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Can chromium help insulin sensitivity?

Supplemental chromium increases the sensitivity of body tissues to insulin, which can improve dry matter intake and milk production of transition cows.

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LACTATION performance is dependent on the success of the transition period from three weeks before to three weeks after calving (Drackley, 1999). Much progress has been made with dry cow and fresh cow nutrition and management to reduce metabolic diseases during this time.

On many commercial dairies, the incidence of clinical disease during the transition period is low, but there are still ample opportunities to reduce subclinical issues and improve performance.

Negative energy balance

Most transition cows experience some degree of negative energy balance due to their high energy demands and insufficient dry matter intake.

To meet these needs, body fat reserves are mobilized and converted to non-esterified fatty acids (NEFAs) to be used as an energy source. Blood NEFA concentrations are about 0.2 milliequivalents (mEq) per liter for a dry cow and rise three weeks before calving to more than 0.6 mEq per liter on calving day.

High plasma NEFA levels are typically associated with metabolic problems during the transition period (Dyk et al., 1995; Chandler, 1997).

Ospina et al. (2010) sampled blood from 15 apparently healthy prepartum cows (from 14 to two days prepartum) and 15 apparently healthy postpartum cows (3-14 days postpartum) from 91 Northeast dairies. Blood NEFA and beta-hydroxybutyrate (BHB) levels were correlated with reproduction and productivity.

This work provides targets for optimum milk production, with NEFA concentrations for prepartum cows to be less than 0.33 mEq per liter and for postpartum cows to be less than 0.72 mEq per liter with BHB of less than 10 mg/dL.

Targets for optimum reproduction were determined to require NEFA concentrations of less than 0.27 mEq per liter for prepartum cows and NEFA concentrations of less than 0.72 mEq per liter and BHB of less than 10 mg/dL for postpartum cows.

Insulin sensitivity

Insulin binds to receptors on the body's

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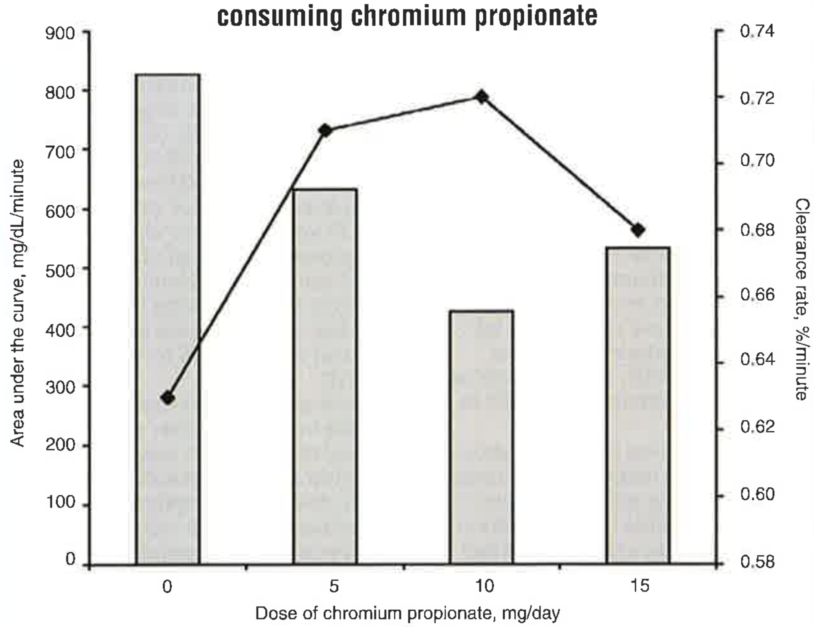
Milk production (kg per day) from cows supplemented with calcium propionate or chromium propionate

	Treatment			Std.	Control vs.	
	Control	Calcium	Chromium	error	Calcium	Chromium
1-35 DIM	40.8	40.7	41.6	0.91	NS	NS
36-56 DIM	47.4	44.7	49.9	0.99	NS	NS
57-90 DIM	45.4	45.8	50.0	1.03	NS	0.13
1-90 DIM	44.2	43.7	46.8	0.87	NS	0.13

Note: NS = not significant. Source: **McNamara and Valdez, 2005.**

Glucose clearance rate and area under the curve in an intravenous glucose tolerance test in Holstein heifers consuming chromium propionate



Note: Bar graphs represent area under the curve (mg/dL/minute); line is clearance rate (%/minute). Average standard error of mean (SEM) for area under the curve was 70.2 mg/dL/minute or 1.2% of the mean; average SEM for clearance rate was 0.0277 %/minute or 4% of the mean. (Reprinted from Sumner et al., 2007.)

cells similarly to a lock and key. Once insulin has "unlocked the door," blood glucose can enter the cell and be used as an energy source to produce adenosine triphosphates or be stored as glycogen.

