SUPPLEMENTAL ORGANIC CHROMIUM FOR BEEF AND DAIRY CATTLE

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Introduction

Chromium was identified 40 years ago to be an essential mineral for laboratory animals. Chromium has been deemed an essential nutrient based on experimentally induced deficiencies in laboratory animals and clinically observed changes in the health of humans. The most commonly observed symptoms of chromium deficiency in humans include impaired glucose tolerance, insulin resistance and elevations in serum insulin, cholesterol and total triglycerides, the long-term effects of which increase risk of maturity-onset diabetes, cardiovascular diseases and hypertension. In laboratory animals, in addition to the above-listed manifestations, there are also decreased longevity, decreased reproductive functions, impaired growth and other adverse effects. All of these clinical symptoms can be reduced or possibly even prevented by organic chromium supplementation to the diet.

Organic Chromium: the Nutrient of the '90's

During the last 30 years, numerous research studies, many reviews (Anderson, 1993; Mertz, 1993) and a few books (Kamen, 1990; Passwater, 1993) have been published on several aspects of chromium in human nutrition and health. Consequently, chromium is generally well recognized by authoritative human nutritionists. Nevertheless, it is only in the last 3 or 4 years that chromium has received much promotion, marketing and education, even in the human field. Thus, chromium supplements are now readily available over-the-counter for humans in most countries worldwide, and have become a major commodity in the health food and body building industries.

It took until the 1990's for animal nutritionists to recognize the potential for supplementation with organic chromium. However, a few animal producers were aware of some practical benefits of supplemental chromium as long ago as the early 1970's, capitalizing on clues in the human literature. The initial scientific research papers suggesting great need and scope for supplemental organic chromium in ruminants and swine were published in 1992 (Chang and Mowat) and early 1993 (Page et al.), respectively. Until recently, the feeling amongst animal nutritionists was that adequate chromium supposedly existed in common diets; therefore, it was okay to forget about this mineral.

Many questions have been answered in the past 3 or 4 years, but even more remain. The story of chromium in animal nutrition has just nicely begun. With improved understanding comes increased ability to predict practical applications and enhance responses.

A major question is why the delay in registering quality chromium products for widespread animal feed use? No doubt a component is the need for further education.

"Knowledge is the beginning of change"

Trivalent Chromium

Trivalent chromium is the nutrient form and also naturally occurring form of chromium. It is very non-toxic in inorganic compounds and most organic complexes. On the other hand, chromium is used extensively in the chemical and metallurgy industries for stainless steel, chrome plating, detergents, leather tanning, etc. In these processes, chromium may be converted to the hexavalent form which is toxic and a carcinogen, and thus, an environmental concern. <u>This poses a major communication or perception problem for the registration and use of chromium as a nutrient</u>. Suppliers of quality chromium products can (*must*) ensure that no hexavalent chromium is present. Increased chromium in excreta from animals supplemented with chromium would be minute relative to chromium in effluent from domestic and industrial uses. Moreover, chromium excreta from animals would be in the non-toxic trivalent form whereas hexavalent chromium may be present in effluent from industrial usage.

Function and Benefits of Organic Form

The predominant physiological role of chromium is an integral component of biologically active chromium or the Glucose Tolerance Factor (GTF), which potentiates action of the vital hormone insulin. Insulin will not function efficiently with diets deficient in chromium. Chromium is also required for normal functioning of the β cells in the pancreas, preventing hyperresponsiveness of insulin secretion to glucose stimulation (Striffler et al., 1995)

"The story of chromium in many ways is the story of insulin"

Chromium in plants is organically complexed with concentrations approximating 30 to 50 ppb reported in very limited studies. Higher concentrations of total chromium in diets would probably be due to contamination (soil, dust, stainless steel) in feedstuffs, particularly in forages, or high contamination in mineral supplements. Analyses of total chromium is of limited value and, in any event, requires a high degree of specialization.

Inorganic chromium is very poorly absorbed. Also, inorganic chromium must be converted to an organic complex, such as GTF, to enable the physiological functioning of chromium. Conversion of inorganic chromium (eg. chromium chloride) in the liver or kidneys to the bioactive form may be slow, or even entirely lacking, in certain individuals particularly aged.

Supplying chromium in the preformed organic complex form increases absorption, reduces variability in responses and negates the need for adequate dietary precursors (eg. nicotinic acid, certain amino acids) to aid inorganic chromium absorption and conversion to the bioactive form. Natural or synthetic organic chromium sources currently available in most human and certain animal markets include high chromium yeast, chromium picolinate, chromium nicotinate, chelated chromium and chromium proteinates.

