrogénables, acide linoléique conjugué, ruminants

The dairy industry is the most important agricultural sector in south coastal British Columbia in terms of both land use and cash receipts. This region has a mild growing season, moderate winter temperatures and high rainfall, well suited to production of temperate forage grasses. The three forages used by the cattle industry, in order of importance, are orchardgrass (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.) and perennial ryegrass (*Lolium perenne* L.). Forages are a princi-

pal component of ruminant diets and consumption rates of forages can be very high, particularly when cattle are pastured. The current interest in routing the dietary acquisition of bioac-

Abbreviations: CLA, conjugated linoleic acid; DM, dry matter; FAME, fatty acid methyl esters; HFA, hydrogenatable fatty acids; OG, orchard grass; PRG, perennial ryegrass; TF, tall fescue

tive fatty acids for health benefits in humans through ruminant food products has enhanced the need to determine the fatty acid composition of forages (Boufaied et al. 2003a). The conjugated linoleic acid (CLA), linolenic acid or its derivatives (Hebeisen et al. 1993) have been shown to protect against coronary heart disease and carcinogenesis [reviewed by Mir et al. (2004)]. Although forages contain only small amounts of lipid, they can be important sources of fatty acids for animals on high forage diets (Harfoot and Hazelwood 1988). Furthermore, forages contain substantial quantities of the monounsaturated fatty acid, oleic acid (C18:1) (Harfoot 1981), and the two polyunsaturated fatty acids (PUFA) (Harfoot and Hazelwood 1988), linoleic acid (C18:2) and linolenic acid (C18:3). Linolenic acid is particularly concentrated in certain grasses (Bauchart et al. 1985; Dewhurst et al. 2001), with the leaf tissue containing the majority of the lipid (Harfoot 1981). Thus, the lipid content of the forage is influenced by the proportion of leaf in the plant, which is affected by plant species, maturity, environmental conditions and management practices such as fertilizer application (Harwood 1980; Boufaied et al. 2003a). The amount of lipid and the specific fatty acids available to the cattle will depend on the amount of leafy tissue consumed. The variations in available fatty acids in feeds cause variations in the content of bioactive lipid components that accumulate in the tissues of the ruminants that consume these forages. Thus, the large variation in concentrations of the bio-active lipid components, CLA and omega-3 fatty acids, in tissues of pastured cattle (French et al. 2000; Rule et al. 2002; Duynisveld et al. 2002) may be due to the relative maturity and species of grass consumed by the animals in these studies. The findings that grass maturity may affect fatty acid composition of forages (Boufaied et al. 2003a) indicates the need for detailed information on the relationship between maturity and fatty acid composition in a wide range of cool-season forages. In particular, there is a need for information on fatty acid composition of forages during the early growth stages of grasses such as perennial ryegrass and tall fescue frequently used for grazing. In a grazing situation, the harvesting of herbage is by the animal continuous, unlike mechanical harvesting of forages, which is managed by plant maturity, harvesting convenience and yield. The fatty acid composition of grazed forages can change over time and needs to be documented. In order to establish the relative amounts of the fatty acids that can be hydrogenated which would be available to cattle consuming the forage on pasture, it is essential to determine the impact of species and sampling date on both total lipid or fat content and fatty acid composition. This study was undertaken under moderate spring conditions of coastal British Columbia to determine the fat content and fatty acid composition of orchardgrass (*Dactylis glomerata* L.) (OG), perennial ryegrass (*Lolium perenne* L.) (PRG) and tall fescue (*Festuca arundinacea* Schreb.) (TF) over the period from the start of grazing to harvest for silage preparation.

MATERIALS AND METHODS

Sample Collection

The study was conducted in 2004 at the Pacific Agri-Food Research Centre at Agassiz in south coastal BC (49°10'N,

125°15'W) in 2004. The soil at the experimental site belongs to the Monroe series, which are moderately well- to well-drained, medium-textured stone-free soils, classified as Eutric Eluviated Brunisols. Three grasses, Mammoth OG, Carnival TF and Aubisque PR (tetraploid) were planted in spring of 2003 in plots (6 × 3 m) arranged in four randomized complete blocks. No fertilizer was applied in 2003, but in spring of 2004, N as ammonium nitrate was applied at 50 kg ha⁻¹ while P, K and S were added according to soil test. The herbage from the three grasses was sampled at 5-cm height beginning when the growth was estimated to be 500-1000 kg ha⁻¹, shortly prior to when grazing would typically begin, then on Apr. 22, Apr. 28, May 12 and May 18. Each sample area (5 m² per plot on the first date and approximately 0.5 m² subsequently) was harvested from a previously unsampled area. Growth stages of the three grasses on each sampling date are shown in Table 1. The herbage samples were harvested without crimping (long stem and leaves) and were immediately dried in a forced air oven at 55°C to constant weight and then ground to pass through a 1-mm screen in a Wiley mill (Arthur H. Thomas. Co., Philadelphia, PA).

Lipid Extraction and Fatty Acid Analysis

The forages were weighed into fat extraction thimbles and dried at 55°C to constant weight and extracted using the Goldfish apparatus with ethyl ether for 5 h. Drying at 55°C has been previously utilized to dry feedstuffs (Sukhija and Palmquist 1988; Boufaied et al. 2003a; Fievez et al. 2004) and solvent extraction under similar conditions has not been found to modify the fatty acid composition of feedstuffs compared with a direct methylation procedure (Sukhija and Palmquist 1988).

The extracted fat was recovered by evaporating the ethyl ether under nitrogen and used for fatty acid analysis after methylation with tetramethylguanidine (Shanta et al. 1993). Methanol (400 µL) and tetramethylguanidine (100 µL) were added to 10-20 mg of the extracted fat, then placed in a boiling water bath for 10 min. A saturated solution of NaCl (5 mL) and petroleum ether (2 mL) was added, mixed for 10 min in a rocker mixer and centrifuged at 640 × g for 10 min. The top petroleum ether layer was collected and evaporated under nitrogen. Then, 5 ml hexane was added, vortexed and an aliquot [containing the fatty acid methyl esters (FAME)] was put into a 2-mL gas chromatography vial, capped and stored at -20°C (Mir et al. 1999) until analysis.

