Connecting the Dots for a Sustainable Future Part 2: Chromium Supplementation: Dairy Cows

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Abstract

In this series of white papers, we review the state-of-the-art of selected aspects of the animal nutrition industry using all available public domain sources. Our objective is to distill and crystallize the problems facing the industry in a deep but non-comprehensive exploration of the main components of the industry. We seek to connect the issues from various perspectives and present a holistic view of how and where various industry and market actors can contribute to solutions. This series contains a number of discussion topics, including nutrient management, animal health and welfare, and the global aspects of the animal nutrition industry. In this paper, selected nutritional and animal health strategies associated with chromium supplementation as a way to help optimize the lifetime productive health of animals are reviewed. This body of evidence connects the dots to nutritional strategies that facilitated chromium supplementation in dairy cows for improved health and production.

Introduction

Why another Chromium Review

Many reviews and meta-analyses of chromium supplementation strategies have been published (Malik, Raboisson, Zhang, & Sun, 2023) (Malik, *et al.*, 2024) (National Research Council, 1997) but none more foundational than "Review: History of chromium in animal nutrition in the United States" by Jerry Spears. (Spears, 2025) We invite you to read full text here (https://doi.org/10.15232/aas.2024-02653). This particular paper serves as a definitive synthesis of a large number of researcher's findings of chromium supplementation in U.S. animal nutrition. Spears anchored mechanistic insights with outcome-based performance data across species. It bridged foundational biochemistry with applied production metrics, offering a rare convergence of metabolic, reproductive, and immunological evidence under a regulatory lens. Spears connected the dots from the glucose tolerance factor in yeast to modern feed additive approvals. He showed how trace mineral research evolved into regulatory policy and market impact, with clear species-specific outcomes and mechanistic depth. His review validated the commercial utility of chromium propionate with peer-reviewed outcomes in swine, cattle, poultry, and horses.

Moreover, Spears effectively consolidated over six decades of research, focusing on chromium sources such chromium propionate (CrProp) and chromium picolinate (CrPic) and their performance, safety, and regulatory status in U.S. animal nutrition. The key mechanistic takeaways from his review were the enhancement of insulin sensitivity through activation of AMP-adenosine monophosphate kinase (AMPK), which in turn upregulates glucose transporter proteins in adipose tissue (GLUT4) and reduces membrane cholesterol (i.e. decreases membrane rigidity). In turn, it was

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shown that CrProp and CrPic improved glucose clearance, reduced insulin:glucose ratios, and modulated lipid metabolism across species. Spears made the important point, among many, that chromium bioavailability from natural feedstuffs is probably low, and contamination during feed and sample processing can skew analytical values. Moreover, the great uncertainty associated with basal chromium doesn't make supplementation necessary. In fact, we don't know how much chromium animals are eating from the basal diet which adds a level of risk that a supplementation strategy can mitigate. No known clinical signs of chromium deficiency have ever been reported. However, a supplementation strategy that reduces this risk can be quite valuable.

A Chemistry and Biochemistry Perspective

The intention of this paper is to not duplicate Spear's review. The scope of this paper does overlap in some respects as it is the same essential element under discussion. However, this particular paper reviews over 50 years of selected extant research and connects the dots using a chemistry/biochemistry lens to chromium's mechanistic and commercial impacts in the dairy industry. Chromium supplementation strategies were shown to facilitate health improvements and production increases with several modes of action in the body. The present analysis concentrates specifically on the molecular and biochemical underpinnings of these effects.

Chromium's Eras

From Glucose Tolerance Factor to Modern Chromium Sources

Chromium is an integral component of the glucose tolerance factor (GTF) proven to be essential while the exact chemical structure remains unknown. (Schwarz & Mertz, 1959) Several models for the GTF are widely used but a oligopeptide known as chromodulin is thought to be the closest structure (Yamamoto, Wada, & Ono, 1987) (Vincent, 1989) which is a complex of Cr^{3+} and a combination of cysteine, glycine, glutamate and aspartate. In the early days of chromium supplementation research, chromium sources were a brewer's yeast extract or amino acid complexed chromium. Eventually, organometallic complexed chromium (Cr^{3+}), particularly as CrProp, became the main commercial chromium source for a multi-domain performance enhancer in livestock nutrition.

Early Evidence for Immune Support

In the mid 90's, Burton *et al.* were among the first to observe the immunomodulatory effects of supplemental chromium from yeast and/or organic complex. (Burton J. , 1995) (Burton, Mallard, & Mowat, 1993) (J.L. Burton, 1994) (Burton, *et al.*, 1995) (Mallard, *et al.*, 1999). Supplementation with chromium was found to enhance cell-mediated immunity (CMI), as evidenced by elevated mitogen-stimulated blastogenic responses in peripheral blood mononuclear cells of supplemented cows. Furthermore, chromium supplementation has been associated with augmented humoral immune (HI) responses, including increased anti-ovalbumin antibody production. At the same time, serum cortisol concentrations were significantly reduced in stressed calves receiving chromium supplementation. This finding is of particular relevance given that glucocorticoids are thought to impair neutrophil function in cattle. Chromium's effects on lymphocytes (especially T-cells) are probably more important than its effect on neutrophils. Cortisol may actually have little effect on neutrophil function, but it reduces the rate of neutrophil migration. Collectively, these observations supported the hypothesis that chromium may influence both adaptive and innate immune responses, particularly under conditions of physiological or environmental stress.