When a cow is said to have "insulin resistance," the normal amount of insulin fails to unlock the door of cells for glucose entry.

Several weeks before calving, insulin concentrations in the cow's blood begin to decrease, ending up at half the normal levels by calving day (Allen and Bradford, 2009). This increases fat mobilization, resulting in higher plasma NEFA levels. At the same time, insulin sensitivity of the cow's tissues is reduced, further increasing fat mobilization (Sano et al., 1993).

Several weeks after calving, insulin levels and insulin sensitivity continue to be low, causing NEFA levels to remain elevated.

According to the hepatic oxidation theory, the breakdown of NEFAs in the liver reduces feed intake and causes blood glucose levels to remain low (Allen and Bradford, 2009). Without more glucose to stimulate insulin secretion, fat continues to be mobilized.

At the liver, NEFAs are first oxidized and converted to energy and, after reaching a limit, will be fully oxidized into ketones (acetone, acetoacetate and BHB). Some tissues can use ketones for energy to help reduce overall glucose usage, but high levels of blood ketones can cause a cow to reduce intake, likely causing additional body fat mobilization, accumulation of liver fat and further inhibition of gluconeogenesis (Overton and Waldron, 2004; Piepenbrink and Overton, 2003).

Calving stress and the risk of infection are high during the transition period. When immune cells are activated, often due to mammary or uterine infections that occur during the transition period, inflammation occurs (Bradford, 2009).

In addition, dietary changes and ruminal acidosis challenges during the transition period can increase blood endotoxins (Khafipour et al., 2009), which will also elicit an inflammation response. Cytokines produced as a response to inflammation generate more body fat mobilization and reduce dry matter intake (Kushibiki, 2001; 2003) as well as reduce insulin sensitivity (Kushibiki et al., 2001).

Cows with excessive body condition are more likely to have metabolic problems during the transition period. Tissues of cows with excessive body condition have reduced insulin sensitivity (Allen and Bradford, 2009). Adipose tissue can generate inflammatory cytokines like tumor necrosis factor-alpha (Hotamisligil et al., 1993), and obesity can result in chronic, low-grade inflammation that increases those levels in the blood without a cow having an infection (Bradford, 2009). Furthermore, it has been found that more lipid peroxides are produced when liver NEFA levels rise, especially in transition cows with excessive body condition.

These lipid peroxides produce an inflammatory response (Bradford, 2009), which reduces immune function and changes nutrient metabolism to increase body fat mobilization and reduce insulin sensitivity.

Feeding strategies that can reduce excessive body reserve mobilization, increase dry matter intake and positively affect insulin sensitivity and gluconeogenesis will control NEFA and ketone levels.

Allen and Bradford (2009) suggested that it is preferable to increase insulin sensitivity rather than increase blood insulin levels in the transition cow since the latter will also reduce the amount of glucose made in the liver. Chromium increases insulin sensitivity of fat tissue and has been shown to reduce plasma NEFA concentrations (Allen and Bradford, 2009).

Chromium

Chromium has been identified as an essential trace element for people and laboratory animals (National Research Council, 1997; Anderson, 1992). Chromium is primarily involved in enhancing glucose uptake by cells (Davis and Vincent, 1997).

Research in people and rodents suggests that stress increases the need for chromium (Spears, 2010). Stress increases cortisol secretion, which reduces insulin sensitivity of cells (Bunting, 1999; Moonsie-Shageer and Mowat, 1993).

Chromium propionate is a bioactive molecular complex mega-cation marketed by Kemin AgriFoods North America Inc. as part of the KemTRACE product line.

McNamara and Valdez (2005) supplemented either calcium propionate (0.125 kg per day) or chromium propionate (10 mg of chromium per day) to 12 multiparous Holstein cows from 21 days before calving to 35 days after calving. All cows were switched to the control diet from 36 to 90 days in milk (DIM).

Both products increased dry matter intake before and after calving — 11% precalving and 13% postcalving with calcium propionate and 7% and 16% with chromium propionate. Cows supplemented with calcium propionate or chromium propionate had greater adipose lipogenesis (fat accumulation) from 14 to 56 DIM, while rates of lipolysis (fat breakdown) were generally 10-15% lower.

Milk fat yields were 92-95% lower in both groups of supplemented cows than in control cows. This is notable since roughly 40% of milk fat produced during the first week of lactation comes from NEFA (Bell, 1995).

