Electrolytes

Livestock

Identification of Petitioned Substance

Chemical Names (Compiled from commercial electrolyte formulations):
Calcium chloride (10043-52-4)
Calcium borogluconate (5743-34-0)
Calcium gluconate (299-28-5)
Calcium hypophosphite (7789-79-9)
Calcium lactate (814-80-2)
Calcium phosphate tribasic (7758-87-4)
Calcium phosphate dibasic (7757-93-9)
Calcium phosphate monobasic (10031-30-8)
Calcium propionate (4075-81-4)
Calcium oxide (1305-78-8)
Calcium sulfate (7778-18-19)
Magnesium borogluconate (not available)
Magnesium citrate, tribasic (3344-18-1)
Magnesium hypophosphite (10377-57-8)
Magnesium sulfate (7487-88-9)
Potassium chloride (7447-40-7)
Potassium citrate (866-84-2)
Potassium phosphate, tribasic (7778-53-2)
Potassium phosphate, dibasic (7758-11-4)
Potassium phosphate, monobasic (7778-77-0)
Sodium acetate (127-09-3)
Sodium bicarbonate (144-55-8)
Sodium chloride (7647-14-5)
Sodium citrate (68-04-2)
Sodium phosphate tribasic (7601-54-9)
Sodium phosphate dibasic (7558-79-4)
Sodium phosphate monobasic (7558-80-7)

Other Name:
Calcium chloride, anhydrous $CaCl_2$
Calcium diborogluconate Ca $[HO.CH_2CH (HBO_3)CH(CH.OH)_2\ COO]_2$
Calcium gluconate $Ca[HO.CH_2(CH.OH)_4COO]_2$
Calcium hypophosphite $Ca(H_2PO_2)_2$
Calcium lactate $Ca[CH_3.CH(OH).COO]_2$
Tricalcium phosphate $Ca_3(PO_4)_2$
Calcium hydrogen phosphate ($CaHPO_4$)
Calcium phosphate monobasic $CaH_4(PO_4)_2$
Calcium propionate, propanoic acid, calcium salt $Ca(CH_3.CH_2.COO)_2$
Calcium oxide, lime CaO
Calcium sulfate, gypsum $CaSO_4$

Magnesium diborogluconate, Mg[(HO.CH2CH $(HBO_3)CH(CH.OH)_2\ COO]_2$
Magnesium citrate, $Mg_3(C_6H_5O_7)_2$
Magnesium hypophosphite $Mg(H_2PO_2)_2$
Magnesium sulfate, Epsom salts $MgSO_4$
Potassium chloride KCl
Potassium citrate, $K_3(C_6H_5O_7)$
Tripotassium phosphate $K_3(PO_4)$
Dipotassium hydrogen phosphate K_2HPO_4
Potassium dihydrogen phosphate KH_2PO_4
Sodium acetate $Na(CH_3COO)$
Sodium bicarbonate, baking soda $NaHCO_3$
Sodium chloride, table salt, NaCl
Sodium citrate, trisodium citrate $Na_3(C_6H_5O_7)$
Trisodium phosphate $Na_3(PO_4)$
Disodium hydrogen phosphate Na_2HPO_4
Sodium dihydrogen phosphate NaH_2PO_4

Trade Names:
These individual electrolyte salts are not sold with Trade Names. They are commercialized as electrolyte formulations such as Rehydral, Revitilyte, Re-Sorb, Vedalyte, and Sav-A-Caf containing mixtures of these salts along with vitamins, minerals, and sometimes microorganisms.

CAS Numbers:
The CAS number is listed in parentheses after the chemical name. The CAS number refers to the anhydrous form unless otherwise specified.

Other Codes:
N/A

Summary of Petitioned Use

Electrolytes are currently listed at §205.603 as synthetic substances allowed for organic livestock production when they do not contain antibiotics. According to the 2013 *OMRI Generic Materials List*, electrolytes are considered to be animal drugs by the FDA (OMRI 2013)**.** Per §205.238 they may only be used when preventive practices and veterinary biologics are inadequate to prevent sickness. They may not be administered in the absence of illness.

Electrolytes are needed in organic livestock production to restore ionic balance, thus treating metabolic conditions such as hypocalcemia, scours, dehydration, milk fever, erratic heartbeat, loss of muscle control, mastitis, ketosis, alkalosis, acidosis, difficulty in labor and prostration. Lack of treatment can often result in death (Goff 2008; Kumaresan, et al. 2012; Grunberg, et al. 2013).

See “Specific Uses” and “Mode of Action” sections for more details.

In practice, individual electrolytes are combined with other materials to make formulations. Formulations are discussed in “Composition of the Substance,” and in “Combinations of the Substance.” Some materials combined with electrolytes are important therapeutic components of the formulation. Glucose and glycine supply nutrients and help with active transport of sodium ion in oral rehydration formulations. Citric acid is a bicarbonate precursor (Kahn and Line 2005). Citric acid, glycine and glucose are not electrolytes, but because of their importance in oral rehydration solutions, they are discussed in more detail in “Specific Uses,” “Mode of Action” and in the Evaluation Questions.