A Broad Range of Benefits

If a deficiency in chromium exists, then insulin action will adversely be affected. In other words, where chromium is deficient, insulin action is impaired to the point that detrimental alterations in carbohydrate, amino acid and lipid metabolism are seen. Since this vital hormone affects so many functions, a broad range of signs of chromium deficiency (Table 1) would be expected.

A major problem in the awareness, recognition, and probably registration of chromium as a nutrient is the lack of any specific deficiency symptoms. Moreover, the chromium status of an animal is not easily determined. Blood chromium concentrations are of no value. However, these problems are not unique to chromium.

"The deficiency that costs a producer the most is the unknown deficiency"

Michael White

Numerous factors affect the bioavailable chromium input to an animal as well as the depletion of body stores of chromium, hence the chromium requirement of animals (Table 2). A key to whether many diets provide adequate bioavailable chromium is stress. Numerous studies with humans and mice have indicated that various stressors (high sugar diets, infection, physical trauma, acute exercise) increase urinary excretion, hence requirement for chromium. During the general response to any stress, blood glucose and hence insulin levels are increased along with subsequent mobilization of necessary chromium from body stores. Once chromium is summoned, it cannot be reused and is rapidly excreted in the urine.

Applications for Feeder Cattle

Receiving Diets

Supplemental organic chromium can increase rate of gain anywhere from 0 to 30% depending upon level of stress and/or disease challenge. In five years of studies at the University of Guelph with stressed newly arrived feeder calves, organic chromium (chromium yeast or chelated chromium) increased 21-28 day weight gain overall by 21% (Mowat, 1996), with the greatest response (173%) occurring with

Table 1. Signs of Chromium Deficiency in Humans and Livestock.

Function	Animals
Impaired glucose tolerance	Human, rat, mouse, squirrel monkey, guinea pig, cattle, pig
Hyperinsulinemia, insulin resistance	Human, rat, pig, cattle
β-cell hypersecretion of insulin	Rat
Glycosuria	Human, rat
Hypoglycaemia, hyperglycaemia	Human, cattle
Decreased cAMP-dependent phosphoesterase activity	Rat
Impaired growth and/or feed efficiency	Human, rat, mouse, turkey, pig, cattle, fish, guinea pig
Sugar-induced hypertension (or elevated systolic blood pressure)	Rat, dogs, monkey, human
Elevated serum cholesterol and/or triglycerides	Human, rat, mouse, cattle, pig, lamb
Elevated blood cortisol	Human, cattle, guinea pig, horse, lamb
Elevated blood lactate	Exercised horse
Increased incidence of aortic plaques	Rabbit, rat, mouse
Neuropathy and encephalopathy	Human
Corneal lesions	Rat, squirrel, monkey
Ocular eye pressure	Human
Decreased fertility and sperm count	Rat, pig
Decreased longevity	Rat, mouse
Decreased insulin binding and insulin receptor number	Human
Decreased lean body mass	Human, pig, rat, broiler chick
Elevated percent body fat	Human, pig, broiler chick
Humeral immune response	Cattle, pig
Cell-mediated immune response	Cattle
Impaired vaccine response	Cattle
Elevated inflammatory response	Cattle
Morbidity, mortality	Cattle, rat, mouse
Impaired milk production	Cattle
Impaired feed intake	Pig
Subclinical ketosis	Cattle
Increased variability (glucose, insulin and glucagon kinetics, growth, feed intake)	Cattle, human, pig

Source: Adapted from Anderson (1994) and Mowat (1994).

bottom-gaining third (Figure 1). Increased uniformity in performance with supplemental chromium has also been observed in starter pigs (fewer runts). Supplemental chromium may only be needed by a portion of a population of animals even under stress conditions, those animals more prone or susceptible to stress.

The fact that chromium is essential for growth has been proven in several species. However, chromium does not actually increase rate of gain, rather it prevents the depression in rate of gain which often occurs under stressful or other conditions leading to chromium deficiency (an important distinction).

Probably the biggest benefit of supplemental chromium for stressed feeder or veal calves is the potentially large reduction in morbidity or sickness due to bovine respiratory disease, still the major disease in many feedlots. Summarizing our results with stressed feeder calves given supplemental chromium from 1989 to 1993, morbidity was reduced by an average of 32% (Figure 1). Reduced relapses of bovine respiratory disease also occurred. Chromium has recently been shown to enhance aspects of the immune system including response to certain vaccines. Chromium appears to be a nutrient whose requirement increases during both phases or components of the acute immune response.

To be fully effective, supplementation at an adequate level must begin early in the disease challenge or stress period and be readily consumed (in a palatable supplement) by calves. A level of 2-3 mg/head/day of supplemental actual chromium should suffice for 250 kg calves. The effectiveness of preconditioning programs would be enhanced with increased attention to micronutrients including chromium.

