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Performance of high-yielding dairy cows supplemented with fat or concentrate under hot and humid climates

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ABSTRACT

Multiparous Israeli-Holstein cows (n = 42) averaging 158 d in milk and 621 kg of body weight were used to investigate the effects of energy source (fat or concentrate) on production, rumination time, energy balance, metabolic heat production, and efficiency under hot and humid conditions. Cows were assigned to 3 diet treatment groups: a lactating-cow ration (1.75 Mcal of net energy for lactation/kg of dry matter (DM; control); supplemented with 0.825 kg/d per cow of ground corn grain (2.7% of diet; HG); or supplemented with 0.300 kg/d per cow of calcium salts of fatty acids (1.5% of diet; HF). Milk production, body weight, and rumination time were recorded daily. Rectal temperature and respiratory rate (RR) were measured weekly. Mean daily maximum ambient temperature, relative humidity, and temperature-humidity index were 31.5°C, 86.6%, and 76.8, respectively. Dry matter intake was lower in HF and HG cows than in controls. Average daily rumination time was lowest in the HG group: 393.0, 377.7, and 390.8 min/d for control, HG, and HF cows, respectively. Milk production was higher in the control group than in the HG group; milk fat content was 0.38 units higher and fat yield was 11% greater in HF cows than in HG cows. Fat-corrected milk yield was higher in HF cows than in HG cows, but not higher than in controls. Energy balance in HF cows was lower than in both other groups, and nonesterified fatty acid concentrations in plasma were increased by fat supplementation. Rectal temperature was highest in HF cows, and RR was higher in the HF cows than in the controls. Metabolic heat production was similar in HG and HF cows and lower than in controls. Body weight gain of the HG cows tended to be higher than that of the others. Efficiency of conversion of DM or energy intake to milk and fat-corrected milk was higher in HF cows than in both other groups; however, when taking the energy retention in body mass into account, no differences in energy utilization were observed between HF and HG groups. A principal component analysis revealed that rumination time played a pivotal role in the deleterious effect of heat stress in dairy cows. In conclusion, increasing the energy density in diets of heat-stressed mid-lactation cows over 1.75 Mcal/kg of DM was not effective in enhancing production. Both dietary treatments were effective in reducing metabolic heat production, but the changes were not reflected in rectal temperature and RR. Fat supplementation increased metabolic efficiency; however, whereas HF cows prioritized milk production, HG cows channeled energy for body mass deposition.
Key words: heat stress, fat supplementation, energy partitioning, rumination time

INTRODUCTION

Enhancing milk production during the hot season is of especial interest in Israel because of the increased demand for milk and milk products during the summer. However, the yields and performance of dairy cows under heat stress conditions are always reduced (West, 2003; Berman, 2008). The effects of hot and humid climate are thought to be mediated by body temperature, and it was reported that rectal temperature (**RT**) increased by 0.02°C/kg of FCM for a cow producing >25 kg/d (Berman et al., 1985). Metabolic heat production (**MHP**) also increased as milk yields increased (Purwanto et al., 1990). Therefore, in light of the dramatic increase in milk production in the last 25 yr, it is plausible that adverse effects of heat stress on production have intensified in the modern high-yielding dairy cow. Increases in MHP often impair milk yield (West, 2003); therefore, using nutritional strategies to enhance milk production under heat-load conditions should take increased MHP into account.

Energy intake is considered the most production-limiting nutrition component during summer (West, 2003). However, recently it was demonstrated that reduced intake accounted for only 35% of the decline in milk yield under heat stress conditions, and it was suggested

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that a shift in postabsorptive metabolism and nutrient partitioning might account for the remaining reduction in milk yield (Rhoads et al., 2009). Alternations in plasma concentrations of several hormones were found in heat-stressed cows: observed changes in thyroxine, growth hormone, and glucocorticoids concentrations in chronically heat-stressed cattle were associated with reduced basal metabolism (Collier et al., 1982), and expression of gene networks was also shown to change in response to heat stress (Collier et al., 2008). However, direct effects of hormonal and gene expression changes on milk production in heat-load conditions were not demonstrated.

