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Effects of supplemental calcium salts of palm oil and chromium-propionate on insulin sensitivity and productive and reproductive traits of mid- to late-lactating Holstein × Gir dairy cows consuming excessive energy

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ABSTRACT

This experiment compared insulin sensitivity, milk production, and reproductive outcomes in dairy cows consuming excessive energy during mid to late lactation and receiving in a 2 × 2 factorial design (1) concentrate based on ground corn (CRN; n = 20) or including 8% (DM basis) of Ca salts of palm oil (CSPO; n = 20), and (2) supplemented (n = 20) or not (n = 20) with 2.5 g/d of Cr-propionate. During the experiment (d 0–203), 40 multiparous, nonpregnant, lactating 3/4 Holstein × 1/4 Gir cows (initial days in milk = 81 ± 2; mean ± SE) were offered corn silage for ad libitum consumption, and individually received concentrate formulated to allow diets to provide 160% of their daily net energy for lactation requirements. From d −15 to 203, milk production was recorded daily, blood samples collected weekly, and cow body weight (BW) and body condition score (BCS) recorded on d 0 and 203. For dry matter intake evaluation, cows from both treatments were randomly divided in 5 groups of 8 cows each, and allocated to 8 individual feeding stations for 3 d. Intake was evaluated 6 times/group. Glucose tolerance tests (GTT; 0.5 g of glucose/kg of BW) were performed on d −3, 100, and 200. Follicle aspiration for in vitro embryo production was performed via transvaginal ovum pick-up on d −1, 98, and 198. Mean DMI, net energy for lactation intake, as well as BW and BCS change were similar across treatments. On average, cows gained 40 kg of BW and 0.49 BCS during the experiment. Within weekly blood samples, CRN cows had lower serum concentrations of glucose, insulin, fatty acids, and insulin-to-glucose ratio compared with CSPO cows, suggesting increased insulin sensitivity in CRN cows. During the GTT, insulin-sensitivity traits were also greater in CRN versus CSPO cows. Supplemental Cr-propionate resulted in lower serum insulin concentrations and insulin-to-glucose ratio within CRN cows only, indicating that Cr-propionate improved basal insulin sensitivity in CRN but not in CSPO cows. During the GTT, however, Cr-propionate supplementation reduced hyperinsulinemia and insulin-to-glucose ratio across CSPO and CRN cows. Milk production, as well as number of viable oocytes collected and embryos produced within each aspiration, were not affected by treatments. Hence, replacing corn by Ca salts of palm oil in the concentrate did not improve insulin sensitivity in Holstein × Gir dairy cows consuming excessive energy during mid to late lactation, whereas Cr-supplementation was effective in improving basal insulin sensitivity in cows not receiving Ca salts of palm oil.
Key words: chromium, dairy cows, energy intake, fat, insulin sensitivity

INTRODUCTION

Excessive energy intake reduces insulin sensitivity and leads to insulin resistance in nonlactating and lactating Holstein × Gir dairy cows (Leiva et al., 2014, 2015). This syndrome, characterized by persistent hyperglycemia despite increased insulin secretion, has been shown to negatively affect welfare and reproductive responses of dairy cattle, particularly oocyte competence (Adamiak, 2005; Baruselli et al., 2016). Excessive energy intake is common and often inevitable among nonlactating and mid- to late-lactating cows in commercial dairies (Van Saun and Sniffen, 1996); hence, nutritional and management strategies that mitigate insulin resistance are warranted to optimize productivity and welfare of dairy cattle.

Chromium is a critical component of the glucose tolerance factor and facilitates the action of insulin on body cells (Mertz, 1992; Vincent, 2001). Accordingly,

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supplementing Cr-propionate to nonlactating and mid- to late-lactating Holstein × Gir dairy cows prevented the decrease in insulin sensitivity caused by excessive energy intake (Leiva et al., 2014, 2015). Insulin resistance can also be caused by chronic hyperinsulinemia, which downregulates insulin receptors and decreases cellular sensitivity to insulin (Moller and Flier, 1991). Thus, reducing dietary content of insulinogenic ingredients, such as starch, may also mitigate the incidence of this syndrome in cattle. Garnsworthy et al. (2008) reported that reducing starch intake by substituting wheat for Ca salts of palm oil reduced mean plasma insulin concentrations in lactating dairy cows, although the effects of this dietary strategy on insulin-sensitivity traits still needs investigation.