Supplemental chromium reduces need for antibiotics, both preventative and therapeutic. Reducing antibiotics would aid public perception. Moreover, for certain niche markets, chromium could be promoted for "organic beef" or "organic pork". In our initial studies with chromium yeast (Chang and Mowat, 1992), improvements in weight gain during the first 28 days after arrival were comparable (30%) between supplemental chromium and a long-acting injectable antibiotic. In fact, with steers not treated with preventative or therapeutic antibiotics, chromium yeast increased rate of gain by 52%. On the contrary, no supplemental chromium may be required with high use of antibiotics. Antibiotics may reduce certain stress symptoms, possibly reducing urinary chromium losses and preventing chromium deficiency.

Preslaughter Diets

The quality of the carcass and the meat which is ultimately produced is influenced by the type of management (and nutrition) an animal receives during the period immediately prior to slaughter. This period combines a number of stresses including extra handling associated with identification, weighing and sorting, mixing with strange animals, introduction to unfamiliar surroundings, transportation and the movement of animals to the slaughter location. Typical marketing procedures are known to contribute to increased frequencies of dark-cutting or dark, firm and dry (DFD) beef (lamb and pork). Problems incurred during preslaughter may be further exacerbated with entire males or bulls. Problems during this period can also cause decreases in the carcass yield (*or shrink*), additional carcass damage due to fighting and be detrimental to animal welfare.

Table 2. Factors Influencing Chromium Requirement.

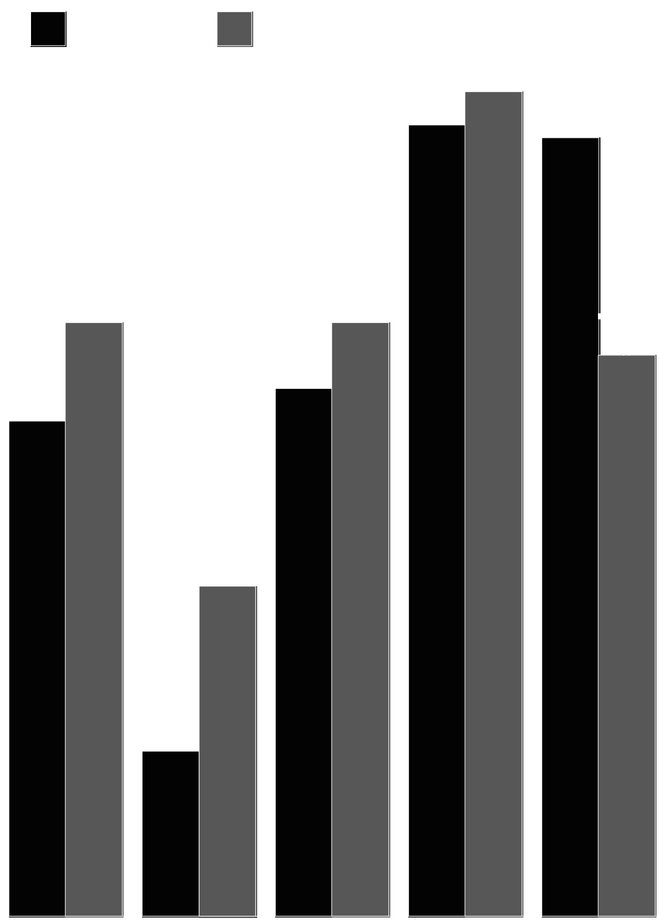
Input of Bioavailable Chromium

- Low dry matter intake
- Low level of feeds rich in bioavailable chromium
- High level of chromium-deficient feeds
- High level of feed grown on soils low in available chromium
- High level of interfering minerals, iron and zinc
- Low level and type (and rumen microbial synthesis) of amino acids
- Low level (and rumen and intestinal microbial synthesis) of niacin
- High level of antacids or intestinal buffers
- Low level of ascorbic acid (human, guinea pig)
- Aging

Output or Depletion of Chromium

- High intake of chromium-robbing diets (eg. high simple sugars or lactose, high propionate, insulin-producing, high NPN
- Bovine somatotropin
- Heat stress
- Market-transit stress
- Pregnancy
- Lactation
- Acute exercise
- Acute hemorrhage
- Physical trauma
- Acute bacterial or viral infections (disease challenge, no or low level antibiotic)
- Obesity
- Other stresses

Figure 1. Increased Initial Gain and Consistency and Reduced Bovine Respiratory Disease with Newly Arrived Feeder Calves Fed Supplemental Chromium.



SOURCE: 1989-1993, UNIVERSITY OF GUELPH. TOTAL CALVES = 393; CONTROL = 159; SUPPLEMENTAL CHROMIUM = 234.