Chromium and Transition Cow Performance

By the turn of the century, chromium supplementation emerged as a promising nutritional strategy to mitigate metabolic stress and enhance productive performance in dairy cattle, particularly during the transition period and under heat stress conditions. During this time multiple studies reported improved dry matter intake (DMI) in chromium-supplemented cows, particularly during early lactation. Soltan found that cows receiving 6 mg/day of organic chromium under heat stress conditions had a 10% increase in DMI across the first 12 weeks postpartum, with significant improvements at weeks 8 and 12 ($p < 0.05$) (Soltan, 2010). Moreover, it was reported that chromium supplementation increased milk yield by 6.7%, 12.3%, and 16.5% at 4, 8, and 12 weeks postpartum, respectively. The overall improvement across the trial was 12.1%. Milk composition (fat, protein, lactose) remained unaffected, indicating that chromium primarily influences yield rather than nutrient density. Finally, Soltan observed a significant reduction in serum NEFA concentrations at 1 week prepartum and at 2 and 4 weeks postpartum in chromium-supplemented cows. Cortisol levels decreased while insulin concentrations increased throughout the experimental period, suggesting improved metabolic resilience under heat stress. It should be pointed out that later meta-analyses confirmed that chromium supplementation usually reduces NEFA concentrations during the transition period, although effects on insulin and cortisol were not statistically significant across all studies (Malik, *et al.*, 2024). Smith *et al.* confirmed that chromium methionine (Cr-Met) supplementation (approximately 0, 4, and 8 mg of chromium/day) linearly increased postpartum DMI and milk yield, independent of prepartum carbohydrate source (Smith, Waldron, Drackley, Socha, & Overton, 2005) The increase in yield was attributed to enhanced feed intake and improved metabolic efficiency. In 2008, Smith *et al.* investigated hepatic metabolism using [1-14C] propionate conversion assays (Smith, *et al.*, 2008). Cr-Met supplementation enhanced gluconeogenesis and oxidation for cows fed low non-fiber carbohydrates (NFC) diets but reduced these pathways in cows fed high NFC diets. This interaction suggests that chromium's metabolic effects can be modulated by dietary carbohydrate source and hepatic substrate availability.

The Modern Chromium Era

By the time Spears wrote his foundational review a number of studies were published from 2011 through 2025. A conceptual shift in AMPK activation and signaling pathway through chromium's role in AMPK activation and cholesterol modulation provided a novel mechanistic explanation for its observed benefits in transition cows (Habegger, Hoffman, Ridenour, Brozinick, & Elmendorf, 2012). This is discussed in more detail below. With respect to energy metabolism during the transition period, it was reported that chromium supplementation reduced NEFA and cortisol, while increasing insulin and glucose postpartum. Lower NEFA indicates an improved negative energy balance (NEB). Lower cortisol is most likely the cause of improved energy balance (i.e. less negative) mostly by increasing DMI as high cortisol levels have been associated with lower feed intake. Effects are strongest in the periparturient window, when cows are mostly likely to be in NEB (Kafilzadeh, Shabankareh, & Targhibi, 2012) (Yasui, *et al.*, 2014). During this time, it was also shown that chromium enhanced immune function in both cows and calves, particularly under stress (Gultepe, Uyarlar , & Bayram, 2018). Also during this period, it became clear that chromium in the form of CrProp consistently reduced rectal temperature and respiratory rate, across multiple trials. This indicated improved thermoregulation under heat stress (Wang, et al., 2023) (Zhang , *et al.*, 2025) (Stojković, *et al.*, 2025). CrProp helped cows cope with heat load, likely via improved glucose metabolism and antioxidant defense. This form of chromium also enhanced feed intake and fiber utilization especially at an optimized inclusion rate of 4–8 mg/d. DMI and digestibles had a quadratic relationship in that DMI and NDF digest were better at 4 and 8 but not at 12. Also they found no difference in DM digest which is unusual if NDF digest increases. (Malik, *et al.*, 2024) (Stojković, et al., 2025; Wang, et al., 2023). CrProp reliably boosted milk yield, especially under stress; composition effects were modest but yields of solids (kg/d) rose. (Wang, *et al.*, 2023) (Sultana, *et al.*, 2022) (Ren, *et al.*, 2025). Also, it was reported that CrProp strengthened oxidative defense and immunity, particularly when paired with antioxidants or choline (Wang, *et al.*, 2023) (Sultana, *et al.*, 2022) (Ren, *et al.*, 2025). Wang *et al*. reported no major effect on total VFA, but acetate proportion rose with CrProp (Wang, *et al.*, 2023). Taken together, these studies established chromium propionate as a validated nutritional strategy that integrates metabolic and immunomodulation, to sustain performance in heat-stressed and transition dairy cows. This overview of the chromium eras illustrates the breadth of chromium research in dairy cows and sets the stage for a closer examination of the chemistry and biochemical mechanisms underlying its actions in the body.