Both the cows fed chromium propionate and those fed calcium propionate consumed more dry matter from one to 90 DIM than those fed the control diet (23.1 and 22.7 kg per day versus 20.0 kg per day for controls). However, only those cows supplemented with chromium propionate produced more milk (Table) from one to 90 DIM (46.8 kg per day for chromium propionate versus 43.7 kg per day for calcium propionate and 44.2 kg per day for controls).

It was concluded that chromium decreased the rate of lipolysis, likely by increasing insulin sensitivity and enhancing glucose transport, thus facilitating higher dry matter intake and milk production.

Following this study, the goal of McNamara's research group was to more fully understand the mechanism of action of chromium in the cow. They looked at the effect of different levels of chromium propionate — 0, 5, 10 or 15 mg of chromium per day — on an intravenous glucose tolerance test in growing Holstein heifers (Sumner et al., 2007).

Glucose solution was infused intravenously, and then concentrations of glucose and insulin in the blood were measured regularly until they returned to original baseline levels. Chromium raised serum glucose and reduced serum insulin and NEFA concentrations. Chromium increased glucose clearance rates (Figure). More glucose went from the blood into the tissues with supplemental chromium.

In a similar study, Spears (2010) supplemented 0, 3, 6 or 9 mg of chromium per day (0, 0.47, 0.94 and 1.42 mg of supplemented chromium per kilogram of diet dry matter) to growing heifers. Chromium reduced serum insulin and insulin:glucose ratios for 15 minutes after glucose infusion, indicating greater insulin sensitivity.

Intake, milk production

Spears et al. (2010) reviewed the literature and concluded that most studies with supplemental chromium significantly increased or tended to increase milk production and intake.

There are additional studies that supplemented chromium in an organic form other than chromium propionate. Researchers at the University of Wisconsin (Hayirli et al., 2001) supplemented cows with 0, 0.03, 0.06 and 0.12 mg of chromium as chromium methionine per kilogram of metabolic bodyweight (approximately 0, 0.28, 0.49 and 1.03 mg/kg of dry matter intake) for 28 days before and after calving.

Insulin sensitivity was increased before calving, and glucose tolerance was improved after calving. There was a linear improvement in prepartum intake with chromium supplementation. However, supplementation had a quadratic effect on intake and milk production after calving, with those supplemented with 0.49 mg/kg being highest.

Using a chromium amino acid chelate, Yang et al. (1996) improved intake and production in primiparous cows — but not multiparous cows — when 0.5 mg of chromium per kilogram of dry matter intake was fed from six weeks prepartum to 16 weeks postpartum.

Some researchers have attempted to determine if diet affects the response of cows to supplemental chromium. Smith et al. (2005) fed a high-starch diet (27.7% of dry matter) or low-starch diet (18% of dry matter) with non-forage fiber supplemented with 0, 0.03 or 0.06 mg of chromium per kilogram of metabolic bodyweight (approximately 0, 0.20 and 0.40 mg/kg prepartum dry matter intake) as chromium-L-methionine during the prepartum period until 28 DIM.

They concluded that diet had no effect on response to chromium supplementation. Postpartum 3.5% fat-corrected milk yield and dry matter intake were increased with chromium supplementation. However, in this study, chromium supplementation had no effect on postpartum plasma NEFA or BHB concentrations (Smith et al., 2008).

When Sadri et al. (2009) supplemented chromium-L-methionine at 0 or 0.08 mg of chromium per kilogram of metabolic bodyweight (approximately 0.87 mg/kg of prepartum dry matter intake) from 21 days prepartum to 28 days postpartum, chromium increased prepartum and postpartum dry matter intake in cows fed a barley-based diet but did not affect intake of cows fed a corn-based diet. Overall, chromium supplementation tended to increase milk yield.

A study was conducted in New Zealand in which 232 grazing dairy cows were supplemented with 0 or 6.25 mg of chromium per day in the form of chromium methionine six weeks prepartum in a grain supplement and 21 weeks postpartum in an oral drench once per day (Bryan et al., 2004). Supplemental chromium decreased serum NEFA concentrations, especially one week before calving, and tended to improve pregnancy rates, but no difference in milk response was observed.

Significance

Dairy producers and their nutritionists know that a great transition period from 21 days before calving to 21 days after calving equates to great lactation for a cow (Drackley, 1999).

Although progress has been made in improving diets and management of transition cows, it remains a challenge to quickly increase dry matter intake to provide the nutrients needed for milk production.

Supplemental chromium increases the sensitivity of body tissues to insulin, enhancing glucose uptake. Chromium reduces mobilization of body fat, consequently lowering blood NEFA levels. By these mechanisms, supplemental chromium can improve dry matter intake and milk production in the early-lactation cow.

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