Fatty acid methyl esters were separated in a gas chromatograph [HP 5890, Hewlett-Packard (Canada) Ltd., Mississauga, ON], fitted with an auto-sampler (HP #18596C), injector (HP 7673), flame ionization detector (FID) and Chemstation software (Hewlett Packard 3365) for chromatogram integration and analysis. Samples were introduced onto the 100-m column (Supelco SP-2560, Oakville, ON) via 1 µL split-less injections. The temperature regime was as follows: level one, 120°C held for 15 min; level two, 120 to 160°C at 5.0°C min⁻¹ then held for 15 min; level three, 160 to 240°C at 4°C min⁻¹ and held for 30 min. Injector temperature was set at 220°C and the detector was set at 275°C. Column head pressure was set at 0.200 kPa. A 2-mm (inner diameter) splitless injection sleeve (Chromatographic Specialties Inc., Brockville, ON) was used

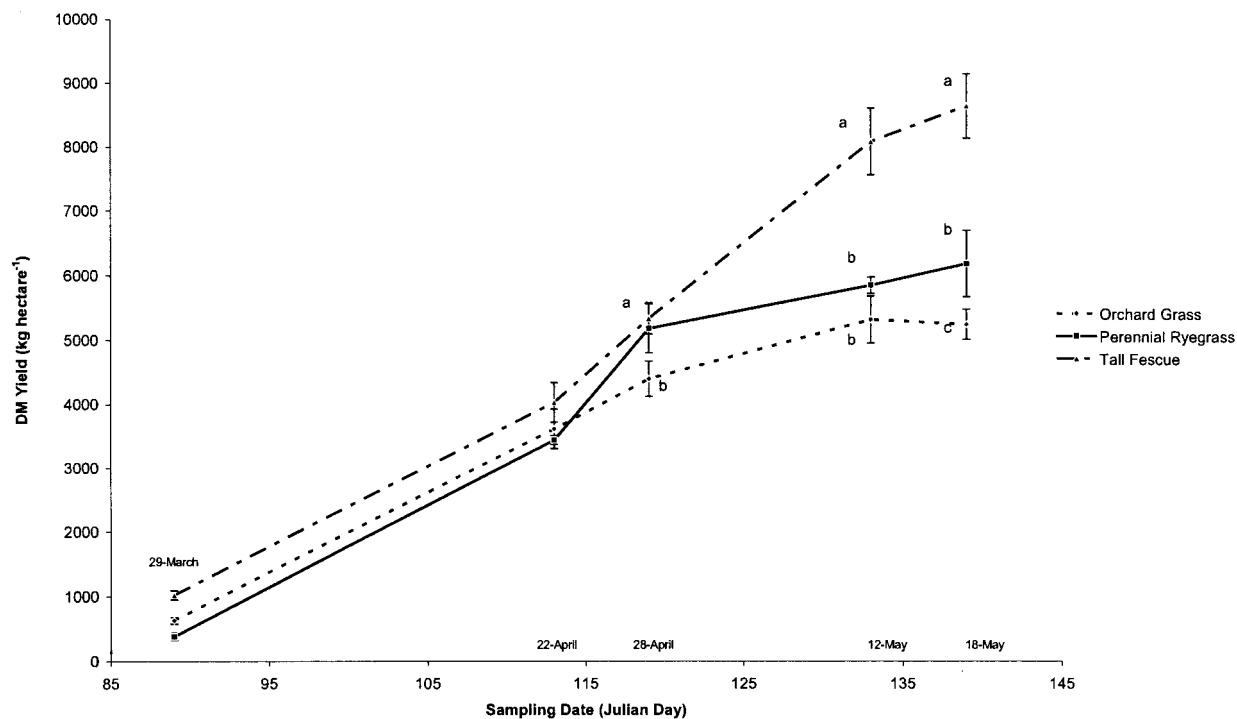


Fig. 1. Dry matter (DM) yield of orchardgrass (OG), perennial ryegrass (PRG) and tall fescue (TF), from Mar. 29 to May 18 on various dates through the first 140 d of 2004. Values on graph not denoted by the same letter are significantly different at $P < 0.05$. Vertical bars denote standard error values.

for all injections. Gas flow rates were: helium (carrier) at 1.7 mL min⁻¹, helium (makeup) at 29 mL min⁻¹, compressed air 320 mL min⁻¹, and hydrogen 34 mL min⁻¹. Identification of fatty acids was based on comparison to retention times of known FAME standards. Prior to sample analysis, FAME standards were individually run on the GC to determine retention times. Standards ranging from C6:0 (caproic acid methyl ester) to C22:6 (docosahexaenoic acid methyl ester) (Sigma-Aldrich, Oakville, ON) were used to determine the retention times. Proportions of fatty acids were determined as weight percentages of total fatty acids and concentration of the fatty acids were converted to content per 100 g of grass DM as the product of fat content and fatty acid concentration (Dhiman et al. 2000).

Statistical Analysis

The dependent variables percent fatty acid and the individual fatty acids that had mostly non-zero values for all sampling dates were statistically analyzed using the MIXED procedure from SAS (SAS Institute, Inc. 1999a) with grass species, sampling date, and their interaction in the model. Since observations were obtained on five different dates, sampling date was treated as a repeated measure and different variance-covariance structures were fitted in an attempt to best account for differences in variance estimates and correlations among the sampling dates according to the smallest Akaike Information Criterion value. Least squares means were generated for significant effects and Fisher's protected LSD test was used to compare differences among

means that were of interest. The UNIVARIATE procedure from SAS (SAS Institute, Inc. 1999b) was used to produce normal probability plots to check the residuals for normality and for outliers. Obvious outliers were removed before rerunning the analysis. Standard errors are shown on the graphs. Critical probability level was set a priori at 0.05.

RESULTS AND DISCUSSION

Yield and Maturity of the Grasses at Each Sampling Date

While tall fescue had generally higher yields than the other grasses (Fig. 1), the divergence in yield among the three species between Apr. 28 and May 18 contributed to a significant species \times sampling date interaction ($P < 0.0002$). Orchardgrass produced less DM than TF after Apr. 28 whereas PRG yield was similar to TF on Apr. 28, but lower than TF and closer to OG from May 12 to 18. Overall, the grasses had fairly similar maturities, although orchardgrass was somewhat earlier than perennial ryegrass and tall fescue (Table 1). Tall fescue has less determinate (or synchronized) flowering than the other grasses, so that a greater proportion of its tillers remained vegetative for a longer period of time (Table 1). This attribute allowed tall fescue to grow more rapidly than the other grasses after Apr. 28 (Fig. 1).