Modes of Action

Chromium potentiates a number of interrelated biochemical and physiological pathways, including insulin signaling, AMPK activation, membrane cholesterol modulation, lipid biosynthesis regulation, cytoskeletal trafficking as well as immunomodulatory and antioxidant defenses. Its modes of action are multi-layered and scientifically compelling.

Improving Insulin Sensitivity

The most well-known mode of action relates to increasing insulin sensitivity. Chromium, via chromodulin also known as low molecular weight chromium, binds to the activated insulin receptor and enhances its tyrosine kinase activity, increasing the rate and extent of phosphorylation. By amplifying receptor phosphorylation, chromium indirectly increases insulin receptor synthase (IRS-1) phosphorylation which essentially creates docking sites for phosphatidylinositol 3-kinase (PI3K), thereby propagating the insulin signal. This in turn activates the molecules that relieve the inhibition of GLUT4 vesicle trafficking. Translocation and fusing of GLUT4 to the cell membrane occurs leading to increased intracellular glucose availability for glycolysis or glycogen and lipid synthesis. Chromium's unique role in this mode is to boost the efficiency of crucial phosphorylation reactions at the insulin receptor, thereby making the whole energy metabolism cascade more responsive.

Activating the Cell's Energy Sensor (AMPK)

Another direct mode of action for chromium is potentiating the AMPK signaling pathway in the energy metabolism system. Chromium directly affects the energy generation cycle, also known as the "energy sensor trigger" colloquially, through the adenosine triphosphate (ATP) synthase (i.e. the enzyme responsible for producing ATP). Chromium can interact with the β-subunit of mitochondrial ATP synthase by replacing magnesium ions (Mg^{2+}) at the catalytic site of the β-subunit, which is where ADP (adenosine diphosphate) and inorganic phosphate (P_i) are normally bound and converted into ATP. By partially interfering with β-subunit activity, chromium reduces ATP synthase efficiency. This leads to a slight drop in ATP production and a rise in the (AMP+ADP):ATP ratio inside the cell. In other words, this interaction partially suppresses ATP synthase activity, which triggers the downstream reactions (Gencoglu, Orhan, & Sahin, 2024) (Wang, *et al.*, 2023). A higher AMP+ADP:ATP ratio is the classic trigger for AMPK activation. Once AMP levels rise, AMPK is phosphorylated and activated by upstream kinases like liver kinase B1 (LKB1) essentially turning on the cell demand for fat and sugar while turning off processes for making cholesterol, fat or storing sugar.

Membrane Cholesterol and GLUT4 Trafficking

An important conceptual shift, whereby AMPK was shown to enhance insulin-stimulated GLUT4 regulation via lowering membrane cholesterol, was reported by Habegger *et al.* (Habegger, Hoffman, Ridenour, Brozinick, & Elmendorf, 2012) (Hoffman, *et al.*, 2014). Pharmacological AMPK activators 5-Aminoimidazole-4-carboxamide ribonucleoside and 2,4-dinitrophenol, which acts like AMP and shifts the AMP/ATP ratio respectively, increased GLUT4 presence at the plasma membrane in muscle cells. This effect occurred both in the absence and presence of insulin, showing AMPK can enhance both basal and insulin-stimulated glucose uptake. AMPK activation reduced plasma membrane cholesterol by ~20–25%. Lower cholesterol improved cortical F-actin (filamentous actin) which is the polymerized form of actin that makes up the cortical cytoskeleton under the plasma membrane and provides tracks and structural support for GLUT4 vesicle docking and fusion. This is structure, which is essential for GLUT4 vesicle trafficking. This was validated by replenishing cholesterol blocked the AMPK-mediated enhancement of insulin action which proved that cholesterol lowering was the key mechanism. Moreover, independent from proximal insulin signaling, AMPK activation did effect did not involve changes in insulin receptor, IRS-1, or Akt. Insulin resistance or insulin insensitivity isn't just about receptor/kinase defects discussed above. It can also stem from biophysical changes in the plasma membrane (i.e. cholesterol overload leading to rigid membranes and then impaired GLUT4 trafficking). AMPK provides a lipid-centric rescue mechanism where the cholesterol synthesis enzyme (3-Hydroxy-3-methylglutaryl-CoA reductase or HMGR) is inhibited, lowering cholesterol and restoring GLUT4 function. Chromium's role on this front is the same, instead of acting like AMP or drastically shifting the AMP/ATP ratio, it suppresses ATP production at ATP synthase so that these structural modifications to the mitochondrial membrane support efficient glucose transport.