Characterization of Petitioned Substance

Composition of the Substance:

From a chemical standpoint, an electrolyte is defined as “a substance that dissociate into ions in solution and acquires the capacity to conduct electricity” (Medicinenet, 2015). When considering them as part of a livestock production system, “electrolytes” are synonymous with electrolyte formulations. In veterinary practice, electrolyte formulations are used to restore ionic balance, especially in oral rehydration solutions to correct dehydration and in oral and injectable formulations for correction of milk fever. According to the Merck Veterinary Manual (Kahn and Line eds 2005) “fluids for oral hydration should promote the cotransport of sodium with glucose and amino acids and should contain sodium, glucose, glycine or alanine, potassium, and either bicarbonate or citrate or acetate as bicarbonate precursors” Kehoe and Heinrichs (2005).
When used in organic animal production they are either formulated by producers from basic ingredients or are purchased as commercial formulations. Commercial formulations can contain needed electrolyte salts plus other active ingredients and excipients such as vitamins, minerals and microbes. For instance, Merrick’s Blue Ribbon™ contains glucose (dextrose), maltodextrin, sodium citrate, sodium chloride, glycine, potassium chloride, calcium lactate, ascorbic acid, inulin, monosodium glutamate , sodium aluminosilicate, dried *Bacillus subtilis* fermentation product, dried *Enterococcus faecium* fermentation product, dried *Lactobacillus acidophilus* fermentation product, carob bean, carrageenan, xanthan standardized with dextrin, and agar. The microbials are added as probiotics to improve digestion, and xanthan gum is used to calm and coat the intestine.

The formulation Rehydral™ contains sodium chloride, potassium chloride, calcium gluconate, magnesium sulfate, and dextrose. See “Combinations of the Substance” for ingredients of other formulations. Essential electrolyte salts, along with some representative formulations and toxicities are given in Table 1 below.

Source or Origin of the Substance:

These electrolytes are mostly of synthetic origin. Many are produced by standard industrial procedures such as the Solvay process (where carbon dioxide gas is bubbled through ammoniated brine, producing sodium carbonate), going back to the late 19th and early 20th centuries. Some are mined, others are produced by fermentation (Rowe, et al. 2009). This subject is discussed further under Evaluation Question 2.

Properties of the Substance:

Major components of electrolyte formulations are salts. That means they dissociate into ions in aqueous solutions. They are very soluble in water and insoluble in organic solvents such as petroleum ether. Components other than salts include dextrose, citric acid, and the amino acid glycine. These components are also soluble in water, and much less soluble in organic solvents. They are metabolized for energy, producing carbon dioxide and water.

There are two types of salts used as electrolytes. One type includes salts like calcium sulfate and calcium chloride that are salts of strong acids and bases that dissociate completely in water, producing pH neutral solutions. Salts of weak acids and strong bases are also used. They include sodium citrate, sodium acetate, sodium propionate, calcium propionate, sodium bicarbonate, potassium citrate, potassium bicarbonate and others. They initially dissociate completely in water, but then the weak acid anions such as acetate react with water, producing a complex equilibrium that includes some undissociated weak acid and hydroxide ions. The overall effect is to make the solution more alkaline.

Specific Uses of the Substance:

Electrolyte balance is very important for normal physiology. When levels of cations such as sodium, potassium, magnesium or calcium, or anions such as chloride, sulfate or phosphate drop too low or rise too high, the health and life of the animal are at risk. Calcium ion, for instance, is needed for nerve transmission and muscle contraction. When levels drop too low, heart and other muscles stop functioning (Murray, et al. 2008).

Ionic balance is important also for maintaining proper plasma pH. Excess cations such as magnesium or potassium lead to alkalosis; excess anions such as chloride can lead to acidosis (Goff and Horst 1998).

Electrolytes are used to treat diseases caused by electrolyte imbalance, including milk fever, dehydration, scours, acidosis, ketosis and other problems. In the organic sector, they are mainly used in dairy operations, but are just as likely to be used in chicken, goat, sheep, swine and other operations. Administration of electrolyte formulations orally or by injection can have lifesaving effects (Goff 2008; Kehoe and Heinricks 2005; Kahn and Line 2005).

Hypocalcemia and Metabolic Problems

Alkalosis and low calcium levels (hypocalcemia) can be problems for milk producing cows. Subclinical hypocalcemia in cows can be the gateway to other diseases such as mastitis, metritis and other problems. In the worst case, clinical deficits of calcium cause a life threatening disease called milk fever, where a cow cannot rise and all muscle systems are severely weakened and non-functional. Injectable electrolytes are needed to rapidly reverse the gross electrolyte imbalance in the cow (Kara 2013); otherwise bloating and potential aspiration pneumonia are likely in recumbent cows.

Birthing cows are called transition cows in the four weeks leading up to calving, and the four weeks afterwards. These periods of time are stressful for a cow, leading to depressed immune system and sometimes gross disturbances of metabolism. Much of this depends on the size of the animal, except for Jerseys, which are more prone to milk fever than the larger Holstein breed (Karreman 2014). As a calf grows, it pushes the heifer’s rumen aside, reducing its volume. Reduced rumen volume causes the cow to reduce intake of dry food by 20% or more (Kara 2013; Stokes and Goff 2001). When the calf is born, at least 15 gallons of fluids are lost, leading to dehydration of the cow and loss of sodium and potassium. Electrolytes may be needed to replace these ions (Stokes and Goff 2001).

Reduced appetite makes it harder to supply the needed nutrition to maintain a positive energy balance. Less dietary calcium is available, leading to hypocalcemia. Hypocalcemia causes reduced secretion of insulin. When insulin production drops, less glucose is utilized. As a result, the pre-birth period may see increased mobilization of fat stores for energy, which may accumulate in the liver and lead to fatty liver syndrome. This condition is very difficult, if not impossible to effectively treat once clinically present. Increased energy production by oxidation of fatty acids leads to the accumulation of ketone bodies, and can result in ketosis. Electrolytes and nutrients may be needed to reverse ketosis, and calcium supplements may be needed to correct hypocalcemia (Kara 2013).