Fat Content of the Grasses

There were significant differences ($P = 0.0012$) in fat content of the grasses across sampling dates (Fig. 2). In all

Table 1. Stage of maturity for the three grasses on each sampling date in 2004

Sampling date	Julian day	Orchard grass	Perennial ryegrass	Tall fescue
Mar. 29	89	Vegetative (3.0-3.3 leaves)	Vegetative (2.5 leaves)	Vegetative (2.5-3 leaves)
Apr. 22	113	Mid stem elongation	Early stem elongation	Early to mid stem elongation
Apr. 28	119	Late boot to early head	Late stem elongation to boot	Mid stem elongation to late boot
May 12	133	Full head to early anthesis	Late boot to early head	Boot to early head
May 18	139	Anthesis to late anthesis	Full head	Mid to full head

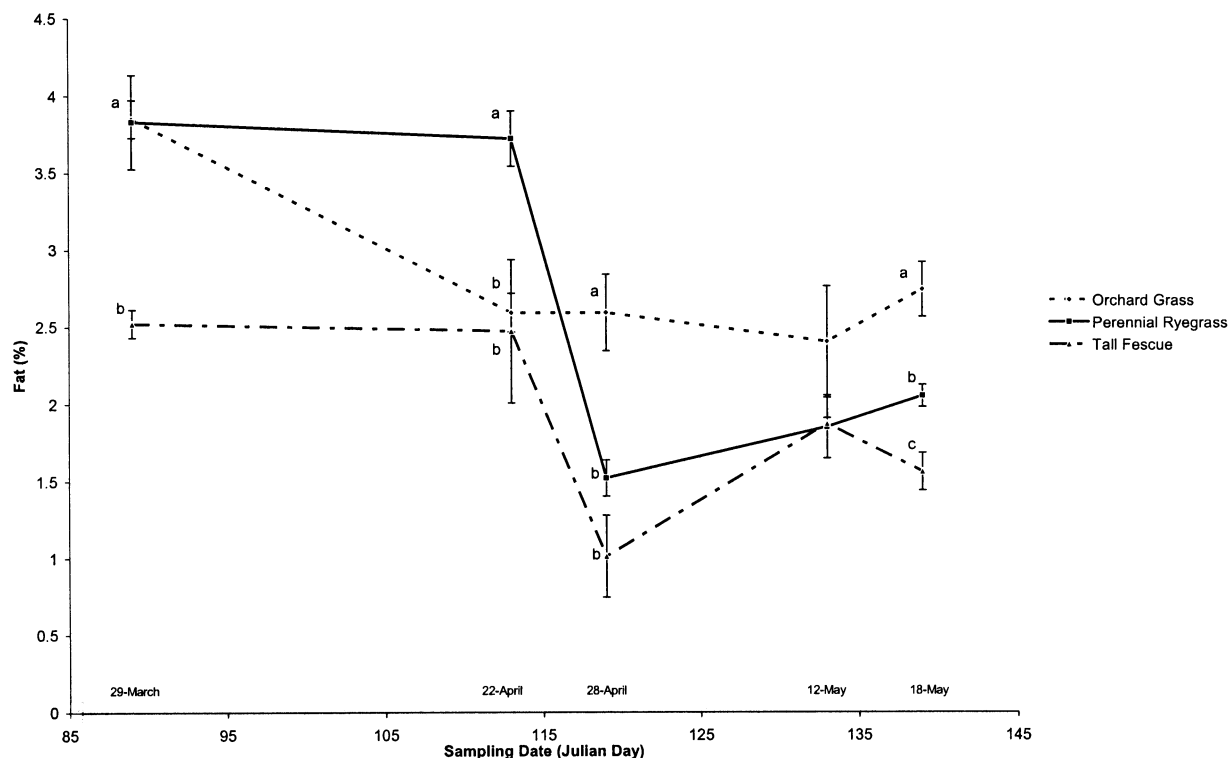


Fig. 2. Fat content of samples of orchardgrass (OG), perennial ryegrass (PRG) and tall fescue (TF) on a DM basis from Mar. 29 to May 18 on various dates through the first 140 d of 2004. Values on a sampling date not denoted by the same letter are significantly different at $P < 0.05$. Vertical bars denote standard error values.

grasses the fat content was greater in early spring and declined before Apr. 28, then remained fairly constant over the next 20 d. On Mar. 29, the fat contents of PRG and OG herbage were similar to each other and significantly greater than that in TF. The fat content of OG declined after Mar. 29, while that of the other grasses remained unchanged, so that by Apr. 22 fat content in OG was similar to that in TF, while fat content in PRG was higher than those of OG and TF. The fat content of OG was stable after Apr. 22 and consistently higher than TF and PRG from Apr. 28 to May 18. Differences between PRG and TF were not significant in samples obtained on Apr. 22 and Apr. 28. The lipid content of forages is related to the proportion of leaf in the herbage (Harfoot 1981). Plants in the early vegetative state appear to have higher lipid content than those in later stages of growth (Boufaied et al. 2003a). However, as the season progresses there appears a period when there is perhaps an increase in the stem component, which is followed by a further increase in the leaf component. This growth habit may be the cause

for the marked decline in lipid content followed by the marginal increase observed for the three forage species studied. The relatively higher concentration of fats in orchard grass beginning Apr. 28, despite its somewhat earlier maturity was unexpected. The nature of the growth is also a response to the environmental conditions related to location, weather and forage management. Although other authors (Boufaied et al. 2003a) have noted differences in total fatty acid content of forages cut at different maturities the effect of date of sampling on different forages was not investigated. While stage of maturity is pertinent for mechanically harvested forage because each forage species is harvested at a stage where the yield and quality are optimized, the date of sampling provides an index of the effect of the fat content for animals grazing a pasture through a season.

Fatty Acid Composition of the Grasses

Along with the changes in total fat content over the season, changes in the fatty acid composition of the forages were

also observed (Fig. 3 A–E for C16:0, C18:0, C18:1, C18:2, C18:3, respectively). The concentrations of saturated C16:0, as weight percentage of the fat, increased ($P < 0.0001$) in the three species over all sampling dates except between Apr. 28 and May 12, while no differences were found among the species (Fig. 3A). All three forages contained substantially lower concentrations of the saturated fatty acid C18:0 (Fig. 3B) relative to those of C16:0. An interaction ($P = 0.008$) between forage species and sampling date was observed for the concentrations of C18:0. The C18:0 concentrations were similar on Mar. 29, but on Apr. 22, OG contained higher concentrations of this fatty acid than the other two forages, while on Apr. 28, OG and TF had higher concentrations than PRG. On May 12, PRG had higher concentrations of this fatty acid than OG and TF, while on May 18, the samples of OG had higher concentrations than TF, and that of PRG was comparable to concentrations in the other two forages.

The proportion of unsaturated fatty acid C18:1 (Fig. 3C) in the forages was affected by both species ($P = 0.009$) and date of sampling ($P = 0.004$), largely due to concentration of C18:1 being greater in TF than in either OG or PRG on Apr. 28, but average concentrations of the three species remained comparable in samples collected on Mar. 29, Apr. 22, May 12 and May 18. An interaction ($P = 0.054$) between forage species and sampling date was observed for C18:2 (Fig. 3D) concentrations. The weight percent for C18:2 was highest for OG on Mar. 29, Apr. 22, Apr. 28 and May 18, and different from concentrations in either PRG or TF, which were similar on these sampling days. However, on May 12, a marked increase in concentration of C18:2 was observed for samples of PRG, and the values were similar to those observed for OG, but different from those of TF. In contrast to C18:2 concentrations, which ranged between 11 and 22% of the fatty acids, 45 to 70% of the fat in these grasses comprised C18:3 (Fig. 3E), which concurs with observation of Dewhurst et al. (2001). The C18:3 concentrations were substantially higher on Mar. 29 than on May 18 for all three forages. An interaction ($P = 0.023$) between forage species and date of sampling was observed, largely because the values for PRG were consistently greater than those for OG or TF on Mar. 29 and Apr. 28, but similar to those of TF on Apr. 22. Also, no differences in C18:3 concentrations among the species were observed on May 12 and May 18.