Potential Links to Growth and Nutrient Partitioning

As discussed above, in the early days of chromium supplementation strategy significant average daily gains in feedlot cattle were observed (J.L. Burton, 1994). To be fair, other researchers have observed no response (e.g. Trojan *et al.* 2023; Smock *et al.* 2020). It is possible that chromium's multilayered mode of actions (insulin potentiation + AMPK activation etc.) intersects with the mechanistic target of rapamycin pathway or mTOR. The mTOR pathway is a serine/threonine kinase enzyme which is responsible signaling BUILD, STORE or CONSERVE in the metabolic sense.

Chromium's role (via insulin potentiation and AMPK modulation) makes it a potential indirect influencer of mTOR activity in livestock. This would be an interesting area for future research.

Chromium and Immune Function

Chromium's role in immunomodulation has taken a back seat to the AMPK signaling pathway effects. However, it remains an extremely interesting aspect of chromium supplementation strategies. Mallard *et al.* reviewed the immunomodulatory effects of chromium in ruminants in 1999 (Mallard, *et al.*, 1999). Focusing on immunomodulation, Mallard *et al.* suggested that chromium's immunological impact is most evident during periods of stress, such as feedlot transition and periparturient phases. In feeder calves, chromium supplementation reduced morbidity by 32 % and improved weight gain and feed efficiency. In dairy cows, chromium enhanced colostral immunoglobulin concentrations, particularly immunoglobulin G1 (IgG1), which is critical for neonatal immunity. Antibody responses to specific antigens, including bovine viral diarrhea and infectious bovine rhinotracheitis, were variably augmented which indicated antigen-dependent modulation. Chromium also stimulated lymphocyte proliferation *in vitro*, both with and without mitogenic stimulation, and enhanced the proliferative effects of insulin and cortisol. However, it did not amplify responses to somatotropin or immunoglobin F1 (IGF1), which suggested selective hormonal synergy. Cytokine profiling revealed that chromium supplementation reduced the expression and activity of interleukin-2 (IL-2), interferon-gamma, and tumor necrosis factor-alpha (TNF-α) in stimulated lymphocytes. These findings supported a model in which chromium exerts immunomodulatory effects through cytokine regulation, potentially influencing both adaptive and innate immune pathways. Additionally, chromium demonstrated selective inhibition of bacterial growth *in vitro*, with species-specific effects on E*scherichia coli*, S*taphylococcus aureus*, and S*treptococcus bovis* (Burton, Mallard, & Mowat, 1993) (Turcatto, *et al.*, 2025). This raises the possibility of chromium-mediated modulation of rumen microflora, which could indirectly affect nutrient absorption and overall health. Markers of the acute phase response, such as serum haptoglobin and total hemolytic complement activity, were modestly affected by chromium supplementation. In transported beef calves, haptoglobin levels were significantly reduced, aligning with lower morbidity rates. However, chromium had minimal impact on complement activity and neutrophil phagocytosis, which suggested that its primary immunological influence lies within the adaptive arm rather than innate defense mechanisms. Yuan *et al.* studied immunomodulation effects of chromium propionate (CrProp) and rumen-protected lysine and methionine (RPLM), or their combination on metabolic parameters, neutrophil immune function, and adipocyte size in lactating Holstein cows (~38 days in milk or mid-lactation) (Yuan, *et al., 2014)*. Their findings indicated that while metabolic outcomes were minimally altered, CrProp exerted notable immunomodulatory effects, with parity-dependent differences in neutrophil cytokine responses. These results underscore the nuanced role of trace minerals and amino acid supplementation in shaping immune function during peak lactation. Horst *et al.* studied the physiological and immunological consequences of dietary chromium (Cr) supplementation in lactating Holstein cows subjected to acute immune activation via lipopolysaccharide (LPS) challenge. (Horst, *et al.*, 2018). They found that while chromium supplementation attenuates insulin surges and enhances neutrophil recovery, it does not significantly alter the immune system's glucose demand during acute activation. The study confirmed that immune activation in dairy cows imposed a substantial glucose burden that chromium supplementation does not alleviate. However, chromium's ability to temper insulin responses and accelerate neutrophil recovery suggests a supportive role in immune regulation. These effects may be beneficial in managing inflammation-related production losses, although chromium does not appear to preserve milk yield during acute stress.

Meta-analytical evidence further refines these observations. Malik *et al.* (Malik, et al., 2024) reported that chromium supplementation significantly reduced circulating non-esterified fatty acids (NEFA) in transition cows, a biomarker of lipid mobilization and metabolic stress. Lower NEFA concentrations prepartum are associated with reduced risk of periparturient disorders such as ketosis and fatty liver (Drackley, 1999). Interestingly, chromium supplementation did not significantly alter cortisol concentrations across studies, although some individual trials have reported reductions including Kafilzadeh *et al.*, Mogahdam *et al.* and Burton *et al.* (Kafilzadeh, Shabankareh, & Targhibi, 2012) (Moghadam, Razavi, Hajimohammadi, Nazifi, & Rowshan-Ghasrodashti, 2023) (Burton, *et al.*, 1995). Malik *et al.* suggested that chromium's stress-mitigating effects may be mediated more through metabolic stabilization than direct suppression of the hypothalamic-pituitary-adrenal axis. Chromium's immunomodulatory effects appear to be context-dependent, with variability observed across antigen types, supplementation forms, and physiological states.

