J. Dairy Sci. 98:1–13
http://dx.doi.org/10.3168/jds.2014-9100

Performance, bioenergetic status, and indicators of oxidative stress of environmentally heat-loaded Holstein cows in response to diets inducing milk fat depression

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ABSTRACT

Effects of grain type and dietary oil supplement on production performance, energy balance, metabolic heat production, and markers of liver function of heat-loaded lactating dairy cows were evaluated using 8 multiparous Holstein cows (77.0 d in milk) in a duplicated 4 × 4 Latin square design with a 2 × 2 factorial arrangement of treatments. Experimental diets contained either ground barley or ground corn supplemented with either fish oil or soybean oil at 2% of dietary dry matter. Mean daily maximum temperature, minimum relative humidity, and maximum temperature–humidity index were 35.3°C, 11.3%, and 77.0, respectively. Dietary treatment did not affect rectal temperature (38.9°C), but respiration rate tended to decrease in cows fed fish oil versus soybean oil. Dry matter intake decreased for the fish oil–supplemented diets (21.1 vs. 24.3 kg/d), which was negatively correlated with plasma concentrations of alkaline phosphatase (r = –0.45; n = 32) and malondialdehyde (r = –0.26; n = 32). Actual milk yield (41.9 kg/d) and energy-corrected milk yield (36.6 kg/d) were not affected by grain type, whereas feeding fish oil decreased milk yield as compared with soybean oil (40.4 vs. 43.4 kg/d). Milk fat depression occurred in all dietary treatments, especially when cows were fed fish oil because of the presence of polyunsaturated FA in the diets. *trans*-10 C18:1 was negatively correlated with milk fat yield (r = –0.38; n = 32). Daily milk *cis*-9,*trans*-11 C18:2 secretion was 29.6% less in cows fed barley- versus corn-based diets but 31.8% greater in cows fed fish oil as compared with cows fed soybean oil. Because of a lower dry matter intake, metabolic heat production was decreased in cows fed fish oil relative to cows fed soybean oil. Although feeding fish oil versus soybean oil decreased net energy for both maintenance and lactation, net energy balance remained unchanged across treatments. In vivo plasma lipoperoxidation was greater in cows fed fish oil versus soybean oil, which substantiated increased susceptibility of plasma lipoperoxidation when cows were fed fish oil. Plasma concentration of malondialdehyde was positively correlated with plasma aspartate aminotransferase (r = 0.38; n = 32), which is an indicator of liver function in heat-loaded cows. Results suggest that in heat-loaded cows fed diets supplemented with soybean oil versus fish oil, biosynthesis in the mammary gland was prioritized over anabolism and oxidation in peripheral adipose and muscle tissues regardless of type of grain used.
Key words: grain and oil, milk fat depression, heat load, dairy cow

INTRODUCTION

Heat-stressed dairy cattle are bioenergetically similar to early-lactation cows in that dietary energy may be insufficient to support maximum milk and production of milk components (Moore et al., 2005). Milk yield of heat-stressed dairy cows is usually decreased during the summer (Drackley et al., 2003; Moallem et al., 2010); therefore, increasing performance of cows is of particular interest in many dairy-producing areas of the world. The bioenergetic mechanism by which heat stress affects milk yield and animal health is partially explained by decreased DMI, but also comprises changed endocrine status, decreased rumination and nutrient absorption, and increased maintenance requirements (Moore et al., 2005; Liu et al., 2008; Baumgard and Rhoads, 2012) resulting in a net decrease in nutrient and energy availability for production as well as liver dysfunction and induction of oxidative stress (Ronchi et al., 1999; Bernabucci et al., 2010). Therefore, the decrease in energy intake, resulting in a reduction in energy balance, partially explains why cows lose significant amounts of BW

Received November 13, 2014.
Accepted March 24, 2015.
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when subjected to heat stress (Bernabucci et al., 2010). Nutritional strategies to alleviate this energy deficit traditionally include increasing the energy density of the diet with starchy concentrates or oil supplements (Drackley et al., 2003; Moallem et al., 2010). Decreasing the energy requirement for milk fat synthesis is an alternative tool to improve energy balance during heat stress (Moore et al., 2005). This strategy is particularly relevant because fat is energetically the most expensive component of milk, so that daily milk fat secretion in early lactating cows represents up to 35% of the net energy intake (Bauman and Currie, 1980). The saved energy may be either partitioned into milk and attenuate or eliminate the harmful effect of environmental heat on production or may be stored in body tissues (Drackley et al., 2003; Moore et al., 2005; Moallem et al., 2010).