Fatty Acid Content of the Grasses

While the proportion of the fatty acids in fat present in the grasses is of interest, the total amount of fatty acid available to cattle is dependent on the content of each fatty acid. As a result, the fatty acid content, as a percent of forage DM, was calculated as the product of fat content and fatty acid weight percent of detected fatty acids (Dhiman et al. 2000). This calculation was conducted for the principal fatty acids C16:0, C18:0, C18:1, C18:2 and C18:3 (Fig. 4 A–E, respectively). A comparison of Figs. 3 and 4 for the individual fatty acids indicates that sampling time affected the fatty acid concentration and the fat content of the forage, thus the fatty acid content at a particular stage of maturity may not

reflect the changing availability of fatty acids, especially from pasture. Although increases in saturated fatty acids C16:0 and C18:0 as a percent of the fat in the grasses were observed, substantial changes in content of these fatty acids over the 5 d of sampling were not observed. The content of C16:0 (Fig. 4A) was greater than that of C18:0 (Fig. 4B), which is in agreement with observations of Boufaied et al. (2003a). Interactions ($P = 0.001$ and $P = 0.025$ for C16:0 and C18:0, respectively) between forage species and sampling date were observed for content of these fatty acids. The significant interaction for C16:0 is largely due to its rapid decline in PRG between Apr. 22 and 28), but not in TF or OG. Similarly, content of C18:0, in PRG was comparable to OG, but greater than in TF on Apr. 22, but on Apr. 28 and May 18 OG contained more C18:0 than PRG or TF. No difference in C18:0 content between PRG and TF was observed on Apr. 28 and May 18.

Very small amounts of C18:1 (Fig. 4C) were present in the forages and only differences due to date of sampling were significant ($P = 0.0004$). Forages contained more C18:2 (4D) than C18:1 with values across all sampling dates averaging 0.25, 0.38 and 0.55% for TF, PRG and OG, respectively. An interaction ($P = 0.054$) between forage species and sampling date was noted because of the changes in C18:2 content in PRG. The content of C18:2 in OG was consistently higher than that of TF at all sampling times, but the content of PRG was similar to that of OG on Apr. 22 and May 12, but comparable to values for TF on Mar. 29, Apr. 28 and May 18. At all five samplings, OG had significantly more C18:2 than reported for the four varieties at early heading (Boufaied et al. 2003a) whereas the C18:2 content in the present study was similar to reported values for TF at early heading (Boufaied et al. 2003a). The C18:2 values for PRG were intermediate between those of OG and TF. The most abundant fatty acid was C18:3, with average contents of 1.14% for TF, 1.6% for PRG and 1.69% for OG. There was a significant treatment interaction ($P = 0.006$) because the content of C18:3 declined more in PRG than the other species. The content of C18:3 at the later samples was comparable to values reported for forages cut at early head (Boufaied et al. 2003a).

It was found that OG and PRG have higher amounts of unsaturated fatty acids than TF at all times in the season (Fig. 5). However, the content of total unsaturated fatty acids declined by a third between samples procured on Mar. 29 and Apr. 28, remaining at that level for the balance of the period. In the case of PRG, the total unsaturated fatty acids were high in samples obtained on Mar. 29 and Apr. 22, but declined substantially in subsequent samples. The total unsaturated fatty acids in TF were lower than those in OG and PRG on Mar. 29 and May 18.

All unsaturated fatty acids undergo extensive biohydrogenation in the rumen, and the extent of biohydrogenation, as indicated by concentration of *trans*-C18:1, is greatest in younger grasses, as demonstrated for timothy (*Phleum pratense* L.) (Boufaied et al. 2003b). The wide range of values for products of fatty acid bioconversion, such as CLA, observed in meat of pastured cattle (French et al. 2000; Rule et al. 2002; Mir et al. 2004) may largely be attributed to dif-