Chromium and Oxidative Stress

Closely tied to immunomodulation, chromium's modes of action also include antioxidant effects. Moghadam *et al.* studied the effect of chromium and probiotics on biomarkers associated with immune function. (Moghadam, Razavi, Hajimohammadi, Nazifi, & Rowshan-Ghasrodashti, 2023) They found that that calves in the chromium supplementation group exhibited significantly lower levels of stress-related markers such as cortisol, interleukin-1β, serum amyloid A, adenosine deaminase, and ferritin. Additionally, malondialdehyde levels, which indicate oxidative stress, were slightly lower in the supplemented group. The total antioxidant capacity (TAC) was notably lower in control group calves, suggesting a diminished ability to counteract oxidative damage. Interestingly, the group receiving both probiotics and chromium showed the lowest mean globulin concentration, which may reflect a nuanced interaction between the supplements and immune protein levels. Overall, the data suggest that dietary supplementation with probiotics and chromium can positively influence immune responses and reduce stress indicators in dairy calves during weaning. Shan *et al.* studied a chromium supplementation strategy for mid lactation dairy cows exposed to heat stress (temp humidity index consistently above 72). (Shan, *et al*., 2020) Chromium increased the activity of key antioxidant enzymes, glutathione peroxidase and superoxide dismutase, as well as total antioxidant capacity. At the same time, levels of malondialdehyde decreased. Chromium supplementation did not affect levels pro-inflammatory protein, IL-6 and anti-inflammatory IL-10, as well as IgA, or IgM. However, it significantly reduced concentrations of pro-inflammatory cytokines IL-2, IL-4, and IL-1β, while increasing levels of IgG, an important antibody for immune defense. Interestingly enough, although chromium did not significantly alter overall milk yield or composition, it did lead to a linear increase in dry matter intake and milk lactose content. These observations suggested that chromium may help modulate the immune response, reduce inflammation and enhance immunity. Horst *et al.* investigated whether supplementing lactating Holstein cows with chromium propionate could influence how their immune systems use glucose and respond to an inflammatory challenge. Activated immune cells are highly insulin sensitive and require large amounts of glucose, the researchers hypothesized that improving insulin sensitivity with chromium might modulate immune dynamics after exposure to bacterial endotoxin (lipopolysaccharide, LPS). (Horst, *et al*., 2018) In summary, supplementing lactating cows with chromium propionate during an acute endotoxin challenge reduced their insulin surge and accelerated neutrophil recovery but did not change how much glucose their immune systems consumed. These findings point to chromium's potential for fine-tuning inflammatory and metabolic responses in dairy cows, though its impact on whole-body energy balance during immune stress appears limited. Chromium's modes of action encompass insulin potentiation, AMPK activation, membrane and cytoskeletal regulation, mTOR signaling, and immunomodulatory and antioxidant effects. Together these mechanisms optimize energy metabolism, strengthen stress resilience, and support immune function in ruminants, with clear implications for improved health, reduced stress, and greater productivity which we discuss below.

Health/Stress Relief/Production

Why Stress Matters in Dairy Cows

The modes of action discussed above showed how chromium supplementation strategies could provide benefits for animal health by facilitating metabolic support, immune competence, antioxidant defense, and resilience under stress. For the dairy cow, stress is a pervasive challenge in modern livestock production, particularly in high-yielding dairy cattle that undergo repeated cycles of pregnancy, parturition, and lactation. Stressors such as heat and nutritional imbalances, exacerbate physiological strain, leading to impaired immune function, reduced feed intake, and compromised production performance. Nutritional strategies have been widely investigated as a means of mitigating these stress-induced losses, chromium emerged as a promising supplement. Its role became particularly critical during stress, when chromium excretion increases and tissue reserves may be depleted.

Heat Stress and Thermotolerance

Heat stress is one of the most detrimental environmental challenges to dairy production, reducing dry matter intake (DMI), milk yield, and reproductive efficiency. Chromium supplementation has been shown to mitigate these effects. In Holstein cows exposed to high temperature-humidity indices with no thermoneutral control group, chromium yeast supplementation reduced rectal temperature and respiration rate, increased DMI, and improved milk lactose content, with the most effective dose observed at 0.36 mg/kg dry matter (Shan, *et al.*, 2020). Similarly, chromium propionate supplementation during summer heat stress reduced milk yield losses, stabilized somatic cell counts, and improved economic returns, with higher doses (8 mg/cow/day) providing the greatest benefit (Zhang , *et al.*, 2025). Earlier work in Saudi Arabia demonstrated that chromium supplementation at 6 mg/head/day increased milk yield by over 12% during the first twelve weeks of lactation under severe heat stress, while also improving DMI and reducing negative energy balance (Soltan, 2010). These reports indicated that chromium supplementation enhances thermotolerance and sustains production during periods of environmental extremes However, these experiments did not have a climate cooled control group for comparison.