According to recent experiments, a decrease in DMI just describes approximately 35 to 50% of the decreased milk yield of heat-stressed dairy cows (Bernabucci et al., 2010; Wheelock et al., 2010; Baumgard and Rhoads, 2012). The remainder of heat-induced milk yield losses may be partially attributed to liver dysfunction, which has been suggested earlier (Ronchi et al., 1999; Bernabucci et al., 2010), or changes in postabsorptive metabolism (Wheelock et al., 2010; Baumgard et al., 2011; Baumgard and Rhoads, 2012). Liver dysfunction may be displayed by alterations in responsiveness to nutrient supply or endocrine regulators, e.g., as has been illustrated in the case of growth-hormone responses (Rhoads et al., 2010). These alterations would directly influence the ability of the liver to coordinate whole-body nutrient flux by changing key metabolic pathways such as gluconeogenesis. Accordingly, heat-induced changes in liver gluconeogenic gene expression might be linked to variation in the supply of precursors for the synthesis of milk solids (Rhoads et al., 2011). Therefore, heat-induced decreased milk lactose secretion (the key osmotic regulator of milk yield) may simply reflect changed rates of liver gluconeogenesis, which would finally decrease glucose delivery to the mammary gland and thereby reduce milk yield. In other cases, liver glucose production in heat-stressed cows was similar to that in thermal-neutral cows on a similar plane of nutrition. Nevertheless, heat-stressed cows yielded almost 400 g less glucose per day as compared with pair-fed, thermal-neutral counterparts (Wheelock et al., 2010), suggesting an increased glucose use by extramammary tissues, which might be another key mechanism explaining the reduction in milk yield under heat stress (Wheelock et al., 2010; Baumgard et al., 2011; Baumgard and Rhoads, 2012).

Recent experiments conducted in thermoneutral conditions have confirmed that a more rapidly fermented starch type (wheat or barley grain) versus a slowly fermented starch type (corn grain) caused milk fat depression (**MFD**) in lactating dairy cows, with varying effects on DMI and milk production (Cabrita et al., 2009; Mohammed et al., 2010). Another strategy to reduce milk fat secretion includes supplementation of marine products. Previous research demonstrated that the feeding of fish oil versus extruded soybeans also decreased DMI and milk yield (Whitlock et al., 2002). AbuGhazaleh et al. (2002) showed neither MFD nor difference in DMI and milk yield of cows fed fish oil compared with cows fed extruded soybeans. However, in an experiment by Alizadeh et al. (2012), cows fed 2% fish oil experienced MFD but maintained milk yield although DMI was depressed.

Information is lacking on the effect of type of dietary grain differing in ruminal fermentability in combination with oil supplements on performance and energy-partitioning priorities of heat-stressed cows. We hypothesized that the greater starch digestibility of barley grain versus corn grain in the rumen would induce MFD and improve milk yield if DMI is maintained and if extra energy is not directed to body reserves by greater insulin secretion. Furthermore, we also hypothesized that soybean oil would induce a more modest MFD as compared with fish oil but could enhance milk production if soybean oil better maintains DMI as compared with fish oil. Therefore, the objective of this experiment was to determine the effects of, and interactions between, grain type and oil supplement on the production performance, bioenergetic status, and metabolic heat production (**MHP**). Moreover, given the interaction of heat stress with liver metabolism, markers of liver function were monitored as well as the antioxidant status of heat-stressed Holstein cows.

MATERIALS AND METHODS

Animals, Experimental Design, and Treatments

The Isfahan University of Technology (**IUT**) Laboratory Animal Care Advisory Committee approved all procedures involving animals. The experiment was conducted (June to September 2011) in Lavark at the Farm Animal Research and Teaching Unit of IUT. Experimental details have been presented in a companion manuscript (Kargar et al., 2013) and are summarized in the following. Eight lactating, multiparous Holstein cows (BW = 670.3 ± 45.8; parity = 3.3 ± 1.3; mean ± SD) averaging 77 ± 22.1 DIM were used in a replicated 4 × 4 Latin square design with 25-d periods. Each experimental period consisted of an 18-d diet adaptation period and a 7-d collection period. Cows within a square were assigned randomly to dietary