Dietary factors can cause metabolic alkalosis. Metabolic alkalosis can blunt the effects of parathyroid hormone, increasing calcium deficit due to milk production. Metabolic alkalosis is caused by a diet high in cations, such as sodium and potassium, and low in anions, such as chloride and sulfur. A pre-calving diet high in anions, such as magnesium sulfate or hydrochloric acid, and low in cations such as sodium or potassium, will prevent alkalosis. Metabolic alkalosis can be prevented by adding electrolytes to the diet (Kara 2013; Goff and Horst 1998).

Alkalosis and excess potassium in the diet also reduce magnesium absorption. Lower magnesium levels may affect blood levels of calcium through parathyroid action. Magnesium concentration is normally between 0.75 and 1.0 mmol/liter. Low magnesium reduces tissue sensitivity to parathyroid hormone. Blood levels of magnesium below 0.65 mmol/liter increase the risk of hypocalcemia. Maintenance of proper magnesium levels requires 3.5 to 4.0 g/kg of magnesium in the diet of the transition cow. Low magnesium levels can be corrected by administration of electrolytes (Goff 2008).

Hypocalcemia and Milk Fever

When milk production starts, large amounts of calcium are secreted into the milk. About 23 g of calcium is lost in every 10 liters of milk. This is about nine times the calcium present in blood plasma. Replacement calcium comes from demineralization of bone, reduced kidney excretion, and increased absorption through the intestine. These actions are controlled by parathyroid hormone (Horst, et al. 1997; Kara 2013).

When calcium mobilization is not fast enough to replace losses, the cow slides into subclinical hypocalcemia. Subclinical hypocalcemia can reduce muscle strength. Loss of udder control leads to mastitis, since the teat sphincters stay slightly open which allows bacteria to enter the teat canal; loss of control of the uterus leads to difficult or delayed labor (dystocia), retained fetal membranes and subsequent metritis, and other problems. About 50% of older cows in the U.S. develop hypocalcemia each year. Normal blood calcium levels in an adult cow are between 2.1 and 2.5 mmol/liter. Hypocalcemia occurs with levels below 2 mmol/liter (Kara 2013; Goff 2008). Oral electrolyte supplements can be used to treat subclinical hypocalcemia when the cow is still standing, but if the cow is too weak to stand and is down, injectable electrolytes are needed quickly.

Hypocalcemia increases with the age and lactation number of the cow. From the 1st to the 6th lactation, U.S dairy herds show 25%, 41%, 49%, 51%, 54%, and 42% incidence of hypocalcemia (<2 mmol/liter of Ca) (Reinhardt, et al. 2011).

When calcium losses reach a clinical stage and the animal is down and cannot rise (recumbent), the disease is called milk fever. This is somewhat a misnomer, as there is usually no fever and the cow is actually colder than normal due to poor heart strength and decreased central circulation. More technical names are periparturient hypocalcemia or periparturient paresis. An average of about 5-10% of cows in the U.S. develop milk fever each year. Actual numbers vary from farm to farm according to management practices. Most cases occur within 24 hours of calving. The cow loses control of leg muscles and cannot stand, becoming a "downer" cow. The longer the condition persists, the more likely the downer cow will die. If left untreated, 60-70% of cows die (Goff 2008; Horst, et al. 1997). Hypocalcemic cows are less likely to become downer cows when blood phosphate levels are sufficient (>0.9 mmol/liter) (Menard and Thompson 2007). Downer cows require intravenous injections of electrolyte solutions containing calcium and magnesium (Goff 2008).

Hypocalcemia and milk fever can vary with the breed and age of cows. Holsteins are less susceptible than Jersey and Guernsey breeds, and older cows are more susceptible than younger cows (DeGaris et al. 2009). According to Hardeng and Edge (2001), the incidence of milk fever is higher when forage is fertilized with potassium. When potassium fertilizers are not used, the potassium content of forage is reduced, preventing alkalosis. They believed this was one reason why organic cows have a lower incidence of milk fever. Organic herds also have a lower incidence of mastitis and ketosis (Hardeng and Edge 2001; Sato, et al. 2005).

Electrolytes to Treat Milk Fever

When lactation starts, milk fever can be treated by intravenous administration of electrolytes containing calcium to the animal. Calcium can be added by oral boluses, pastes, or drenching if the animal is still standing, but when the animal is down, intravenous injection is needed. Oral doses of calcium chloride can be effective, but it is caustic, causing ulcerations. It can also lead to acidosis. Calcium propionate is less caustic, does not cause acidosis, and the propionate fatty acid is glucogenic. One dose is given at calving, and another 24 hours later (Goff 2008; Goff, et al. 1996).

The most serious forms of milk fever, resulting in a downer cow, must be treated with calcium injections. The standard treatment is injections of calcium borogluconate. Calcium borogluconate is used instead of calcium gluconate because it is much more soluble in water, making quick replacement of calcium levels easier. The best route of administration is an intravenous injection (IV), providing quick restoration of calcium levels. Once the cow is able to stand, oral calcium should be given until recovery is complete (Goff 2008; Kahn and Line 2005). Subcutaneous injections of calcium borogluconate are sometimes elected, depending on clinical presentation.

Effectiveness of Oral Drenching

Most of the experiments on oral calcium drenching to correct for calcium deficiency and prevent milk fever have used calcium chloride. Oral drenches in the U.S. started as an alternative to calcium borogluconate injections. Calcium chloride was dissolved in a bucket of water and applied with a stomach tube. Calcium chloride gels have been used for this purpose since 1967 (Pehrson, et al. 1998). Typically, about 40-50 g of a bolus, paste, gel or liquid is used in about four doses distributed evenly from 12 hours before calving to 24 hours after (Thilsing-Hansen, et al. 2002).