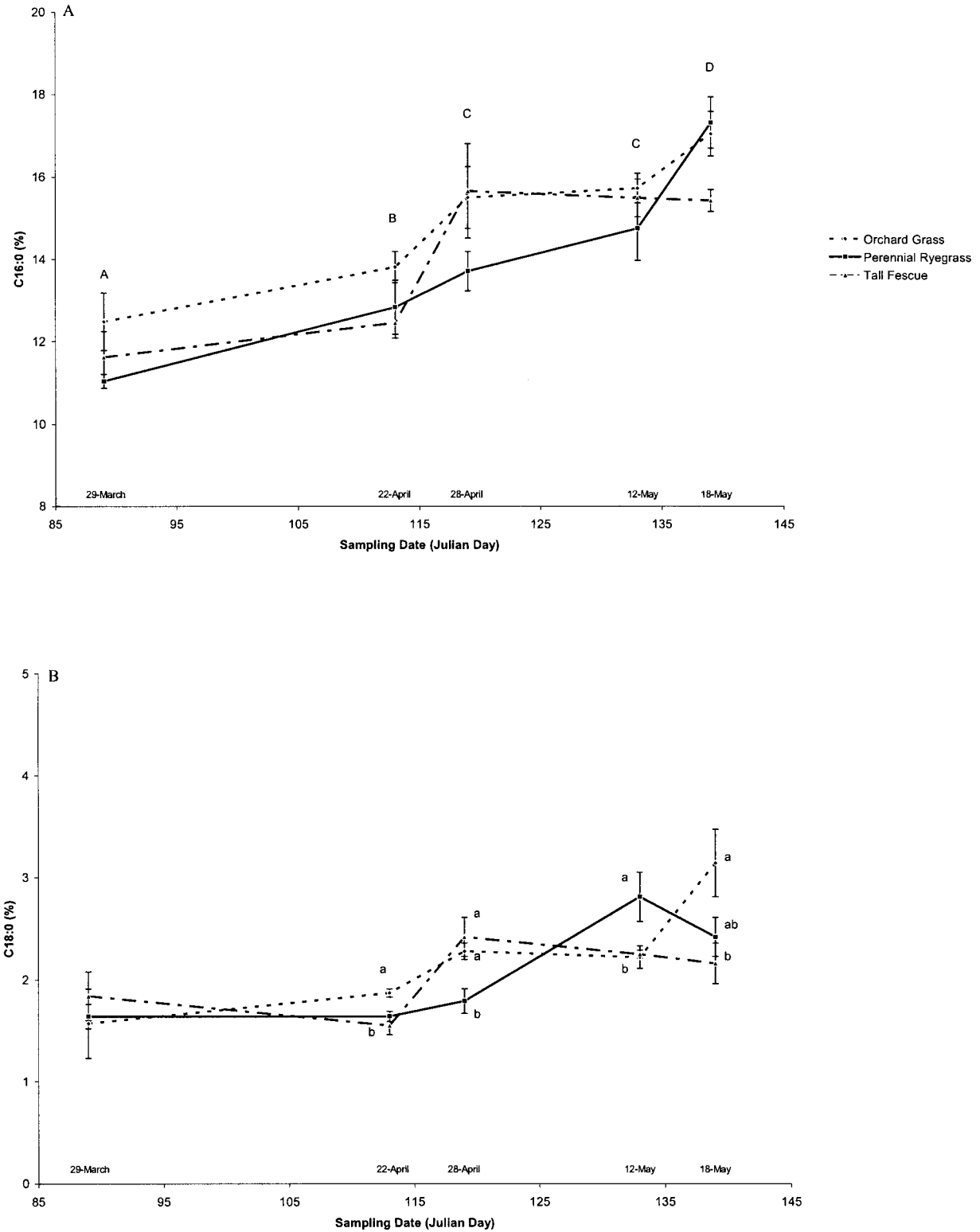


Fig. 3. Concentrations of fatty acids (C16:0 – A, C18:0 – B, C18:1 – C, C18:2 – D, and C18:3 – E) as percent of total fat content in samples of orchardgrass (OG), perennial ryegrass (PRG) and tall fescue (TF) from Mar. 29 to May 18 obtained on various dates through the first 140 d of 2004. a–c: values for grass species within a sampling day not denoted by same lowercase letter are significantly different ($P < 0.05$); and A–C: values on different dates within a species not denoted by same uppercase letter are significantly different ($P < 0.05$). Vertical bars denote standard error values.

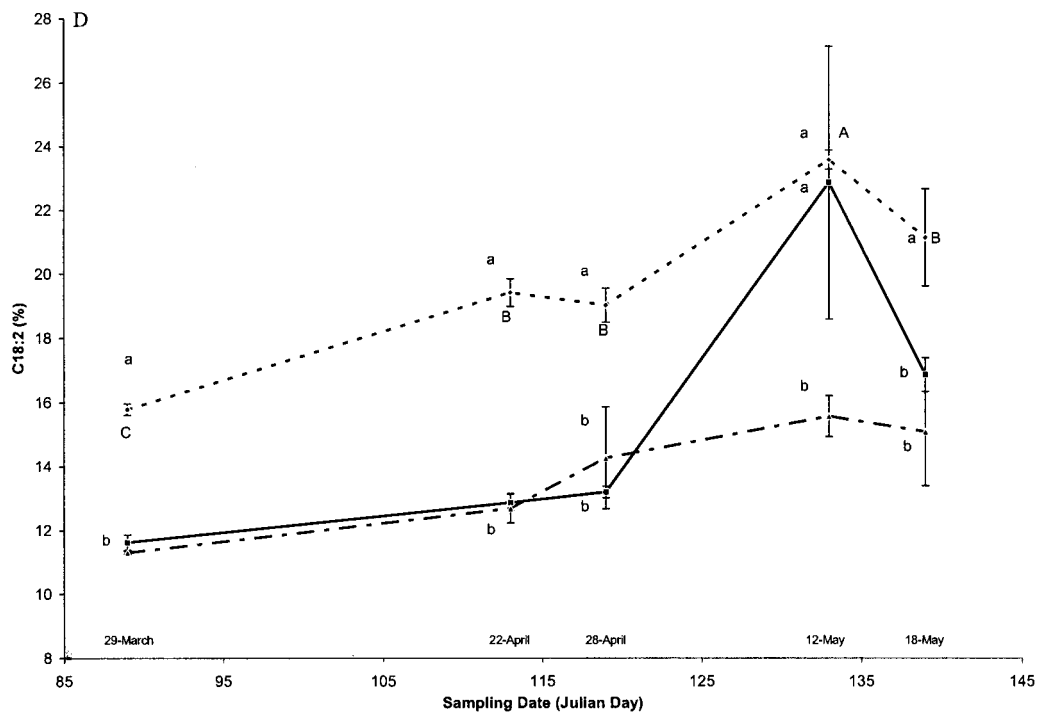
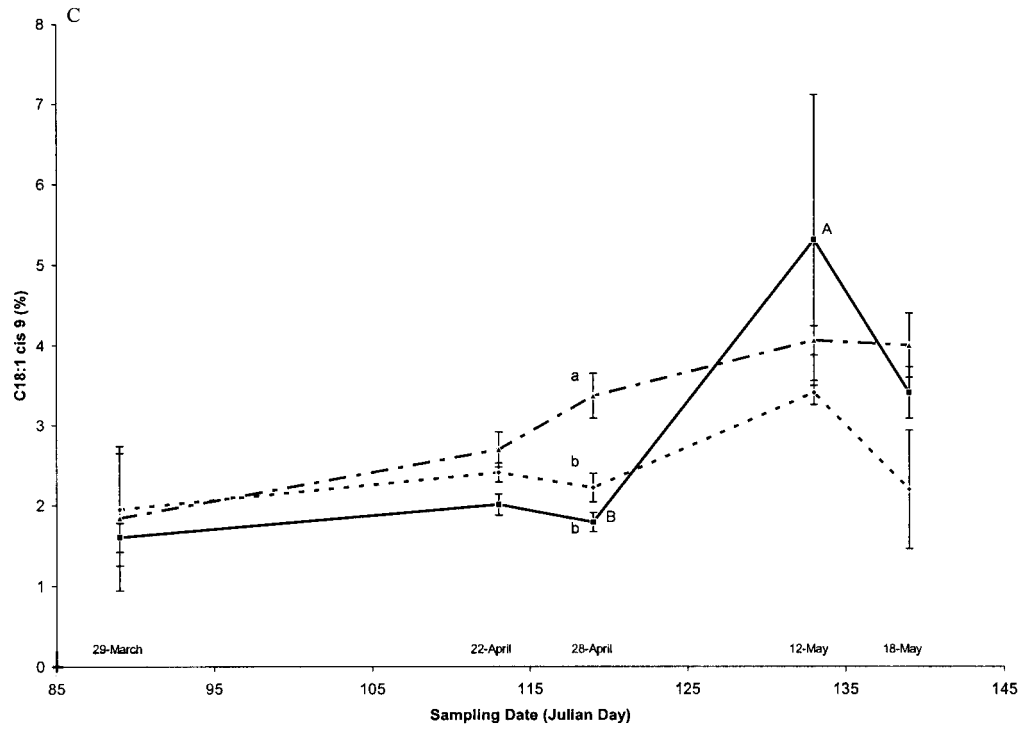