DFD beef is a persistent quality defect characterized by an ultimate pH value in excess of 6.0, dry firm sticky lean-cut surface, and a dark red to almost black lean colour. It has been estimated that DFD costs the beef industry in the U.S. alone approximately $132.5 million, or approximately $5.00 for every steer and heifer slaughtered (Apple et al., 1995). Transport exhaustion, hunger, fear, climatic stress or aggressive behaviour with mixing unfamiliar animals causes depletion of muscle glycogen and thus limits the amount of lactate formed postmortem. In beef, heat stress often creates a seasonal rise in incidence of dark cutting. Young bulls have the worst reputation for dark cutting. The slaughter of heifers in estrus also increases the incidence of DFD.

Supplemental chromium is an anti-stress nutrient since it frequently decreases serum cortisol in chromium-deficient diets in stressed calves (Moonsie-Shageer and Mowat, 1993) and several other species. In addition, supplemental chromium can also increase storage of sugar energy as glycogen in muscles. Thus, less DFD should occur with supplemental chromium.

In addition, losses in carcass weight or shrink represent a further significant economic loss. Shrink losses can take a big bite out of profit prospects. Beef cattle lose weight rapidly in the period following their removal from feed at the farm to the point of slaughter. These live weight losses are also linked with losses in carcass weight. In one study, in the first 24 hours of fasting in steers, loss in carcass weight was 8.5 kg on a 500 kg animal (Jones et al., 1992). Ease of handling and proper management are important. Supplemental chromium should benefit due to reduced cortisol production.

Stress alters behaviour. Chromium-fed animals appear quieter or calmer. Enhanced insulin action with supplemental chromium prevented sugar-induced hypertension or elevated blood pressure in rats (Preuss et al., 1995). The role of proper nutrition, including chromium, in benefitting animal welfare is not fully appreciated. Animal welfare is a major society issue. <u>However, further research or field monitoring is necessary to validate these postulated effects of chromium on carcass weight shrink and meat quality</u>.

Apart from microbial spoilage, lipid oxidation is generally accepted as the primary process by which quality loss or shelf life of muscle foods occurs. Directly affected are many quality characteristics such as rancid flavour, colour, odour, texture, nutritive value and safety of the food. The antioxidant defense system can be weakened by dietary deficiencies (eg. vitamin E, selenium). The role and extent of oxidation of muscle foods are also likely to be influenced by preslaughter stress.

Chromium may have an antioxidant role, possibly also benefitting meat quality. A protective effect of chromium against lipid peroxidation in rats and mice has been suggested (Tezuka et al., 1991) along with protecting ascorbate (vitamin C) from oxidative destruction in guinea pigs (Seaborn et al., 1994). Furthermore, interest in the possible toxicological effects of cholesterol oxidation products has increased in a variety of processed foods, including meat (Buckley et al, 1995). Supplemental chromium has decreased circulating blood levels of cholesterol in humans, laboratory animals and farm animals fed chromium-deficient diets. Cholesterol also serves as a precursor for cortisol synthesis.

How long and at what level supplemental organic chromium should be fed to market cattle before slaughter to fully replenish chromium stores and muscle glycogen, and reduce cortisol production, are questions. Of course, the correct answers would be influenced by level of dietary, pathogenic and environmental stresses. A supplemental level of 200-300 ppb of actual chromium for 3 weeks preslaughter would be a suggestion.

Growing and Finishing Diets

This is the third priority for supplemental chromium for cattle feeders. Dietary supplementation may not be universally warranted during the full growing and finishing periods. However, stress levels are higher in certain feedlots, locations, diets and times of year. Attention to details is what profitable feeding is all about.

Our data suggest that chromium requirements for growth are less than for certain other functions (cortisol regulation, enhanced immunity). Whether supplemental chromium increases carcass leanness is less clear in beef cattle than pigs (or humans).

Supplemental organic chromium may be needed or economically beneficial in the following circumstances:

a) *During heat stress periods*. Supplemental organic chromium has often reduced blood concentrations of the stress hormone, cortisol, in beef cattle. Moreover, supplemental organic chromium has decreased body temperature by 0.5^{o}C with newly arrived calves (Moonsie-Shageer and Mowat, 1993) when temperature of both sick and healthy calves normally rises for a week or so, possibly explaining the slightly increased dry matter intake.

b) *With poor producers more than top-flight producers*. Poorly managed units display more pathogenic, environmental and even nutritional stress. But not as good records are kept and it is more difficult to gauge responses. Yet, we often measure response or obtain our data from better producers or at research stations.

c) *In borderline or lower protein diets*. Excess of certain amino acids can aid absorption and bioactivity of dietary inorganic chromium and amount of precursors (niacin, picolinate) synthesized for bioactivity. In addition to possibly reducing protein input costs, reduction of nitrogen disposal from animal production units is a major concern in many countries or areas.