One review showed that oral calcium chloride formulations had a 48-86% preventive effect on milk fever. The preventive effect is calculated as 1 minus the relative risk (RR), where RR is the incidence of milk fever in the experimental group divided by the incidence of milk fever in the control group (Thilsing-Hansen, et al. 2002).

Administration of 3-10 doses as a water soluble gel had a preventive effect of 50-55%. Drenching with 4 doses of a calcium chloride/calcium sulfate mixture had a preventive effect of about 73%. Calcium chloride as a paste had a preventive effect of about 40% (Thilsing-Hansen, et al. 2002). Administration of calcium chloride in capsules is about as effective as the gel (Pehrson, et al. 1998).

Oral drenches of calcium chloride are also used to supplement the effects of injections when downer cows relapse. If a cow goes down again, she is given calcium intravenously again, not oral drenches. Oral drenches are contraindicated when an animal is down with milk fever. Typically about 50 to 125 grams are used in single doses. Supplementary drenches have a preventive effect of about 65-77%, although some experiments showed less effectiveness (Thilsing-Hansen, et al. 2002).

Side effects include irritation of the mouth and the gastrointestinal tract, sometimes causing bleeding lesions. Calcium chloride in oil formulations are tolerated better. Since chloride is a strong anion, overdosing can lead to acidosis (Thilsing-Hansen, et al. 2002). A major drawback to giving oral drenches is the real possibility of creating aspiration pneumonia (when liquid gets into the lungs) by the farmer. Veterinarians see this with some regularity (Karreman 2014)

Calcium Propionate Versus Calcium Chloride

Oral formulations of calcium propionate have also been used. Calcium chloride may be more effective in correcting calcium deficiency and preventing milk fever than calcium propionate. However, calcium chloride is more of an irritant and can produce gastrointestinal lesions. Since calcium chloride contains the strong ion chloride, care has to be used to prevent rebound acidosis. The propionate ion cannot cause acidosis, as it is converted into energy and water through normal pathways of metabolism (Thilsing-Hansen, et al. 2002).

Although some experiments have shown that calcium propionate is less effective than calcium chloride in preventing milk fever, the doses of calcium propionate used were smaller. About 40-50 g of calcium chloride in four doses is typical. Pehrson et al. (1998) found that six, 20 g doses of calcium propionate gave about a 30% preventive effect versus untreated cows. Goff et al. (1996) found that four, doses of 37 g calcium propionate gave a 42% preventive effect. This was about as effective as a calcium chloride gel, but was less effective than aqueous calcium chloride solutions (Goff and Horst 1993). According to one veterinarian, intravenous electrolyte solutions of calcium are the most effective – an immediate, direct elevation of blood calcium levels (Karreman 2014).

Aqueous solutions of calcium chloride may also be more effective because calcium chloride is more soluble than calcium propionate (75 g versus 49 g per 100 ml of cold water). The acidifying actions of chloride ions also increase the rate of absorption of calcium ions from the digestive tract. Some calcium salts, such as calcium carbonate, are so insoluble that they are ineffective as a treatment for milk fever. Calcium propionate is more soluble than calcium carbonate, calcium sulfate, and calcium lactate. It is sufficiently soluble to be a good treatment (Pehrson, et al. 1998).

If oral solutions can be used to treat subclinical hypocalcemia, clinical milk fever and downer cows can be prevented. Prevention is important because cows that have recovered from milk fever after injections are less productive and are more prone to other metabolic and infectious diseases (Goff, et al. 1996).

Effectiveness of Calcium Borogluconate

In the most serious cases of milk fever, the cow loses control of leg muscles and cannot stand, becoming a downer cow. There are various degrees of severity. The longer the condition persists, the more likely the downer cow will bloat since rumen muscles are not working, thus causing aspiration pneumonia and then death. If left untreated, 60-70% of cows die in this manner (Goff 2008; Horst, et al. 1997).

About 75% of downer cows treated by calcium borogluconate or calcium gluconate injections are able to stand within two hours. Some of the 25% remaining are able to stand within four hours; others will die despite treatment. Of the cows able to stand, about 25-30% relapse within 24-48 hours and must receive additional treatment. Relapses are usually treated with oral calcium or CMPK (calcium, magnesium, phosphorus and potassium) IV (Karreman 2014; Kahn and Line 2005).

Diarrhea and Scours

While milk fever is associated with alkalosis, acidosis often occurs as a result of diarrhea and dehydration in a condition called scours. Scours usually occurs in calves within a month or so of birth. Diarrhea and dehydration cause more than 50% of the losses of neonatal dairy calves in the U.S. Economic losses also occur with labor, drugs, and veterinary expenses (Grunberg, et al. 2013).

A common use of electrolytes is to rehydrate and aid recovery of calves that have extreme diarrhea or scours. Electrolytes are also needed to correct dehydration in other food animals such as pigs and chickens (Kumaresan, et al. 2012; Grunberg, et al. 2013).

Dehydration of 5% to 10% water loss in calves can occur in one day. Losses of 6-8% lead to depression, weakness, and skin tenting for 2-6 seconds. (Skin tenting refers to pinching skin, and estimating time to return to normal.) Dehydration is treated with oral electrolyte solutions. At about 8-10% dehydration, the calf may lie down, eyes sunken, and skin tenting may last for more than 6 seconds. With over 8% dehydration the calf may need IV fluid therapy in addition to oral electrolytes. About 12-14% dehydration leads to death (Kehoe and Heinrichs 2005).