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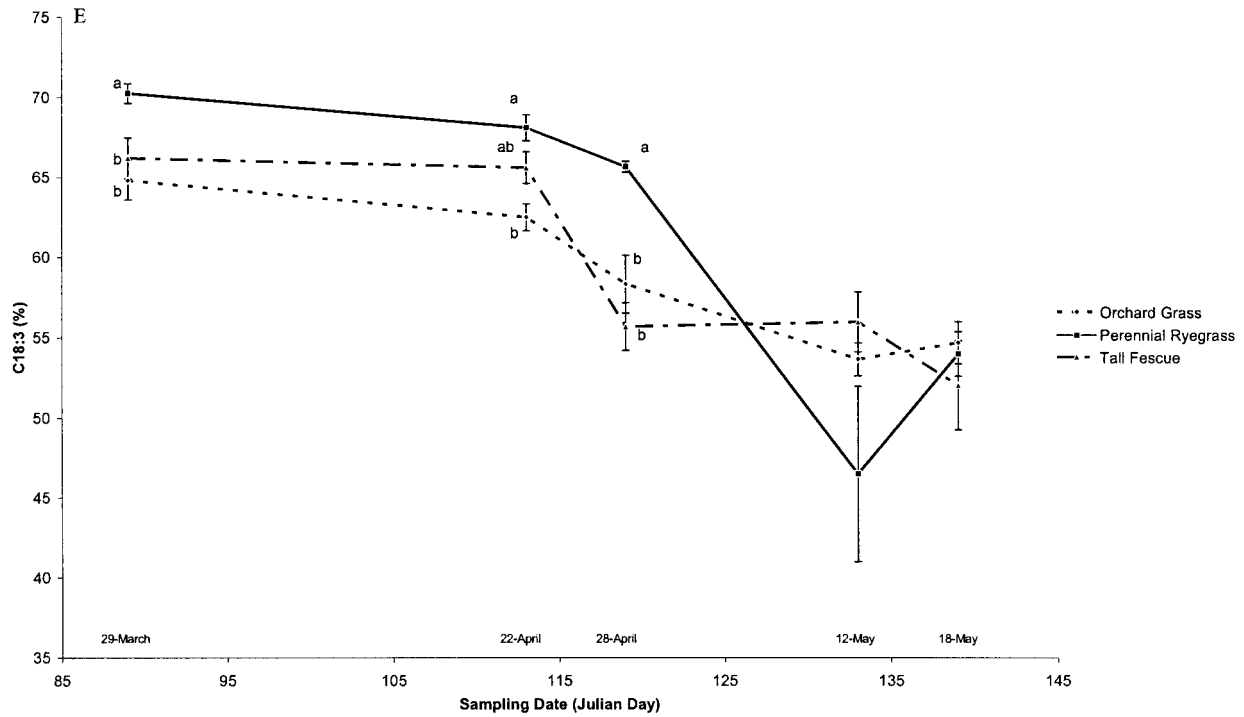


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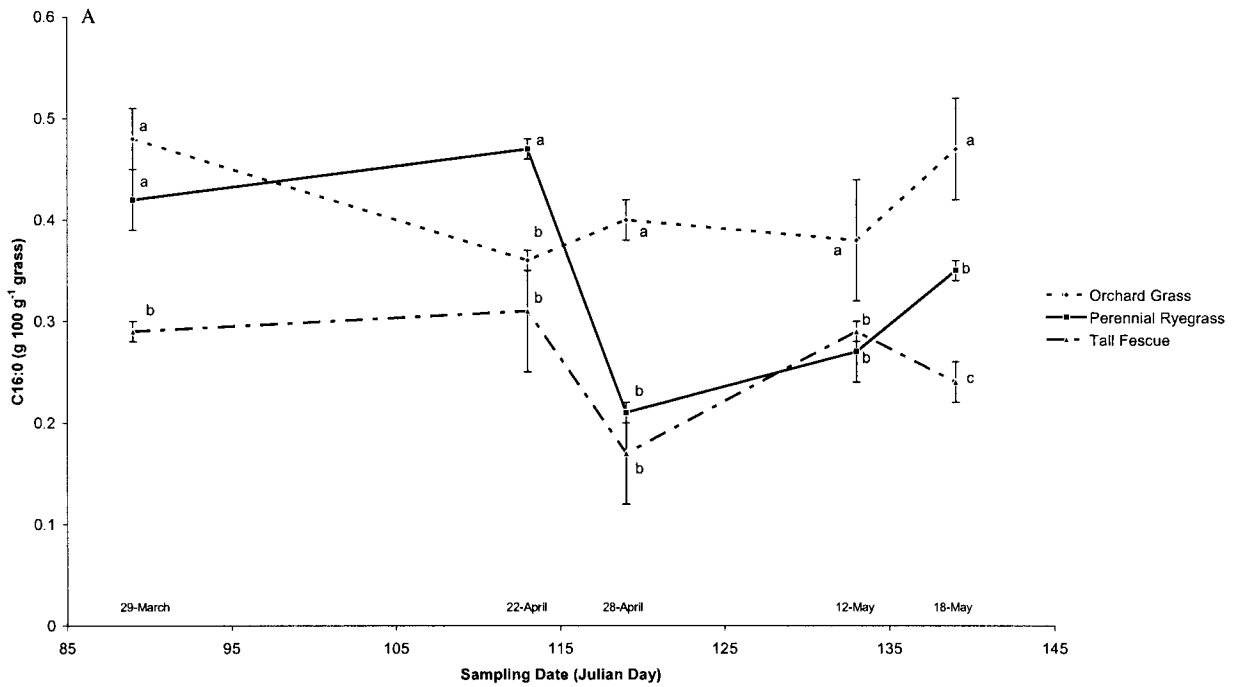


Fig. 4. Contents of fatty acids (C16:0 – A, C18:0 – B, C18:1 – C, C18:2 – D and C18:3 – E) on a dry weight basis in samples of orchard grass (OG), perennial ryegrass (PRG) and tall fescue (TF) from Mar. 29 to May 18 on various dates through the first 140 d of 2004. a–c: values for grass species within a sampling day not denoted by same lowercase letter are significantly different ($P < 0.05$); and A–C: values on different dates within a species not denoted by same uppercase letter are significantly different ($P < 0.05$). Vertical bars denote standard error values.