Reproductive Performance Under Stress

Reproductive efficiency is highly sensitive to stress, particularly heat stress, which impairs follicular development, reduces conception rates, and delays return to estrus. Based on limited data, chromium supplementation has been associated with improved reproductive outcomes, including reduced postpartum anestrus and higher pregnancy rates in the early breeding period (Soltan, 2010). The proposed mechanisms include reduced NEFA mobilization, improved insulin sensitivity, and enhanced immune function, all of which contribute to improved ovarian activity and uterine health. Cumulative evidence from controlled trials, mechanistic studies, and field observations supports the conclusion that chromium supplementation provides multifaceted benefits to dairy cattle under stress and perhaps under no stress as well. Chromium supplementation represents a valuable nutritional strategy to mitigate the adverse effects of stress in dairy cattle. By enhancing insulin action, stabilizing energy metabolism, and supporting immune and antioxidant defenses, chromium improves both health and productivity during critical periods such as the periparturient transition and summer heat stress. The consistent improvements in DMI, milk yield, immune competence, and reproductive performance across diverse studies underscore its potential as a management tool to sustain profitability and animal welfare in intensive dairy systems.

Prepartum vs Postpartum vs Mid Lactation

The Transition Period: A Unique Stress Event

The body of literature reviewed to this point indicates that the beneficial effects of chromium supplementation seem to be most pronounced under conditions of physiological or environmental stress. Among the various stressors encountered by dairy cattle, the periparturient period represents a particularly critical window, as calving imposes a profound homeorhetic challenge characterized by dramatic shifts in nutrient partitioning, endocrine regulation, and immune function. This form of stress, which is intrinsic to the biological transition into lactation, differs fundamentally from abiotic stressors such as heat load or nutritional restriction, as it reflects the coordinated reprioritization of metabolic resources to support milk synthesis and postpartum recovery. By distinguishing homeorhetic stress associated with calving from external abiotic stressors, it becomes evident that chromium's role as a modulator of insulin sensitivity and immune competence may be especially valuable in mitigating the metabolic strain and immunosuppression that accompany the onset of lactation. This distinction underscores the importance of evaluating chromium not only as a general nutritional supplement but as a targeted intervention for enhancing resilience during the biologically programmed stress of the transition period. Chromium supplementation in dairy cattle has been investigated extensively in both the prepartum and postpartum periods, with evidence suggesting that its physiological effects are stage-dependent and influenced by the unique metabolic and immunological challenges surrounding calving.

Benefits of Prepartum Supplementation

During the prepartum transition period, dairy cows experienced a marked decline in insulin sensitivity, increased mobilization of NEFAs, and a heightened risk of immunosuppression. Several studies have demonstrated that chromium, particularly in the form of chromium propionate or chromium-methionine, can mitigate these challenges by enhancing insulin sensitivity and improving glucose clearance. For example, Sano *et al.* and Hayirli *et al.* reported separately that chromium supplementation reduced circulating insulin concentrations while improving glucose tolerance in periparturient cows, thereby alleviating the insulin resistance that typically characterizes late gestation (Sano, Terashima, & Shiga, 1993) (Hayirli, A, Bremmer, Bertics, Socha, & Grummer, 2001). McNamara and Valdez further observed that chromium propionate supplementation beginning three weeks before calving increased dry matter intake and milk yield in early lactation, while simultaneously stimulating adipose tissue lipogenesis, suggesting that chromium may facilitate more efficient nutrient partitioning during the transition period (McNamara & Valdez, 2005). In addition to these metabolic effects, chromium has been shown to enhance mitogen-induced lymphocyte proliferation function and reduce the degree of periparturient immunosuppression, thereby lowering the risk of infectious diseases such as mastitis and metritis (Burton, Mallard, & Mowat, 1993) (Burton, *et al.*, 1995). These findings indicate that prepartum chromium supplementation can play a critical role in priming both metabolic and immune systems for the demands of lactation.

Benefits of Postpartum Supplementation

On the other hand, the postpartum period presents a different physiological context in which chromium supplementation appears to exert more variable effects on baseline metabolism but demonstrates clear benefits under conditions of stress. Yuan *et al.* reported that chromium propionate supplementation in peak-lactation Holstein cows did not significantly alter plasma glucose, NEFA, or glucagon concentrations, nor did it affect adipocyte size. However, chromium did potentially enhance neutrophil responsiveness to lipopolysaccharide stimulation, as evidenced by increased TNFα transcript abundance, which suggested that chromium may act as an immunomodulatory nutrient during lactation. Horst *et al.* extended this understanding by demonstrating that chromium supplementation reduced the magnitude of the insulin surge following an intravenous endotoxin challenge and increased circulating neutrophil counts, although it did not alter the overall glucose requirement of the immune system during acute activation (Horst, *et al.*, 2018). These findings suggest that chromium may improve the efficiency of immune responses without exacerbating the already high energetic costs of immunoactivities in lactating cows.