The two major causes of scours are nutritional and pathogenic. Nutritional scours occurs when calves are fed large amounts of milk on an infrequent basis, or when they are fed milk replacer. Indigestion and diarrhea are results. Cold, wet weather is also a predisposing condition. Scours can also occur when calves are not fed enough colostrum in the first 24 hours after calving. Two liters must be fed within two hours of birth, and another two liters within 24 hours. The immunoglobulins for resistance to disease must be obtained from the milk of the mother (Kumaresan, et al. 2012).

Pathogens are another cause. The most common causes are K99 *E. coli*, rotavirus, coronavirus, and cryptosporidia, although there can be a relatively large number of pathogenic causes (Garry 1993; Stoltenow and Vincent 2003).

As a result of diarrhea and dehydration, losses of Na^+, K^+, and water occur. Losses of the strongly dissociated ("strong") cations such as Na^+ lead to an excess of strong anions in plasma, leading to acidosis. Other problems include low plasma volume, low glucose levels, and excess plasma K^+ (Trefz, et al. 2013; Kehoe and Heinrichs 2005; Stampfli, et al. 2012).

Paradoxically, although K^+ is lost in the feces, and there is depletion of total body K^+, there occurs an excess of K^+ in the plasma. This is because only 2% of the body potassium occurs in the plasma. Movement of small amounts can lead to a large variation in plasma K+. As pH goes down from loss of potassium ion, hydrogen ions are exchanged for potassium ion inside the cell, increasing plasma K+. Quantitatively, every 0.1 unit drop in pH leads to an increase of 0.6 mmol/liter K+ in blood plasma. Hyperkalemic effects are very complicated, as the pH relationship just stated refers only to strong acids, and lactate acidosis may have no effect. Also, dehydration and low plasma volume interfere with the sodium/potassium ATPase "pump" that moves potassium ions inside cells. These actions leave an excess of K+ in plasma, with an overall body deficit of potassium due to diarrhea and dehydration (Trefz, et al. 2013).

The hyperkalemia (excess potassium ion) in the plasma due to scours can lead to a range of adverse physiological effects, such as irregular heartbeat and skeletal muscle weakness. As a result, calves are not able to stand and can die from heart attacks. Administration of electrolytes restores ionic balance, and allows excess potassium in plasma to re-enter the cells where it belongs, stabilizing heartbeats and muscle action (Trefz, et al. 2013).

Electrolytes as a Treatment for Scours

Treatment of dehydration and scours is usually oral administration of electrolyte solutions. In extreme cases, there may be intravenous injections needed. There are more than 20 different commercial formulations. Important constituents include sodium ion to restore electrolyte balance and treat acidosis, and glucose for energy and to increase sodium ion absorption into plasma (Kehoe and Heinrichs 2005).

Electrolytes as a treatment for dehydration, scours, and milk fever are discussed further under "Mode of Action."

Approved Legal Uses of the Substance:

The FDA considers electrolyte formulations to be animal drugs, but many of the formulations have not been formally approved by the FDA. Often this is because they are non-proprietary, general use materials, and no company has applied for a New Animal Drug Approval (NADA) (OMRI 2013; USDA 2005b).

Over 3,000 animal drugs currently being marketed have not been formally approved by the FDA. Many are benign, and have a long history of safe use. For instance, calcium borogluconate formulations have been in use since 1935. FDA enforcement and regulation of these unapproved drugs has a low priority. They are generally marketed without FDA interference (USDA 2005b) via FDA's use of regulatory discretion with illegally marketed drugs (US FDA 2011).

Many of these electrolytes are Generally Recognized as Safe (GRAS) when used in food applications, or they are FDA approved food additives (US FDA 2013; US FDA 2014).

A number of electrolytes along with representative formulations are listed in Table 1. All of these materials except magnesium citrate, calcium borogluconate, magnesium hypophosphite, and magnesium borogluconate are listed as FDA permitted food additives.

All of these materials except glycine, calcium borogluconate, magnesium borogluconate, and calcium sulfate are Generally Recognized as Safe (GRAS).

Table 1. Electrolytes, Formulations and Toxicities (US FDA 2013; US FDA 2014).

Electrolyte	Formulation	Food Additive	GRAS	Oral LD50 in rats mg/kg	Reference
For dehydration and scours					
Sodium chloride	Rehydral	yes	Yes	3,000	Rowe, et al. 2009
Potassium chloride	Rehydral	yes	Yes	2,600	Rowe, et al. 2009
Calcium gluconate	Rehydral	yes	yes	>5,000	AppliChem 2012a
Magnesium sulfate	Rehydral	yes	yes	5,000	Loveridge 2002
Dextrose	Rehydral	yes	yes	25,000	Rowe, et al. 2009
Glucose	Rehydral	yes	yes	25,000	Rowe, et al. 2009
Sodium bicarbonate	Revitilyte	yes	yes	4,220	Rowe, et al. 2009
Glycine	Revitilyte	yes	no	7,930	Rowe, et al. 2009
Calcium phosphate	Revitilyte	yes	yes	1,000	Rowe, et al. 2009
Calcium lactate	Vedalyte 8X	yes	yes	3,730	Univar 2000
Magnesium citrate	Vedalyte 8X	no	yes	11,700	Benseng 2011
Sodium citrate	Vedalyte 8X	yes	yes	6,730	Labchem 2013
Potassium citrate	Sav-a-Caf	yes	yes	11,700	AppliChem 2012b