d) *In backgrounding programs fed high levels of forage silages*. Silage, particularly legume silages, contain excess NPN or soluble nitrogen. This nutritional imbalance is a stress. Glucose-insulin metabolism is known to increase (Fernandez et al., 1988); hence, need for chromium. Moreover, such diets are often deficient in true protein. If not adequately supplemented with rumen escape protein, utilization of dietary inorganic chromium may be impaired.

e) *In low effective fiber diets*. Diets producing high rumen propionate increase blood glucose and insulin, therefore mobilization of chromium from body stores and probably increased urinary chromium excretion. Many factors increasing need for effective fiber (eg. extent of dry or wet processing of grain) should increase chromium requirements. Thus, a portion of the need for effective fibre may, in fact, be needed for organic chromium. Chromium may reduce blood lactate and incidence of acidosis. Conversely, acidosis should increase the need for supplemental chromium.

Applications for Dairy Cows

With the ever increasing intensity of farming and increased milk production, today's dairy cows are experiencing considerable pressure. Several stressors affecting dairy cows can be listed (Table 3).

Table 3. Stressors for Dairy Cows.

- Late pregnancy
- Calving
- Early lactation
- High genetic production
- Bovine somatotropin
- High body condition score
- Infection (mastitis)
- High energy diet
- Other nutritional
- Heat and humidity
- Social interaction
- Environmental

The transition period of late gestation through early lactation is a particularly crucial time for high producing dairy cows. There are about 30 days which have the greatest influence on the entire lactation, 21 days prior to 14 days postpartum. During this time, cows are under great physical, nutritional, psychosocial and metabolic stresses which are reflected in altered hormone profiles and increased disease or disorder susceptibility. Typical high yielding dairy cows are in a negative energy balance during the first weeks after calving. During this time, animals require a large amount and rapid supply of glucose for milk lactose synthesis which results in lower plasma glucose and insulin compared with later in lactation. The ability of insulin to control glucose utilization and partitioning determines milk production, fertility and health status of cows.

It stands to reason that the need for chromium should increase during this critical period. In humans, pregnancy has been shown to predispose chromium deficiency due to placental transport and increased urinary losses (Anderson, 1994). Moreover, lactating women have greater urinary chromium losses plus losses in milk.

<u>First Parity Cows Deficient in Chromium</u>

No test is presently available to specifically diagnose chromium status. However, a method that has been commonly used to evaluate deficiency of chromium in human nutrition and glucose metabolism in animals is the glucose tolerance test.

In our glucose tolerance tests conducted 2 weeks prepartum, first parity cows appeared to be particularly deficient in chromium as shown by markedly decreased plasma insulin, insulin to glucose ratio, triglyceride and chromium with chromium supplementation (Subiyatno et al., 1996). While blood glucose disappearance was not affected, much less insulin was needed to get the job done. Little, if any, effect on these parameters occurred during late pregnancy with multiparous cows. This confirmed previous studies which suggested that primiparous cows were more insulin resistant than multiparous cows during late pregnancy (McClary et al., 1988). These data demonstrate chromium's remarkable ability to stimulate insulin action.

Supplemental organic chromium increased milk yield by 11% during the first 14 weeks of lactation with first parity cows (Figure 2) combining two trials (Yang et al., 1996). The greatest difference tended to occur during the first 8 weeks of lactation. Since peak milk yield was increased, chromium should have a carry-over effect on milk production during later lactation. Recently, cows fed chromium picolinate had higher DM intake and milk production compared to control cows (Besong et al., 1996). No effects on milk production or composition with multiparous cows were obtained in our studies. However, a reduction in metabolic disorders may occur in aged cows fed supplemental chromium. Despite the increased milk production observed in first parity cows, no adverse effects on reproduction were clearly obtained.

First parity cows may be more stressed than mature cows; nutritionally, psychologically and physiologically. When group housed, younger animals have to compete for available bunk space with older larger animals. First parity animals are attempting to adapt to new phenomena of pregnancy and lactation, new social interaction and often new surroundings or environment. In addition, first parity animals need to direct some nutrients for growth in order to achieve mature size. Finally, first parity cows appeared to be beginning lactation already depleted in chromium stores. However, supplemental chromium may only be required for first parity cows during the heavy stress period of late gestation and early lactation. Moreover, as dry matter intake increases to a maximum at 10-12 weeks postpartum, chromium intake accordingly increases. Also, adaptive mechanisms may eventually lead in first parity cows to decreased urinary losses, increased absorption, and increased concentration of body chromium stores or redistribution of chromium in specific tissues as shown with trained athletes (Anderson, 1994).