Based on this information, we hypothesized that replacing corn by Ca salts of palm oil in the dietary concentrate mitigates the decline in insulin sensitivity in lactating Holstein × Gir dairy cows consuming excessive energy, whereas Cr-propionate supplementation is an alternative to further alleviate this outcome. Therefore, the current experiment compared insulin-sensitivity traits, milk production, and reproductive outcomes in Holstein × Gir dairy cows consuming excessive energy during mid and late lactation receiving a corn-based concentrate including or not Ca salts of palm oil and supplemented or not with Cr-propionate.

MATERIALS AND METHODS

This experiment was conducted at the São Paulo State University–Lageado Experimental Station, located in Botucatu, São Paulo, Brazil. The animals used were cared for in accordance with acceptable practices and experimental protocols reviewed and approved by the São Paulo State University–Animal Ethics Committee (#17/2015).

Animals and Diets

Forty lactating, multiparous, nonpregnant 3/4 Holstein × 1/4 Gir cows (initial mean ± SE; parity = 2.3 ± 0.12, BW = 590 ± 9.4 kg, BCS = 3.18 ± 0.06, milk yield = 26.9 ± 0.95 kg, and DIM = 81 ± 2) were assigned to this experiment (d 0–203). On d 0, cows were ranked by DIM, milk yield, BW, and BCS (Wildman et al., 1982), and assigned to 2 × 2 factorial arrangement design with treatments of (1) concentrate based only on ground corn (**CRN**; n = 20) or including 8% (DM basis) of Ca salts of palm oil (**CSPO**; EnerFAT Kemin Agrifoods South America, Indaiatuba, São Paulo, Brazil; n = 20), and (2) supplemented (n = 20) or not (n = 20) with 2.5 g/d of Cr-propionate (10 mg of Cr/cow daily; KemTrace 0.4% Cr; Kemin Agrifoods South America). All treatment combinations had equivalent initial average DIM, milk yield, BW, and BCS.

Table 1. Composition and nutritional profile of concentrate based on ground corn (CRN; n = 20) or with the inclusion of Ca salts of palm fatty oil (CSPO; n = 20)

Item	CRN	CSPO
Composition, % (as-fed basis)		
Ground corn	69.0	59.5
Soybean meal	28.0	29.5
Ca salts of palm fatty acids[1]	—	8.0
Mineral mix[2]	3.0	3.0
Nutritional profile (DM basis)		
NDF, %	11.8	11.1
Starch, %	50.2	42.8
Crude fat, %	3.3	10.3
NE_M, Mcal/kg	2.13	2.36
NE_L, Mcal/kg	1.96	2.24
CP, %	20.4	20.3

[1]EnerFAT (Kemin Agrifoods South America, Indaiatuba, São Paulo, Brazil).

[2]Containing 22% Ca, 7.5% P, 6.5% Na, 1.0% K, 3.6% Mg, 2.0% S, 0.003% Co, 0.115% Cu, 0.004% I, 0.220% Mn, 0.003% Se, 0.400% Zn, 400,000 IU/kg of vitamin A, 100,000 IU/kg of vitamin D_3, and 0.150% vitamin E (Milk MAC; M. Cassab Tecnologia Animal, São Paulo, Brazil).

From d −15 to 203, cows were maintained in a single drylot pen with ad libitum access to corn silage, water, and a commercial mineral mix without the inclusion of Cr (described in Table 1). Corn silage was provided in feed bunks that allowed 1.5 m of linear bunk space/cow and offered at daily rates to result in ≥15% (DM basis) of nonconsumed silage. Cows were milked twice daily in a side-by-side milking system (0600 and 1700 h), and individually received their concentrate through self-locking head gates immediately after each milking.

From d −15 to −1 (adaptation period), cows received a concentrate containing (as-fed basis) 40% of soybean meal, 57% of ground corn, and 3.0% of a commercial mineral mix (described in Table 1). From d 0 to 203, cows received concentrate treatments described in Table 1. Concentrate intake was formulated to each individual cow so the diet (concentrate + corn silage) provided 100 (d −15 to −1) or 160% (d 0–203) of their daily NE_L requirements, as previously described and accomplished by Leiva et al. (2015). All dietary treatments were formulated to similarly meet CP, mineral, and vitamin requirements (NRC, 2001). Concentrate intake was adjusted weekly (d −15 to 203) using the Spartan Dairy Ration Evaluator/Balancer (version 3.0; Michigan State University, East Lansing, MI) according to DIM, milk yield, BW, BCS, treatment, and corn silage intake estimated by the software.

Chromium-propionate was offered in the amount recommended by the manufacturer (2.5 g/cow daily of KemTrace; Kemin Agrifoods South America), mixed with 97.5 g of finely ground corn, and top-dressed daily