Sodium acetate	Hydra-Lyte	yes	yes	3,530	Rowe, et al. 2009
Potassium phosphate	Electro-Charge	yes	yes	>5,000	US EPA 1998
Citric acid	Electro-Charge	yes	yes	3,000	Science Lab 2013
For milk fever					
Calcium borogluconate	Glucalphos	no	no	>5,000 form	Bayer 2013
Magnesium hypophosphite	Glucalphos	no	yes	980	Clearsynth 2014
Dextrose	Glucalphos	yes	yes	25,000	Rowe, et al. 2009
Calcium borogluconate	Milk Fever CP	no	no	950 IV	Norbrook 2010
Magnesium borogluconate	Milk Fever CP	no	no	NA	NA
Calcium hypophosphite	Milk Fever CP	yes	yes	>4,500	US FDA 2014
Dextrose	Milk Fever CP	yes	yes	25,000	Rowe, et al. 2009
Calcium propionate	Calcium Gel	yes	yes	3,920	Acros Organics 2009
Calcium oxide	Calcium Gel	yes	yes	7,340	Fisher 2005
Calcium sulfate	Bovikalc	yes	no	>3,000	Spectrum 2011
Calcium chloride	Bovikalc	yes	yes	1,000	Rowe, et al. 2009
Calcium propionate	Goff's Formula	yes	yes	3,920	Acros Organics 2009
Magnesium sulfate	Goff's Formula	yes	yes	5,000	Loveridge 2002
Potassium chloride	Goff's Formula	yes	yes	2,600	Fisher 2003
For downer cows, add					
Sodium phosphate	Goff's Formula	yes	yes	8,290	Rowe, et al. 2009
Potassium chloride	Goff's Formula	yes	yes	2,600	Fisher 2003

Acute toxicity is given as the oral LD50 in rats unless otherwise specified, and the Reference refers to the acute toxicity.

Action of the Substance:

Mode of Action Milk Fever Electrolytes

Milk fever electrolytes work by re-establishing normal ionic balance in an animal with dangerously low key minerals in the blood stream. Oral calcium drenches treat mild hypocalcemia once absorbed by the rumen by boosting plasma levels of calcium in the postpartum cow. Low calcium levels lead to loss of muscle control. If calcium can be maintained at a high enough level (> 2mmol/liter), other secondary problems associated with hypocalcemia, such as uterine inertia, mastitis, metritis and bloating can be avoided (Goff 2008).

The most serious forms of milk fever, resulting in a downer cow, must be treated with intravenous calcium injections. The best route of administration is intravenous, leading to quick restoration of calcium blood levels. Once calcium reaches normal levels (>2mmol/liter), the cow is able to stand. About 75% of downer cows treated with injections stand within two hours. Oral calcium should be given until recovery is complete, but not while the cow is down (Goff 2008; Kahn and Line 2005).

Milk fever can be treated by adding electrolytes to the animal's diet, or by adding electrolytes directly to the animal through oral formulations or injections. Electrolytes are added to the diet to reverse alkalosis. Forage diets are high in potassium, and unmodified diets can lead to alkalosis. Alkalosis interferes with the action of parathyroid hormone in calcium mobilization, and can lead to hypocalcemia and milk fever (Goff and Horst 1997).

Excess potassium in the diet can be reversed by manipulating the Dietary Cation Anion Difference (DCAD). Strongly dissociated cations tend to make blood pH more alkaline; strongly dissociated anions make it more acidic. Experiments have shown that as DCAD increases, plasma pH increases. As DCAD becomes more negative, due to excess of strong anions, plasma pH decreases (Degaris, et al. 2009).

Although all dietary ions are involved, the greatest quantitative effect comes from sodium, potassium, chloride and sulfate. So a good approximation of the DCAD is millequivalents of sodium plus potassium ions minus the millequivalents of chloride plus sulfate ions, expressed in the equation $(Na^+ + K^+) - (Cl^- + S^{--})$. When urine pH is used as a measure of plasma acid-base balance, chloride has about 1.6 times the acidifying activity of sulfate (DeGaris, et al. 2009; Goff, et al. 2004; Afzaal, et al. 2004).

Electrolytes such as hydrochloric acid (HCl) or calcium chloride (CaCl2) can be added to forage in the dry cow period before calving to reduce the incidence of milk fever. The disadvantage of this approach is that the treated forage tends to be unpalatable, reducing dietary intake. Hydrochloric acid is the most palatable source of anions. Successful use of DCAD diets reduces urinary pH from about 8.2 to a range between 6.2 and 6.8 (Goff 2008). The practice of regularly adding non-mineral acids such as HCl to forage may not be permitted in organic production.

The DCAD diet can also be achieved without the addition of electrolyte salts to food. Please see Evaluation Question 12 for a discussion of how the DCAD diet may be used as an alternative to electrolyte administration.

Electrolytes for Dehydration and Scours

As a result of scours, dehydration occurs, resulting in low Na+, high K+ plasma concentrations, strong ion acidosis due to loss of Na+ and excess anions such as Cl-, lactate acidosis, reduced plasma glucose levels (hypoglycemia), and reduced blood volumes (Kehoe and Heinrichs 2005; Stampfli, et al. 2012).

Treatment is usually oral administration of a combination of energy and electrolyte solutions. Important constituents include sodium ion to restore electrolyte balance and treat acidosis, and glucose for energy and to help with active transport of sodium ion into plasma (Kehoe and Heinrichs 2005).

Plasma hyperkalemia is corrected by administration of glucose or sodium bicarbonate or both. Glucose and bicarbonate assist active transport of K+ from the blood plasma into the cell through the sodium/potassium ATPase pump. Some decrease in plasma K+ concentration is also due to expanded plasma volume from the watery solutions (Grunberg, et al. 2011).

