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Intake, milk production and heat stress of dairy cows fed a citrus extract during summer heat

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ABSTRACT

This study determined effects of feeding a citrus extract (CE) to high producing dairy cows during summer heat on measures of heat stress, as well as milk production and composition, in a replicated 2 × 2 Latin square experiment with two 28 d periods on a dairy farm near Hanford (CA, USA). Four 'high group' pens were used (*i.e.*, cows which had cleared the fresh pen but were not yet confirmed pregnant), each with ~310 early lactation multiparity cows/pen. The two total mixed rations contained 171 g/kg dry matter (DM) crude protein (CP), 55 g/kg fat, 335 g/kg neutral detergent fiber (aNDF) and 135 g/kg starch, and were the same except for inclusion of the CE at 4 g/cow/d in the treatment diet (CED). Average daily high temperatures during the study were 35 to 37 °C with lows of 16–17 °C. In general, cows showed mild heat stress, but CE feeding had no effect on respiration rate, panting score or rump temperature at any time of the day (*i.e.*, 02:45, 09:15, 17:30 h). However at 02:45 h, a higher ($P < 0.01$) proportion of CED cows were lying (*versus* standing) compared with Control cows (68.6 *versus* 53.7 cows/100 cows), which is an indicator of reduced heat stress. Intake of DM (25.3 kg/d) and whole tract digestibility of CP (703 g/kg) and aNDF (510 g/kg) did not differ between treatments. Milk production (47.3 kg/d) and its fat and true protein levels (35.4, 28.6 g/kg) did not differ, and changes in body condition and locomotion scores were also not impacted by treatment. However mammary health improved based on lower SCC (somatic cell counts; $P < 0.04$) of CED *versus* Control cows (160,000 *versus* 196,000 cells/μL), and lower linear SCC scores ($P < 0.01$; 2.12 *versus* 2.30). Feeding this CE to lactating dairy cows during summer heat decreased SCC with no impact on other aspects of performance.

1. Introduction

A popular contemporary topic in ruminant nutrition is the study of naturally occurring dietary additives which modulate rumen fermentation in order to improve nutrient utilization by rumen microorganisms, and/or reduce enteric production of greenhouse gases such as methane. Essential oils (EO) encompass a wide range of naturally occurring secondary compounds

Abbreviations: AA, amino acids; ADF, acid detergent fiber expressed with residual ash; ADFom, ADF expressed without residual ash; aNDF, neutral detergent fiber assayed with a heat stable amylase and expressed with residual ash; BCS, body condition score; CE, citrus extract; CED, CE diet; CP, crude protein; DM, dry matter; EE, ether extract; EO, essential oils; LS, locomotion score; PS, panting score; RR, respiration rate; RT, rump temperature; SCC, somatic cell count; THI, temperature/humidity index; TMR, total mixed ration.

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which occur in leaves, flowers, stems and seeds of many plants, and may have antimicrobial properties which modify rumen microbial fermentation.

Reviews of various EO compounds, their possible modes of action and effects on rumen fermentation have been described (*e.g.*, Benchaar et al., 2008), and limonene, an EO found in citrus products, has been suggested to have beneficial effects on rumen fermentation, and animal production, in ruminants (Calsamiglia et al., 2007). While few *in vivo* studies have examined EO mixtures containing limonene, Tassoul and Shaver (2009) reported increased milk protein production, with an overall trend to increased feed efficiency (*i.e.*, kg of fat corrected milk/kg of DM intake), when an EO mixture including limonene was fed to dairy cows. In contrast, Benchaar et al. (2006, 2007) had earlier reported that the same EO mixture used by Tassoul and Shaver (2009) had no effect on milk production, dry matter (DM) intake or feed efficiency.