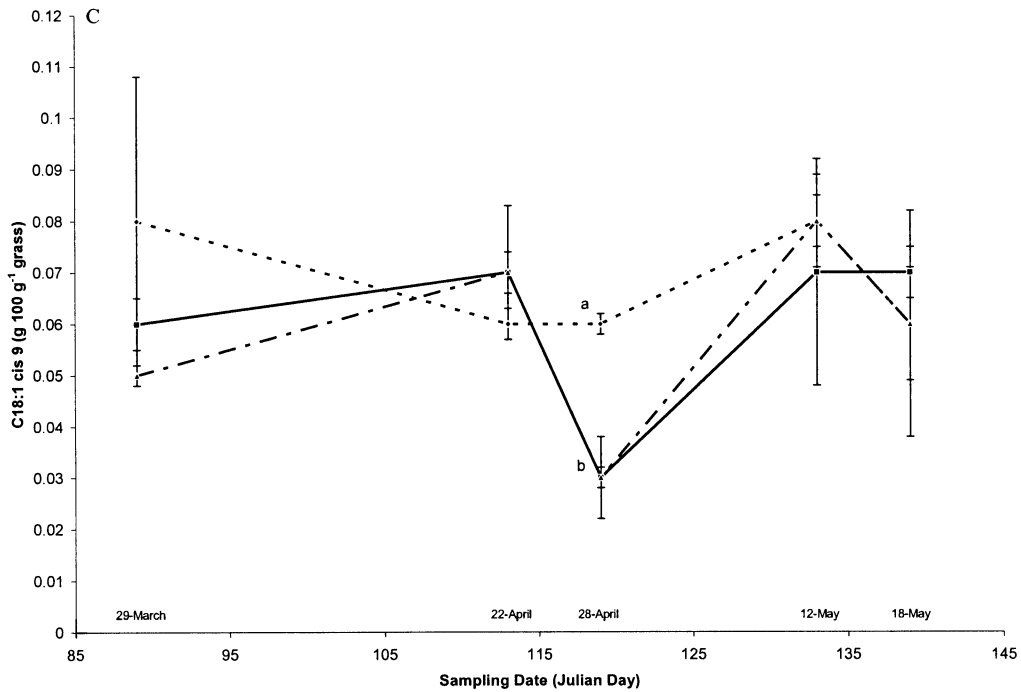
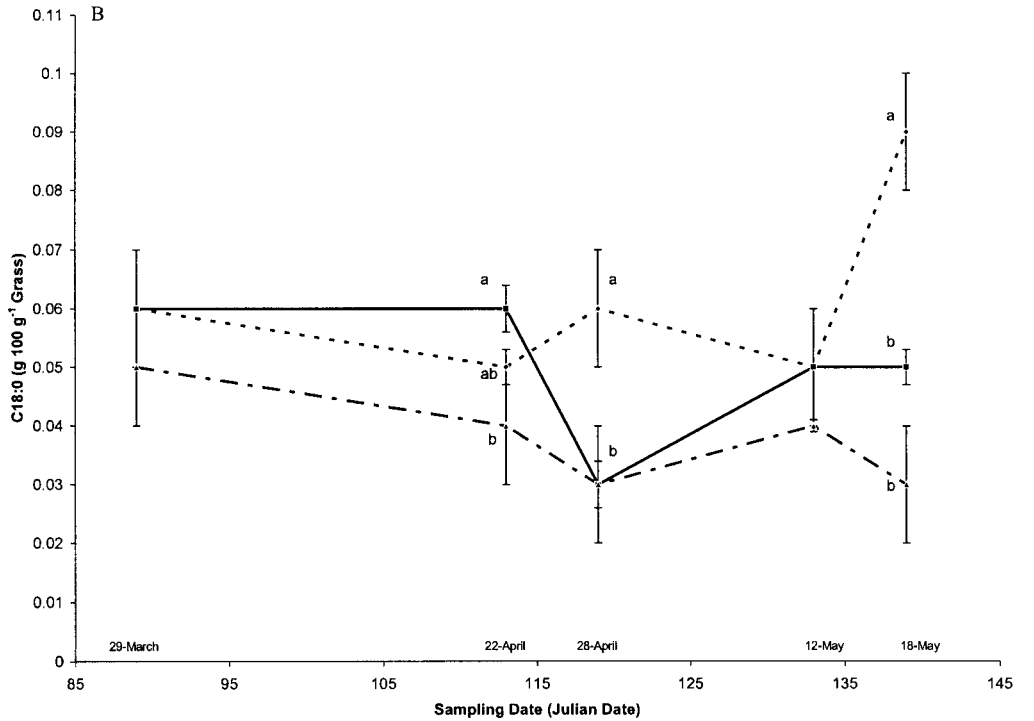


Fig. 4. Continued

ferences in amounts of fatty acids available for the biohydrogenation in different grass species consumed by the animals. In the study by French et al. (2000), the pasture species used by cattle was PRG, but the forage on the range

was not specified in the study by Rule et al. (2002). The lower values for CLA in the latter work could have been due to the choice of species or to environmental conditions such as temperature and rainfall in that region in the year the