Sodium ion and glucose are often included in electrolyte solutions on a 1:1 molar basis. This is the ideal ratio for active transport of both through intestine into the bloodstream by transport proteins. Glycine is added to enhance glucose absorption and form metabolic glucose through gluconeogenesis. Glycine is enzymatically deaminated and converted into glucose by mammals (Kehoe and Heinrichs 2005; Grunberg et al. 2011).

Other essential ingredients are bicarbonate, citrate, lactate, acetate, or propionate ion to make the blood more alkaline, correcting for acidosis. The weak anions bind strongly with H+, increasing OH-, and making plasma more alkaline through hydrolysis. Also, as these organic anions are metabolized, excess sodium remains, alkalizing the blood through the strong ion difference (Kehoe and Heinrichs 2005; Grunberg, et al. 2013).

Potassium ion and chloride ion are needed in electrolyte solutions to restore ionic balance, since there has been a total body loss of K+ though dehydration (due to multiple bouts of diarrhea). Amounts in oral rehydration solutions vary, but should not exceed 145 mmol/liter sodium, 200 mmol/liter of glucose, 145 mmol/liter glycine, 80 mmol/liter alkalizing agents, 30 mmol/liter potassium, and 100 mmol/liter of chloride (Kehoe and Heinrichs 2005).

Other ingredients that may be helpful, but not essential, are microbial probiotics to restore microbial balance. Gelling agents may be added to soothe the intestine, increasing absorption of nutrients, but they might have the detrimental effect of retarding excretion of toxins (Kehoe and Heinrichs 2005).

Combinations of the Substance:

These electrolyte substances are combined in many commercial formulations. For instance, the oral rehydration product Rehydral™ contains sodium chloride, potassium chloride, calcium gluconate, magnesium sulfate and dextrose as basic ingredients. Hydra-Lyte™ contains dextrose, sodium acetate, potassium chloride, glycine, sodium citrate and sodium chloride. Re-Sorb™, contains sodium chloride, potassium phosphate, citric acid, potassium citrate, aminoacetic acid (glycine), and glucose.

Besides the basic electrolyte ingredients needed for rehydration, correction of acidosis, and correction of hypocalcemia and hyperkalemia some of the products contain an extended list of ingredients and excipients that may be helpful, but are outside the scope of this review. For instance, Merrick's Blue Ribbon contains glucose (dextrose), maltodextrin, sodium citrate, sodium chloride, glycine, potassium chloride, calcium lactate, ascorbic acid, inulin, monosodium glutamate, sodium aluminosilicate, dried *Bacillus subtilis* fermentation product, dried *Enterococcus faecium* fermentation product, dried *Lactobacillus acidophilus* fermentation product, carob bean, carrageenan, xanthan standardized with dextrin, and agar. The microbials are added as probiotics to improve digestion, and xanthan gum is used to calm and coat the intestine. Excipients are permitted in electrolyte formulations if compliant to §205.603(f), which requires them to be GRAS, approved as FDA food additives, or part of a NADA or NDA.

Sav-A-Caf contains dextrose, glycine, sodium bicarbonate, kaolin, citric acid, potassium chloride, corn starch, sodium silico aluminate, dried *Bifidobacterium lactis* fermentation product, dried *Lactobacillus acidophilus* fermentation product, dried *Bacillus licheniformis* fermentation product, dried *Lactobacillus lactis* fermentation product, potassium citrate, artificial flavor and artificial color. Artificial flavors and colors would be considered excipients in this formula.

Sav-A-Chick contains potassium chloride, sodium citrate, sodium bicarbonate, magnesium sulfate, vitamins, artificial color and silicon dioxide. Artificial colors would be considered excipients in this formula.

A number of these formulations, and toxicities of their components are provided in Table 1.

According to the *Merck Veterinary Manual*, the most important components of electrolyte formulations are sodium, potassium, chloride, glucose, water, and alkalizing agents such as sodium bicarbonate, sodium acetate, and sodium citrate. Microbials probably do no harm in rehydration, but are not necessary (Kahn and Line 2005).

Microbials may not help with dehydration, but there is published evidence that microbials can help prevent calf diarrhea and reduce the number of days affected when fed in milk replacement solutions (Timmerman, et al. 2005).

Milk Fever Formulations

The milk fever injectable formulation Glucalphos contains calcium borogluconate, magnesium hypophosphite, and dextrose. The most important ingredient is the calcium salt; magnesium ion may be needed, but the phosphite ion cannot be utilized. Dextrose provides needed energy to get the cow back on her feet (Thilsing-Hansen, et al. 2002; Braun and Jehle 2007).

An oral source of calcium is Calcium Gel, which contains calcium propionate and calcium oxide. The oral formulation bolus Bovikalc contains calcium sulfate and calcium chloride. Goff's formula contains calcium propionate, magnesium sulfate and potassium chloride. For downer cows, sodium phosphate and potassium chloride can be administered in addition to Goff's formula (Goff 2008).

See Table 1 for more information on formulas. Commercial electrolyte solutions may also be formulated with excipients to aid in active ingredient delivery.

Status

Historic Use:

Dehydration and milk fever have been problems since the beginning of dairy operations. Victorian veterinarians named the milk fever disorder (Murray, et al. 2009). Milk fever was specifically identified as a calcium deficit disorder in the early 20th century (Little 1932). Injections of calcium chloride were being used to raise downer cows in the 1930s. The injections were effective, but sometimes produced cardiac problems. Cardiac problems were lessened when both calcium chloride and a magnesium salt were injected (Sjollema, et al. 1932). A further refinement was the use of calcium gluconate beginning in 1932.