Vitamin C, found at high levels in citrus products, is not considered an essential nutrient for healthy cattle because their liver can synthesize it from glucose at levels believed to be sufficient to meet their needs (Padh, 1990). However cattle under stress, such as those in early lactation at high production levels and/or under summer heat, may not synthesize adequate amounts of vitamin C to compensate for oxidative stress due to sub-clinical infection or illness (Weiss et al., 2004; Ranjan et al., 2005), and feeding supplemental vitamin C can replace depleted reserves (Weiss, 2001). As high somatic cell counts (SCC) in milk are the result of degraded mammary health, and have a negative impact on animal performance and milk quality, the limonene and vitamin C in citrus products may help minimize SCC in dairy cows, thereby improving efficiency of feed utilization as a result of improved immune function (Chaiyotwittayakun et al., 2002; Castillejos et al., 2006). Indeed Jaramillo et al. (2009) and Giannenas et al. (2011) fed citrus pulp to ewes and reduced milk SCC.

In a review of citrus product feeding to ruminants, Bampidis and Robinson (2006) concluded that their feeding did not affect DM digestibility, but decreased crude protein (CP) digestibility, while increasing neutral detergent fiber (NDF) and acid detergent fiber (ADF) digestibility.

Our objective was to evaluate impacts of a CE on feed intake and productive performance of dairy cows during hot weather.

2. Materials and methods

2.1. Animals, management, and experimental design

High group multiparity Holstein cows (*i.e.*, those cows which had cleared the fresh pen but were not yet confirmed pregnant) in 4 early lactation pens of ~310 cows each, on a commercial dairy farm near Hanford (CA, USA), were used in a study with two 28 d experimental periods in a replicated 2 × 2 crossover design during summer. Each pen had 300 head gates and free stalls. The only source of cooling was bunk line misters which switched on automatically at 24 °C, and were on in each pen for 4 mins and then off for 12. Cows were assigned weekly to one of the 4 pens at random from a common fresh cow pen, and moved to a mid pen by ~200 days in milk once they were confirmed pregnant.

Cows were milked three times daily in a double 40 herringbone parlor. Pen 1 started milking at 04:00, 12:00 and 20:00 h. Pens 2, 3, and 4 were milked in sequence after pen 1, at intervals of ~45 min. The total mixed ration (TMR) was fed twice daily, between 04:00 and 08:00 h, prior to cows returning to their pens from milking, and again between 11:30 and 12:30 h. The amount of TMR delivered was determined from the previous days intake to create orts equal to ~10 g/kg of total TMR delivered (as fed). Orts were removed daily and weighed individually by pen while cows were in the parlor during the first milking, just prior to the first TMR feeding.

Head-locks were set prior to cows returned from the morning milking, to facilitate artificial insemination, such that the cows were head locked in the stanchions for 45–60 min daily. Cows were housed in covered barns with access to free stalls bedded with dried manure, which was renewed weekly and groomed bi-weekly. Cows also had free access to an uncovered manure pack drylot at all times. Inside alleyways were flushed with water three times daily while the cows were being milked. Cows had *ad libitum* access to clean drinking water at all times.

At the start of the study, two pens were fed the CE containing diet (CED), while the two other pens were fed the Control diet. After the first 28 d period, treatments were reversed. Each period contained a 21 d adjustment and 7 d collection period during which all samples were collected.

2.2. Environmental conditions

Four portable weather data loggers (HOBO U23; Onset, Bourne, MA, USA) were recorded ambient temperatures and relative humidity every 30 min throughout the study. One station was placed in each experimental pen on a pole at its center ~3 m above the floor and out of direct sunlight. The study took place in the 2 mo after the summer solstice to minimize variation of day length and weather, while maximizing expected temperature/humidity indices (THI) which was calculated as:

$$\mathrm{THI} = t_{\mathrm{db}} - \left[0.55 - \left(\frac{.55 \times \mathrm{RH}}{100}\right)\right](t_{\mathrm{db}} - 58.8)$$

where: t_{db} = dry bulb air temperature (°F) and RH = relative humidity (%). THI ≤ 74 is considered “normal”, 75–78 is “alert”, 79–83 is “danger”, and ≥84 is “emergency” according to the Livestock Weather Safety Index (LCI, 1970).