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Short communication

Milk from cows grazing on cool-season pastures provides an enhanced profile of bioactive fatty acids compared to those grazed on a monoculture of pearl millet

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ABSTRACT

The demand for dairy products from grass-fed cows is driven, in part, by their more desirable fatty acid (FA) profile, containing more n-3 FA and conjugated linoleic acids (CLA) than conventionally produced dairy products. This study investigated the effects of pearl millet (PM) *vs*. cool-season pasture (CSP) on animal performance and milk FA in a grazing system. Eight Holstein dairy cows were used in a repeated measures design with four-week periods. Forage type had no effect on animal performance (estimated dry matter intake, milk production, fat, or protein). The contents of CLA and n-3 FA in a serving of whole milk (3.25% fat) increased when cows grazed CSP compared to PM. A serving of whole milk from cows grazing PM had a higher content of saturated FA and branched-chain FA. In conclusion, the contents of various bioactive FA were higher in milk fat of cows grazing a CSP compared to PM.

1. Introduction

The demand for organic food in the United States (U.S.) is primarily driven by the favorable view of its nutritional content and the ecological benefits of its production (Lee & Yun, 2015). Organic milk, for example, contains higher amounts of the bioactive compounds, n-3 fatty acids (FA) and conjugated linoleic acids (CLA), than conventionally produced milk (Butler, Stergiadis, Seal, Eyre, & Leifert, 2011). This demand for foods with added nutritional value is reflected by the 25% increase in organic whole-milk sales from 2014 to 2015, in comparison to a <1% increase for low-fat and fat-free versions (Maltby, 2016). It is not the effect of the management system (organic *vs*. conventional) *per se*, but the consequence of the dietary feeding regime associated with the management system that leads to the improved milk FA profile of organic milk (Butler et al., 2008). The feeding regime on any particular dairy farm is driven by economic, philosophic, and regulatory factors (McBride & Greene, 2009). For example, the U.S. Department of Agriculture (USDA), requires organic dairy producers to have 30% of their cows' dry matter intake (DMI) come from pasture for a 120-day grazing season (U.S. Department of Agriculture, 2010). While the inclusion of fresh forage in the diet of dairy cows leads to an improved milk FA profile, not all forage species affect the milk FA profile in the same way. Turner et al. observed a higher content of n-3 FA in milk when cows grazed birdsfoot trefoil (*Lotus corniculatus* L.) in comparison to ryegrass (*Lolium perenne* L.) (Turner, Waghorn, Woodward, & Thompson, 2005), and Soder et al. demonstrated an increased content of CLA in milk with additional forage species in the pasture (3, 6, and 9 species mixtures *vs*. 2 species mix) (Soder, Sanderson, Stack, & Muller, 2006). There has been no evaluation, however, of the influence of summer annual species on the milk FA profile. Summer annuals are C4 plants that grow rapidly and are more productive during the hot summer months when cool-season (C3) perennial plants experience reduced growth and productivity. Therefore, C4 plants contribute to the dry matter needed to meet the energy demands of the animal and the regulations of the USDA, making them increasingly popular on Northeastern U.S. grass-based dairies. Thus, the objective of this study was to compare the effects of grazing a warm-season annual, pearl millet (*Pennisetum glaucum* L.), on forage quality, animal performance, and bioactive FA in milk with a cool-season diverse pasture.