Increasing the energy intake of heat-stressed cows could be achieved via 2 main approaches: by increasing the concentrate content at the expense of dietary forage, or by fat supplementation. Fat supplementation is thought to be preferable because fat digestion, especially that of inert fat, in the rumen is minimal, so this practice might supply extra energy to the cow with less MHP (West, 2003). Several studies investigated the effects of fat supplementation during the hot season on production, and results have varied. Increasing dietary fat density from 4.6 to 7.4% in heat-stressed cows improved milk production efficiency by 9% in cows maintained in sheds, but not in those kept under an evaporative cooling regimen (Chan et al., 1997). Likewise, increasing dietary fat enhanced milk production in the warm season but not in the cool season (Skaar et al., 1989). In contrast, another study found greater milk production in thermoneutral cows than in heat-stressed fat-supplemented cows (Knapp and Grummer, 1991). Increasing dietary fat from 2.6 to 6% in heat-stressed mid-lactation cows enhanced milk production and efficiency and tended to increase energy retention (Drackley et al., 2003). The inconsistency in results could be attributed to variations in heat stress intensity or to other factors, such as energy density and housing conditions.

Cows under thermoneutral conditions fed a diet high in glucogenic nutrients have been shown to channel nutrients toward body reserves, whereas cows fed a lipogenic diet produced more milk containing more fat and energy (van Knegsel et al., 2007). There is a lack of knowledge on the effect of the type of nutrient supplementation on energy-partitioning priorities of the heat-stressed cow. The only study that compared the effect of lipogenic versus glucogenic substrates on the metabolism of heat-stressed cows was conducted by Drackley et al. (2003); however, the diets in that trial contained only a moderate NE_L content (1.5 to 1.6 Mcal/kg of DM).

Heat stress in ruminants was associated with reductions in both frequency and amplitude of rumen contractions (Attebery and Johnson. 1969) and an increase of digestion of DM and fiber components (Beede and Collier, 1986). Beede and Collier (1986) reviewed several other factors, such as water intake and appetite, that might affect digestibility under heat stress. In the present study we measured rumination time, hypothesizing that it might be influenced directly by heat stress with respect to dietary manipulations.

We hypothesized that increasing the energy density beyond 1.75 Mcal/kg of DM would increase milk production and that protected fat supplementation might decrease MHP and therefore be more efficient than concentrate in increasing production. The objectives were to examine the effects of energy supplementation, either as fat or as concentrates, of high-yielding dairy cows that already were maintained on high-energy diets on production, energy partitioning, energy balance, rumination time, and efficiency of milk production during hot and humid conditions.

MATERIALS AND METHODS

Cows and Treatments

The procedures used were approved by the Volcani Center Animal Care Committee. The experiment was conducted at the Volcani Center experimental farm in Bet Dagan, Israel, and continued from early July to mid September (11 wk), which typically is the hot season in Israel. Forty-two multiparous Israeli-Holstein dairy cows averaging 158 DIM (SD = 36) and 621 kg of BW (SD = 52) were housed in covered loose pens with adjacent outside yards that were equipped with a real-time electronic individual feeding system. Each feeding station was equipped with an individual identification system (I.D. tag, SAE Kibutz Afikim, Israel) that allowed each cow to enter a specific feeding station and automatically recorded each meal. After 10 d of adaptation to the feeding stations, cows were divided into 3 treatment groups, each with 14 cows. Cows were stratified randomly within stratum and strata were defined by milk production, DIM, parity, and BW. Dietary treatments were as follows: lactating cow ration formulated to meet NRC (2001) nutrient requirements (1.75 Mcal of NE_L/kg of DM; control); control diet supplemented with 0.825 kg/d per cow of ground corn (2.7% of diet, DM basis; **HG**); or control diet supplemented with 0.300 kg/d per cow (1.5% of diet, DM basis) of calcium salts of fatty acids of palm oil distillate (Adolac, Koffolk, Tel Aviv, Israel; **HF**). The average milk production, DIM, and BW at the beginning of the experiment for control, HG, and HF cows were, respectively, 45.6, 45.7, and 45.0 kg/d (SD = 4.6), 155.7, 158.5, and 161.2 d (SD = 36), and 618.0,