The critical transition period is the time "to pay more to make more", with supplemental chromium or other needed quality ingredients. It is usually advantageous to separate first parity cows or heifers from older cows. Greater attention can be given to ensure proper development and growth of heifers as well as ease social order concerns. Supplemental chromium might be readily incorporated for the heifer group which appears to have first priority for any added chromium.

Chromium supplementation tended to increase DM intake in first parity cows during the first 4-6 weeks postpartum. Reduced variability in DM intake also occurred. Reduced variability (or increased consistency) with supplemental chromium has also been observed for rate of gain with newly arrived feeder calves, glucose-insulin-glucagon kinetics in early lactating dairy cows, and glucose-insulin kinetics in swine. Similarly, human studies have shown that in low-chromium diets, supplemental chromium increased blood glucose with hypoglycaemic subjects and decreased blood glucose with hyperglycaemic subjects. This reduced variability indicates that in a population of animals, certain individuals are deficient in chromium whereas others may obtain adequate chromium and precursors necessary for bioactivity from the diet.

In our glucose tolerance tests conducted 2 weeks postpartum during negative energy balance, supplemental chromium appeared to decrease insulin sensitivity with first parity cows (Subiyatno et al., 1996). This apparent increase in insulin resistance is opposite to effects of supplemental chromium normally experienced, such as during prepartum in first parity cows. The increased milk production with added chromium could be explained by this increased insulin resistance, probably due to hormonal manipulations. A marked increase occurred in maternal as well as fetal plasma concentrations of IGF-1 in pregnant gilts periodically injected with chelated chromium (Okere and Hacker, 1995). If supplemental chromium increases plasma IGF-1, it may cause the suggested increased insulin resistance noted during early lactation. IGF-1 can bind to insulin receptors in peripheral tissues without necessarily producing its biological effects. Mechanisms might be similar to those proposed for bST action. However, more refined or authoritative metabolism techniques are needed to verify the proposed insulin resistance and clarify hormonal manipulations with supplemental chromium during early lactation.

Reduced Age-Related Metabolic Disorders

Metabolic disorders are attracting increasing attention in all farm animals. In dairy cows, most metabolic disorders occur at or shortly after parturition, and represent a failure of the cow to adjust to the rapid onset and stress of high milk production. Incidence of many metabolic disorders increases with parity or age. Feeding and handling to minimize ketosis, fatty liver formation, hypoglycaemia and other metabolic disorders are critical to cow health, productivity, reproduction and longevity. Specific rations and strategies must be used including possible supplementation with organic chromium. Prevention is much more profitable than treatment of individual cases once they occur.

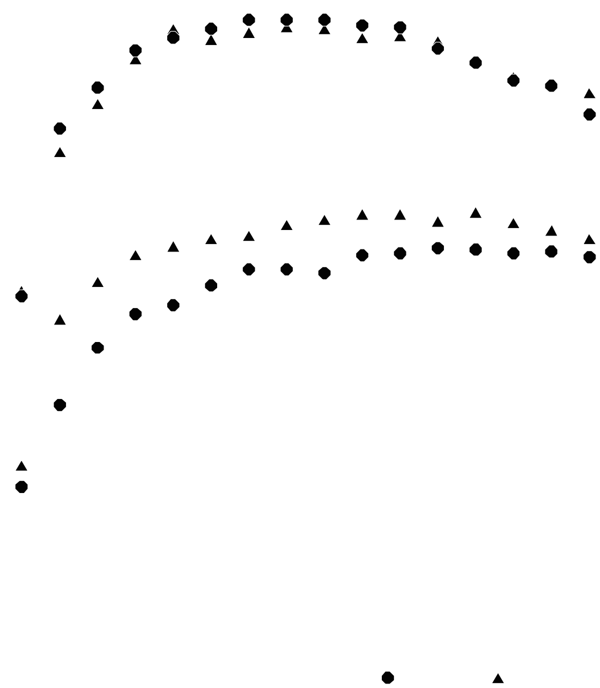
Ketosis is a metabolic disorder characterized by hypoglycaemia, hyperketonemia, decreased feed intake and decreased milk production, or even reproduction. In 1981, costs of clinical and subclinical ketosis in the US alone were estimated to be $150,000,000. Estimates of the incidence of clinical ketosis in the US are variable, ranging from less than 5 to over 10%. Incidence of subclinical ketosis is presumed to be greater. In a recent epidemiological survey in Ontario dairy cattle, the prevalence of subclinical ketosis for cows in early lactation (less than 65 days in milk) was 14% (Duffield et al., 1995). Prevalence increased with increasing parity or age.