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2. Materials and methods

2.1. Experimental design

All procedures involving animals were approved under the University of Vermont Institutional Animal Care and Use Committee. Eight multiparous (parity: 2.9 ± 0.6 lactations) mid-lactation (179 ± 20 days in milk) Holstein cows were used in a repeated measures design on a commercial organic dairy farm in northwest Vermont. The treatments consisted of two grazing regimes; a diverse cool-season pasture (CSP) and a warm-season monoculture of pearl millet (PM) (Table 1). PM was chosen because it can be grazed directly as soon as it reaches 60 cm, is palatable and produces high yields, is drought tolerant, is adapted to low pH soils, and lacks prussic acid. Cows were grazed on CSP or PM for four-week periods from the months of July to September 2014 in the following sequence: PM, CSP, and PM (the final grazing period was intended to account for the effect of growing month on PM). A 0.5 ha paddock of previously established CSP was chosen based for its uniform composition of forage species and proximate location to the pearl millet on the farm. The CSP consisted of more than 15 species; orchard grass (*Dactylis glomerata* L.), timothy grass (*Phleum pretense* L.), perennial ryegrass (*Lolium perenne* L.), junegrass (*Koeleria macrantha* (Ledeb.) Schult.), meadow fescue (*Festuca pratensis* Huds.), smooth bromegrass (*Bromus inermis* L.), creeping bentgrass (*Agrostis palustris* Huds.), quackgrass (*Elymus repens* (L.) Gould.), kentucky bluegrass (*Poa pratensis* L.), white clover (*Trifolium repens* L.), red clover (*Trifolium pretense* L.), common vetch (*Vicia sativa* L.), dandelion (*Taraxacum officinale* H.F. Wigg), burdock (*Arctium minus* Bernh.), milkweed (*Asclepias syriaca* L.), and bull thistle (*Cirsium vulgare* (savi) Ten.) consistently made up the majority. Two 0.25 ha paddocks were tilled and seeded at 22.4 kg/ha with PM in two-week successions to eliminate the effect of maturity on forage composition. The paddocks were re-seeded in the same manner for the second grazing of PM. The average mean daily temperatures for each treatment period were 20.0°C for PM, 18.9°C for CSP, and 17.3°C for the second grazing of PM. Cows received grain at 2.42 kg/day (dry matter (DM) basis) during each treatment. The cows were milked twice daily at 0630 h and 1730 h; after each milking, the cows were rotated to a new paddock.

Table 1
Ingredient and chemical composition (mean ± standard deviation) of the diet components; cool-season pasture (CSP), pearl millet (PM), and grain.

	Diet component		
	CSP	PM	Grain[a]
%DM	19.3 ± 2.4	19.9 ± 2.6	89.6 ± 0.6
Chemical composition, % DM			
aNDFom[b]	42.5 ± 3.3	53.7 ± 5.0	7.4 ± 1.7
ADF[c]	32.8 ± 2.1	40.5 ± 1.3	10.0 ± 1.4
CP (N × 6.25)[d]	17.4 ± 2.3	14.4 ± 2.3	11.9 ± 1.0
Starch	2.1 ± 0.2	1.2 ± 0.2	30.4 ± 1.1
NFC[e]	24.9 ± 0.7	18.4 ± 1.3	64.1 ± 3.3
Total fatty acids	2.4 ± 0.2	1.3 ± 0.2	2.4 ± 0.1
Fatty acid composition (mg/g DM)			
16:0	4.13 ± 0.11	2.93 ± 0.67	4.26 ± 0.41
18:0	0.41 ± 0.01	0.26 ± 0.05	0.56 ± 0.06
18:1 *c*9	0.74 ± 0.10	0.26 ± 0.05	6.63 ± 0.44
18:2 *c*9,*c*12	5.08 ± 0.31	1.83 ± 0.36	10.72 ± 0.96
18:3 *c*9,*c*12,*c*15	12.04 ± 0.96	6.49 ± 0.93	0.69 ± 0.10
∑ other[f]	1.32 ± 0.23	1.16 ± 0.22	0.70 ± 0.09
Total SFA[g]	5.57 ± 0.04	4.10 ± 0.84	5.19 ± 0.49
Total MUFA[h]	0.93 ± 0.13	0.49 ± 0.18	6.89 ± 0.43
Total PUFA[i]	17.17 ± 1.91	8.33 ± 1.26	11.45 ± 1.04
Total n-3 FA	12.07 ± 0.96	6.51 ± 0.94	0.72 ± 0.08
Total n-6 FA	5.13 ± 0.35	1.84 ± 0.36	10.76 ± 0.95