Chromium in Mid-Lactation Cows

Stojković *et al.* reported that mid-lactation Simmental cows supplemented with chromium propionate during periods of elevated temperature-humidity index exhibited increased dry matter intake, higher milk yield, and improved yields of milk fat, protein, lactose, and total solids (Stojković, *et al.*, 2025). Supplementation also increased blood glucose concentrations while reducing blood urea nitrogen and beta-hydroxybutyrate, indicating improved glucose and nitrogen metabolism as well as enhanced energy balance under heat stress conditions. The reported evidence suggested that the timing of chromium supplementation was critical in determining its physiological impact. Prepartum supplementation appears to be most effective in reducing insulin resistance, limiting excessive lipid mobilization, and enhancing immune competence during the transition period. Postpartum supplementation, while less consistent in altering baseline metabolic parameters, demonstrates clear benefits under conditions of physiological or environmental stress, including immune activation and heat stress, where it supports feed intake, milk yield, and immune resilience.

Chromium Supplement Combinations

Chromium + Antioxidants

The 2022 study by Sultana and colleagues explored the combined and individual effects of chromium propionate, vitamin E, and selenium supplementation on Holstein Friesian cows exposed to heat stress during early lactation (Sultana, *et al.*, 2022). The environmental conditions during the study were characterized by temperature-humidity index values ranging from 75 in the morning to 80 in the afternoon, confirming that the animals were under mild to moderate heat stress. The researchers observed that supplementation improved feed intake, with the most pronounced increase in dry matter intake occurring in the group that received the combination of chromium, vitamin E, and selenium. Milk yield was higher in all supplemented groups compared with the control, with the greatest improvement again seen in the combination group. Hematological parameters such as hemoglobin, packed cell volume, and leukocyte counts did not differ significantly among treatments, but values tended to be higher in supplemented cows, suggesting improved resilience to oxidative stress as one might expect with such combinations. Biochemical and hormonal analyses revealed that chromium supplementation, particularly when combined with vitamin E and selenium, reduced circulating cortisol concentrations, indicating a mitigation of stress responses. Antioxidant enzyme activity, especially glutathione peroxidase, was lower in supplemented groups, reflecting reduced oxidative load. Other parameters, including thyroid hormones, liver enzymes, cholesterol, triglycerides, glucose, urea, and creatinine, remained unaffected by supplementation, suggesting that the benefits were specific to stress modulation, and thermoregulation rather than broad systemic changes. The authors concluded that chromium propionate at 0.5 mg/kg dry matter, either alone or in combination with vitamin E at 500 IU per day and selenium at 0.3 mg/kg dry matter, alleviates the negative effects of thermal stress in lactating Holstein Friesian cows. The combination of chromium with antioxidant vitamins and minerals was particularly effective, leading to improved feed intake, higher milk yield, reduced cortisol, and better physiological stability under heat stress conditions.

Chromium + Supplemental Fat

A 2025 study by Parales-Giron *et al.* investigated how supplemental palmitic acid and chromium propionate influence production responses in multiparous Holstein cows during the immediate postpartum period (Parales-Girón, dos Santos Neto, Contreras, & Lock, 2025). Early lactation is characterized by a sharp increase in nutrient demand and a negative energy balance, which forces cows to mobilize body reserves and often predisposes them to metabolic stress. Palmitic acid has been widely used to increase dietary energy density and drive milk fat synthesis. The results showed that palmitic acid and chromium exerted distinct but complementary effects. Palmitic acid supplementation increased yields of milk fat, energy-corrected milk, and fat-corrected milk, though it slightly reduced milk protein concentration. Chromium supplementation increased overall milk yield as well as milk protein and lactose yields. Importantly, chromium supplementation also had a carryover effect, with higher milk, protein, and lactose yields persisting even after the treatment diet was withdrawn. Interactions between the two nutrients were observed in the first weeks postpartum where combined supplementation enhanced milk fat yield and energy-corrected milk compared with the control. Across the duration of the experiment, significant dietary interactions were observed between chromium (Cr) supplementation and fat inclusion. Independent effects were evident, in that fat elicited responses in the absence of Cr, and Cr elicited responses in the absence of fat. When combined, treatments influenced a broader range of variables (e.g., both fat and protein metabolism); however, within any single variable, the combined treatment did not confer additive or synergistic benefits beyond those achieved by either treatment alone. Plasma metabolites reflected these changes, with palmitic acid tending to increase NEFA and insulin, while chromium moderated some of these responses and influenced beta-hydroxybutyrate dynamics. In other words, these results indicate that chromium supplementation did not mitigate the elevation in NEFA associated with dietary fat. While fat supplementation alone increased NEFA and Cr supplementation alone reduced NEFA, the combination of Cr with fat still resulted in elevated NEFA concentrations, comparable to the fat treatment. Dry matter intake, body weight, and body condition score were not significantly affected by treatments. If the observed responses were attributable to nutrient partitioning, one would expect energy to be directed toward milk synthesis at the expense of body reserves. However, this was not the case. Cows receiving supplemental fat consumed greater amounts of energy (though not more dry matter) than control cows, suggesting that the primary effect of fat supplementation was simply increased energy intake. In contrast, chromium supplementation appeared to enhance metabolic efficiency, as evidenced by greater milk yield without additional body weight loss relative to controls. The study concluded that palmitic acid drives energy partitioning toward milk fat, while chromium enhanced overall milk volume and component synthesis. Chromium supplementation in the immediate postpartum period provided lasting benefits beyond the supplementation window. Together, these findings suggested that strategic use of palmitic acid and chromium propionate can improve both the efficiency and resilience of dairy cows in early lactation.