During our two dairy trials, we found preliminary evidence suggesting that supplemental chromium may reduce the level of subclinical ketosis or serum beta-hydroxybutyrate (Yang et al., 1996). Plasma beta-hydroxybutyric acid and liver triglyceride concentrations were lower on day 30 after calving for cows fed chromium picolinate (Besong et al., 1996). Possible increased gluconeogenesis with supplemental chromium during early lactation could account for the decreased ketone bodies (Subiyatno et al., 1996).

Over-conditioned cows with fatty livers (Fat Cow Syndrome) are particularly susceptible to developing ketosis and also milk fever. Preventing development of severe fatty liver has been suggested to prevent 80-90% of ketosis cases. This may be related to compromised ability to synthesize glucose. Supplemental chromium may reduce fatty liver in dairy cows, although limited direct evidence has been obtained so far. Supplemental chromium has been shown to decrease fat concentrations in the liver of obese mice (Li and Stoecker, 1986). One of the management factors in reducing fatty liver in cows is to minimize extra stress around calving. This may be another mechanism whereby supplemental chromium may reduce the incidence of fatty liver through its effect in reducing cortisol levels.

Niacin is widely used as a supplement for late pregnant/early lactating dairy cows to alleviate ketosis and fatty liver. Although evidence for its benefits vary, the main reason given for the periodic improvement in milk production with supplemental niacin is reduced subclinical and clinical ketosis. The mechanisms involved with supplemental niacin are unclear. It is questionable if the added niacin is functioning solely in its traditional role. Supplemental niacin may be acting simply by synthesizing GTF to increase absorption and bioactivity of dietary inorganic chromium. Human studies demonstrated that the inability to respond to inorganic chromium supplementation may result from sub-optimal levels of dietary nicotinic acid (Urberg and Gemel, 1987). A biologically active form of chromium, GTF, contains trivalent chromium, nicotinic acid and the amino acids in glutathione. While preliminary and theoretical evidence suggest that supplemental chromium may reduce fatty liver and

Figure 2. Effect of Chromium Supplementation on Milk Yield During Early Lactation over Two Experiments.



SOURCE: Yang et al., 1996.

possibly other metabolic disorders (Figure 3), much more data are needed. If the proposed hypothesis is correct, it would seem much more efficient, reliable and probably economical to supply preformed organic chromium than rely on variable biosynthesis.

Figure 3. Postulated Cascade of Events How Chromium Deficiency During Late Pregnancy Leads to Metabolic Disorders in High Producing Dairy Cows.

The incidence of metabolic disorders around the time of calving is highly interrelated. One study (Curtis et al., 1985) showed that cows with milk fever were four times more likely to have retained placenta and 24 times more likely to develop ketosis. Ketosis was 16 times more likely in cows with retained placenta and 54 times more likely in cows with displaced abomasum. Acidosis is claimed by some as the major metabolic disorder in fresh dairy cows under intensive production. The possibility of supplemental chromium reducing milk fever, retained placenta and even acidosis as well as ketosis, should be monitored closely with large numbers of animals in field or epidemiology studies. Increased longevity of cows (and sows) could result when fed supplemental chromium, as noted in rats (Passwater, 1993), in part due to decreased age-related metabolic disorders.

Variables Affecting Chromium Requirement

Factors affecting the input of bioavailable chromium and output or depletion of chromium have already been briefly mentioned (Table 2). Because of low DM intake during the critical few weeks immediately before and after calving, we used approximately 0.5 ppm supplemental organic chromium in our initial trials with dairy cows. However, this may be a higher level than necessary or economically desirable, particularly postpartum. A level of 4-5 mg/head/day of supplemental actual chromium during the last 3 weeks prepartum and 5-6 mg/head/day during the first few weeks postpartum may suffice.

That chromium interacts with other nutrients is detailed in Table 4. Chromium requirements may be interwoven with effective fiber requirements for the high producing dairy cow. Fineness of silage or hay chop (Figure 4) and level or type of non-structural carbohydrates have a major effect on rumen propionate, hence blood glucose and insulin; therefore, mobilization of chromium from body stores and probably increase urinary chromium excretion. Thus, how much of the effective fiber requirements in diets for early lactating dairy cows could be reduced with supplementation with organic chromium?

Diets that lead to elevated circulating insulin lead to increased urinary chromium losses in humans. Administration of bovine somatotropin to dairy cows increases plasma glucose, insulin and non-esterified fatty acids (Gallo and Block, 1990). Thus, bovine somatotropin would be expected to increase the dietary requirement for chromium.

Another nutritional or dietary factor which may influence chromium depletion, hence requirement, in ruminants is hyperammonemia or elevated blood ammonia or urea nitrogen concentrations. A portion of the decreased performance associated with higher NPN or soluble nitrogen feeding may, in fact, be need for organic chromium. This nutritional imbalance is a stress. Glucose-insulin metabolism is known to increase, hence, need for chromium. Thus, early-cut, finely chopped alfalfa silage, as the main forage component for early lactating dairy cows (at least when combined with H.M. ground corn), should deplete chromium stores due to production of higher propionate levels and probably excess soluble nitrogen content. Moreover, if such diets are not adequately supplemented with rumen escape protein, utilization of dietary inorganic chromium may be impaired.