[a] The grain consisted of: 47.5% organic corn meal, 16.9% organic whole grain barley, 15.0% organic field peas, 12.5% organic wheat middings, 3.75% calcium carbonate, 1.5% sodium bicarbonate, 1.5% salt, 0.75% kelpmeal, 0.35% magnesium oxide, and 0.25% concentrated base vitamins consisting of: amino acid chelate, manganese amino acid chelate, copper amino acid chelate, vitamin E supplement, selenium yeast, zinc sulfate, zinc hydroxychloride, vitamin A acetate, vitamin D3 supplement, basic copper chloride, sodium selenite, cobalt carbonate, biotin, calcium iodate.
[b] aNDFom = Ash-corrected neutral detergent fiber.
[c] ADF = Acid detergent fiber.
[d] CP = Crude protein.
[e] NFC = Non-fiber carbohydrate = 100 − (NDF + CP + ether extract + ash).
[f] ∑ other: 12:0; 14:0; 15:0; 16:1 *c*9; 17:0; 18:1 *c*11; 20:0; 18:3 *c*6,*c*9,*c*12; 20:2 *c*11,*c*14; 22:0; 22:1 *c*13; 20:4 *c*5,*c*8,*c*11,*c*14; 24:0; 24:1 *c*15.
[g] SFA = Saturated fatty acids.
[h] MUFA = Monounsaturated fatty acids.
[i] PUFA = Polyunsaturated fatty acids.

2.2. Data and sample collection

DMI was estimated using an electronic rising plate meter (Jenquip; Feilding, New Zealand) three times per week by taking sixty measurements each in both pre-grazed and post-grazed paddocks. The rising plate meter was calibrated weekly by taking ten 0.2 m^2 quadrats, cut to ground level, in both pre and post-grazed paddocks for a total of twenty measurements per week. Samples were dried at 65°C for 48 h to determine DM content. DM (kg) of these samples was plotted against the pasture height/density to obtain an equation with an $R^2 > 0.8$. Rising plate meter values were used in the equation derived from the calibration to obtain kg of DM consumed by the eight dairy cattle per ha. Estimated DMI per cow was then calculated from measured pasture areas and the number of cows grazing the pasture. Forage samples for quality measurements were collected weekly from the next paddock in the pasture rotation. Thirty samples, clipped to the height of the post-grazed paddock, were composited then divided into forage classes; grasses, legumes, broad-leaf weeds, and dead matter. Each fraction was dried at 65°C to determine DM and ground through a Wiley Mill (Arthur H. Thomas, Philadelphia, PA) with a 2 mm screen and then through an Udy Mill (UDY Corporation; Fort Collins, CO) with 1 mm screen. Ground forage samples were analyzed by near-infrared reflectance spectroscopy (NIRS) for forage quality. Milk weights and samples were collected during weeks 3 and 4 of each period from both AM and PM milking. Samples were composited by weight and one aliquot was frozen at −20°C for FA analysis. A second aliquot was preserved with 2-bromo-2-nitropropane-1,3 diol and analyzed by mid-infrared spectroscopy by Lancaster Dairy Herd Improvement Association (Manheim, PA) for total fat, protein, ands organic solids.

2.3. Milk and forage FA analysis

Forage and milk FA compositions were determined by the method of Bainbridge, Lock, and Kraft (2015). A typical chromatograph produced by this method is presented in Supplemental Fig. 1. The content (mg) of individual FA in a serving (244 g) of whole milk (3.25% milk fat (U.S. Department of Agriculture Agricultural Research Service, 2008)) was calculated as follows, assuming milk fat to be 93.3% of FA (Glasser, Doreau, Ferlay, & Chilliard, 2007):

Total FA per serving (mg) = 7.93 g fat/serving × 0.933 × 1000
FA per serving (mg) = Total FA per serving (mg) × [FA proportion (g/100 g)/100]

2.4. Statistical analysis

Data were analyzed by a repeated-measures ANOVA using the PROC MIXED procedure in SAS 9.4 (SAS Institute, Cary, NC). All sta-