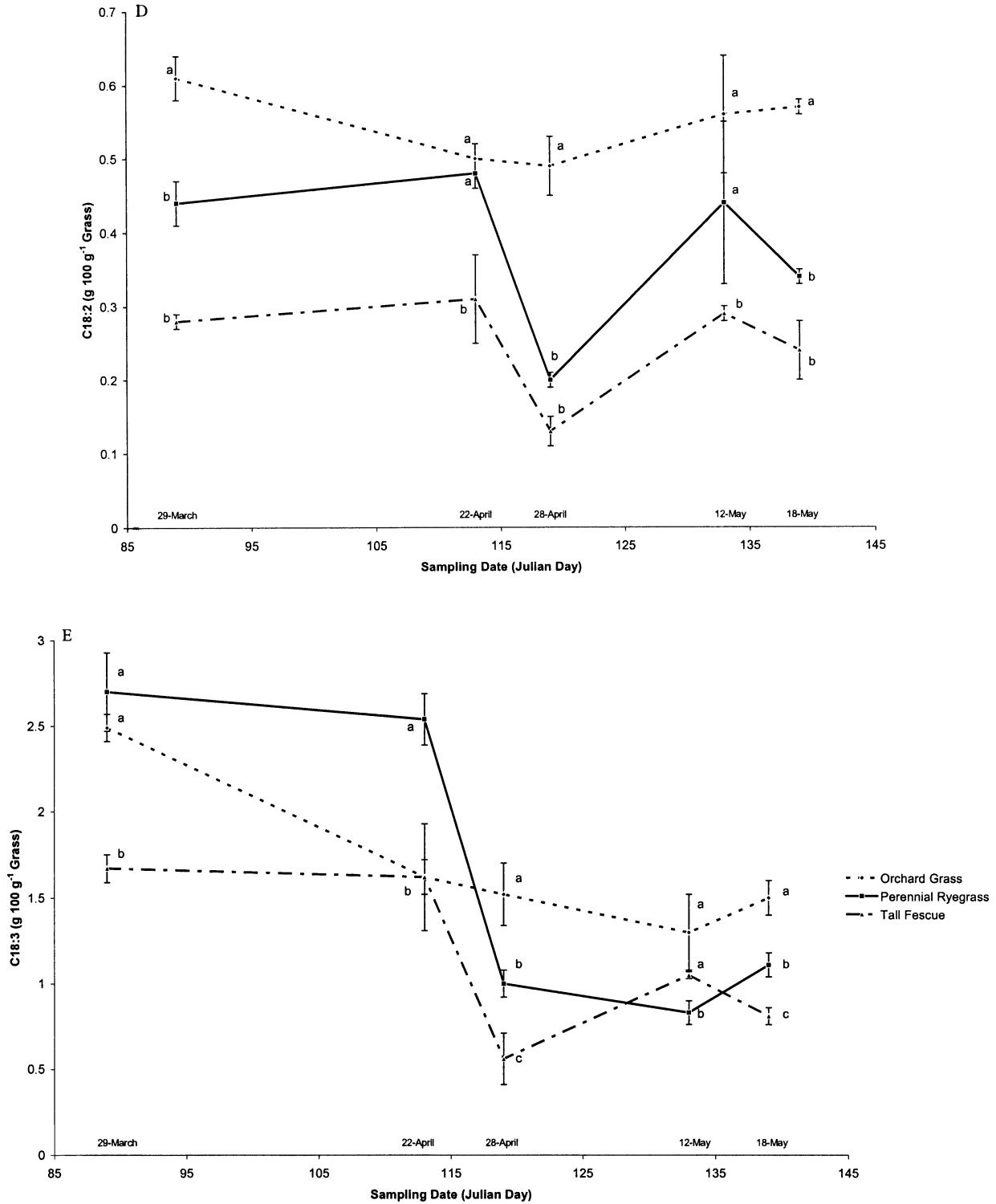


Fig. 4. Continued

study was conducted. In contrast to the observation of Boufaied et al. (2003b), that biohydrogenation potential in timothy was greater for haylage and silage than for fresh

grass, Martin and Jenkins (2002) found that ensiling restricted biohydrogenation in vitro. French et al. (2000) also reported substantially lower CLA concentrations in the meat

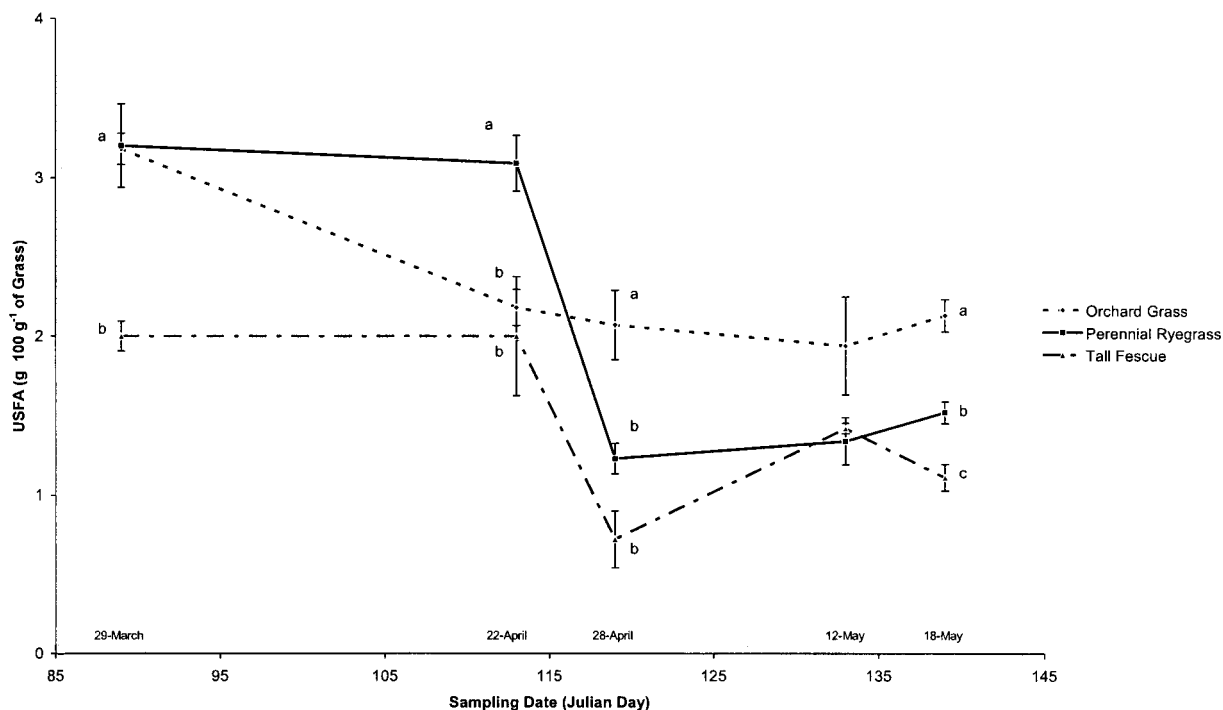


Fig. 5. Unsaturated fatty acid (USFA) content (Sum of content of C18:1, C18:2 and C18:3) in samples of orchard grass (OG), perennial ryegrass (PRG) and tall fescue (TF) from Mar. 29 to May 18 on various dates through the first 140 d of 2004. a–c: values for grass species within a sampling day not denoted by different letter for a sampling day differ ($P < 0.05$). Vertical bars denote standard error values.

of beef cattle fed hay or silage rather than those grazing on pasture. This difference may be due to the maturity at which the grass was harvested for preservation, since increasing maturity can decrease the content of hydrogenatable fatty acids and can affect the biohydrogenation potential. Furthermore, the ensiling process is thought to deplete the readily available sugars, which are considered to be necessary for encouraging the colonization by bacteria that produce the biohydrogenation products (Martin and Jenkins 2002). The present study indicates that pasture management to allow cattle to graze only young vegetative tissue can be beneficial in producing beef that would contain many healthful lipid components for the consumer because the cattle would be consuming young forage with higher leaf content, thus higher fat content with higher levels of hydrogenatable fatty acids.

CONCLUSION

The present study identifies the change in fatty acid concentration and availability to pasturing cattle, which could help explain some of the differences observed in accumulation of bio-conversion products in beef cattle among different pasture trials. The results of the current study indicate that under cool maritime conditions in coastal British Columbia, using PRG early in the season and OG later in the season may provide cattle with 300 to 200 g of hydrogenatable fatty acids, assuming that forage consumption is about 10 kg DM d^{-1} . This falls short of the 600 g d^{-1} (from 6% oil) recom-

mended for beef cattle (Mir et al. 2004) but may be adequate for pastured dairy cattle since their feed intake is greater. The climate in this region enables a long grazing season. To further assess the intake of hydrogenatable fatty acids by cattle, it may be necessary to retrieve and analyze digesta collected from oesophageal cannula.

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