Chromium + Choline and Amino Acides

Ren *et al.* examined the combined/combined replacement supplementation of rumen-protected choline and chromium propionate as a novel feeding strategy to improve health and productivity in transition dairy cows (Ren, *et al.*, 2025). Rumen-protected choline has been shown to improve hepatic metabolism, immune function, and milk production, but its high cost may limit widespread use. The authors hypothesized that a combination replacement for choline alone of these two supplements could provide synergistic benefits while reducing the cost barrier associated with choline alone. They did not include a low dose choline treatment so they cannot say that Cr can replace 30 g of choline. It might be possible that 30g of choline may have done the same as 60 g of choline. The results demonstrated that both rumen-protected choline alone and the combination of choline with chromium propionate significantly increased dry matter intake, rumination time, milk yield, and milk quality compared with the control. Improvements in immune function were evident through higher serum and milk immunoglobulin G and M concentrations, while antioxidant status was enhanced by increased superoxide dismutase and catalase activities and reduced malondialdehyde levels. Importantly, the incidence of common transition disorders including ketosis, ruminal acidosis, milk fever, and mastitis was reduced in all supplemented groups relative to the control. The combined supplementation of rumen-protected choline and chromium propionate produced effects comparable to choline alone, indicating that chromium propionate may partially substitute for higher doses of choline while maintaining health and production benefits. Yuan *et al.* also looked at CrProp, and rumen protected amino acids (Yuan, *et al.*, 2014).

Supplementation of lactating Holstein cows with chromium propionate (CrProp; 8 mg/d of Cr) and rumen-protected lysine and methionine (RPLM; 10 g/d Lys and 5 g/d Met) over a 35-day feeding period during peak lactation was evaluated for its effects on intermediary metabolism, immune cell function, and adipose tissue morphology. The results of this controlled trial demonstrated that neither CrProp nor RPLM supplementation produced significant alterations in circulating glucose concentrations, plasma NEFA, or adipocyte cross-sectional area, indicating that the direct metabolic impact of these interventions on energy balance and lipid mobilization was limited under the conditions of the study. In contrast, supplementation with RPLM was associated with a measurable increase in circulating plasma insulin concentrations, suggesting that provision of these first-limiting amino acids may act as a physiological stimulus for pancreatic insulin secretion in the lactating cow. This finding aligns with prior evidence that amino acid availability can influence endocrine responses and nutrient partitioning, even in the absence of overt changes in glucose or lipid metabolism. These findings underscored the complexity of nutrient–immune interactions and suggested that physiological stage and parity may critically influence the immunological outcomes of targeted nutritional interventions.

The Bigger Picture: Chromium as Part of a Nutritional Strategy

Taken together, these studies demonstrate that chromium propionate not only improves lactation performance directly but also interacts synergistically with other targeted nutrients, such as calcium propionate, antioxidant vitamins and minerals, palmitic acid, and rumen-protected choline or amino acid. While its effectiveness is further shaped by the basal diet, since carbohydrate source and energy density determine how chromium influences glucose metabolism, rumen fermentation, and immune function (Smith, Waldron, Drackley, Socha, & Overton, 2005) (Smith, *et al.*, 2008). This positions chromium propionate as a cornerstone of integrated nutritional strategies to sustain health, productivity, and resilience in heat-stressed and early-lactation dairy cows.

Chemlock Mission

The mission of Chemlock Nutrition is to use its deep knowledge and understanding of chemistry to bring multi-generational products to the dairy industry that are inherently useful and are born out of connecting the dots in the 21st century. Connecting the dots for chromium supplementation strategies in dairy cows yields a multi-layered mechanism, with insulin sensitization as the central hub and complementary effects on energy partitioning, AMPK activation, immune modulation, and reproduction. The result is improved milk yield, better energy balance, enhanced stress resilience, and stronger reproductive outcomes. A robust body of peer-reviewed evidence, chromium propionate represents a scientifically validated, commercially differentiated solution for modern dairy production in the 21st century. Chemlock Nutrition supplies Nutrilock® Chromium for supplemental CrProp strategies as well as CalBal®[Pro] for your transition cow calcium management strategy with prepartum chromium for effective, healthy and productive transitions.

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