Table 4. Chromium Interacts with Other Nutrients.

Amino Acids

Certain amino acids affect inorganic chromium absorption

Excess tryptophan can be converted to nicotinate and/or picolinate, precursors of bioactive forms of chromium

The tripeptide glutathione is a component of GTF, a readily absorbed and bioactive form of chromium

Plasma proteins, transferrin and albumin, can increase inorganic chromium absorption

Certain amino acids stimulate insulin secretion, thus affecting chromium requirement

Vitamins

Nicotinate (niacin) can complex with inorganic chromium increasing absorption and/or bioactivity

Ascorbate (Vitamin C) can increase absorption of inorganic chromium and act in synergy with chromium in reducing cortisol or glucocorticoids

Minerals

Zinc, vanadium and iron can decrease inorganic chromium absorption

Supplemental chromium protect the stress-induced urinary losses of zinc, copper, iron and manganese

Carbohydrates

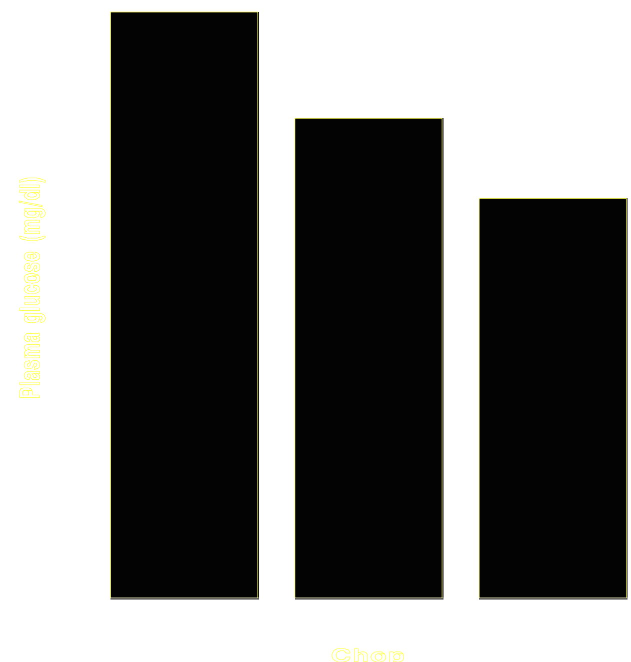
Diets high in refined or simple sugars increase urinary chromium losses and also are low in chromium. Differences exist even between sucrose versus starch diets in chromium retention in rats

Similarly, diets producing high levels of propionate in ruminants (eg. finely chopped forage silages, finely ground high moisture corn) would be expected to deplete body chromium stores

Fat

Supplemental fat may induce insulin resistance or impair glucose tolerance, thus increasing chromium requirements

Figure 4. Plasma Glucose of Cows Fed Alfalfa Silage Differing in Particular Size.



SOURCE: Grant et al., 1990.

Summary

Numerous factors affect the bioavailable chromium input as well as the depletion of body stores of chromium, hence the requirement of animals. When marginal chromium deficiency occurs, supplementation of organic chromium can benefit a wide range of functions. This should not be surprising since the vital hormone insulin influences so many functions.

In a population of animals (or humans), certain individuals are deficient in chromium, whereas others may obtain adequate chromium and precursors necessary for bioactivity from the diet. However, a major problem in the awareness, recognition and probably registration of chromium as a nutrient is the lack of any specific deficiency symptoms.

Trivalent chromium is a safe and essential nutrient vital to animal health, welfare, longevity, productivity and probably product quality.

Feed organic chromium in specialty receiving and probably later preslaughter diets for feedlot cattle. However, the perceptive benefits of supplemental chromium on carcass weight shrink and meat quality need to be proven as fact. During the growing and finishing periods, supplemental organic chromium may be economically beneficial only in more stressful situations.

With dairy, first parity cows appear to have first priority for added organic chromium. A reduction in metabolic disorders may occur in aged cows fed supplemental chromium. Supplementation may only be necessary or economical in specalty diets during the critical transition period. A portion of the need for effective fiber may, in fact, be need for organic chromium.

We have just nicely begun the exciting area of chromium supplementation of diets. Much more scientific, epidemiological and clinical proof of various proposed benefits of organic chromium are warranted. There are still some sceptics, but many less than a few years ago when there was almost total ignorance. Discoveries or new ideas often encounter some resistance before they are generally accepted.

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