Calcium gluconate is less irritating and less toxic than injections of calcium chloride, and is just as effective (Grieg and Dryerre 1932; Hepburn 1932). Calcium borogluconate was introduced in 1935 because it is more water soluble than calcium gluconate. Calcium borogluconate has been used in dairy operations to treat milk fever in the U.S. since 1935 (Dryerre and Grieg 1935; Thorshaug 1935; MacPherson and Stewart 1938).

History of Oral Rehydration Solutions

Oral rehydration solutions have been used since the 1940s in clinical medicine to treat dehydration from diarrhea and diseases such as cholera (Elliott, et al. 1989). They are often used in pediatric medicine (Sack et al. 1978; Finberg 1980). Oral rehydration solutions were being used to treat calf scours and diarrhea in the 1960s and 1970s. One formulation, containing sodium chloride, calcium gluconate, magnesium sulfate, monopotassium phosphate, glycine, glucose and water is very similar to formulations used today (Hamm and Hicks 1975).

Electrolytes and the National Organic Program

Electrolytes were an early addition to the list of allowed synthetics for organic livestock production. A TAP review written in 1995 requested that electrolytes be listed (USDA 1995a), and this was followed by an NOSB recommendation in 1995 (USDA 1995b). Electrolytes were on the National List of Allowed and Prohibited Substances when it was implemented on October 21, 2002. Since then, electrolytes at 205.603 have been renewed every five years (NOSB 2005a; USDA 2010). Electrolytes are currently on the National List, and are due for Sunset on October 21, 2017 (US Code 2014).

Although inclusion of electrolytes on the National List has never been controversial, specific additions of calcium borogluconate and calcium propionate as treatments for milk fever have a more detailed history. The NOSB recommended in November 2000 that calcium borogluconate be added as an allowed synthetic for treatment of milk fever, and in 2002 they recommended that calcium propionate be added for the same use (OMRI 2006).

A TAP review of calcium propionate in livestock operations was written in 2002. In 2003 NOSB recommended that calcium propionate be added to the list as a mold inhibitor for herbal products. Listing of calcium propionate as a mold inhibitor would presumably have allowed its addition to organic animal feed (OMRI 2006; Fed Reg 2007).

The stumbling block for implementation of these recommendations was an opinion from the FDA in 2003 that livestock medications added to the list of allowed synthetics must meet with FDA approval (NOSB 2005b). Calcium borogluconate and calcium propionate formulations for treatment of milk fever are not FDA approved drugs, and for this reason the NOP decided not to add them to the list at §205.603 (Fed Reg 2007). The NOSB in 2005 ultimately decided that no specific listings of calcium borogluconate and calcium propionate were necessary, since their use was covered by the general listing of electrolytes at §205.603 (USDA 2005b; Fed Reg 2007).

On May 6, 2009 the NOSB recommended that electrolytes be specifically allowed for use in injectable formulations as nutritive supplements at §205.603 (g). This recommendation has not been implemented by the NOP (USDA 2009; US Code 2014).

<u>Organic Foods Production Act, USDA Final Rule:</u>

Electrolytes are not specifically listed in the Organic Foods Production Act of 1990 (OFPA 1990). Electrolytes are listed in the Final Rule of the National Organic Program at 205.603 as synthetic substances allowed for organic livestock production. When used on organic animals, they cannot contain antibiotics. Specific electrolytes or their formulants are also separately listed in § 205.603, including glucose, magnesium hydroxide, and magnesium sulfate. According to the 2013 *OMRI Generic Materials List*, electrolytes are considered to be animal drugs by the FDA (Fed Reg, 1992). They may only be used when preventive practices and veterinary biologics are inadequate to prevent sickness. They may not be administered in the absence of illness (OMRI 2013).

<u>International</u>

Canada - Canadian General Standards Board Permitted Substances List
http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/internet/bio-org/index-eng.html
http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/internet/bio-org/documents/032-0311-2008-eng.pdf

In Canada, the Permitted Substances List for Organic Animal Production allows electrolytes as part of Table 5.3 'Health Care Products and Production Aids.' Calcium borogluconate is specifically permitted as a treatment for milk fever. 'Electrolytes without antibiotics' are permitted, and electrolyte solutions 'with no added active ingredients' are permitted (Canadian Standards 2011).

CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999) - ftp://ftp.fao.org/docrep/fao/005/Y2772e/Y2772e.pdf

Electrolytes are not specifically mentioned. However under Health Care, Section 22 "where specific disease or health problems occur, or may occur, and no alternative permitted treatment or management practice exists, or, in cases required by law, vaccination of livestock, the use of parasiticides, or therapeutic use of veterinary drugs are permitted." However, veterinary drugs are not permitted to be used for preventive purposes (Codex 2001).

European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008
http://www.organic-world.net/news-eu-regulation.html
http://eur-lex.europa.eu/LexUriServ/site/en/oj/2007/l_189/l_18920070720en00010023.pdf

Electrolytes are not mentioned specifically in 834/2007. However, Article 14 Section 1 (e) (ii) states "chemically synthesised allopathic veterinary medicinal products including antibiotics may be used where necessary and under strict conditions" (EU EEC 2007).

In 889/2008 many of the electrolyte salts are permitted as feed additives. The list is in Annex V, Feed Materials of Mineral Origin (EU EEC 2008).

Japanese Agricultural Standard (JAS) for Organic Production
http://www.ams.usda.gov/nop/NOP/TradeIssues/JAS.html

The Japanese Agricultural Standard (JAS) for Organic Production originally considered only crops and processing (JAS 2005). Later revisions included livestock. A summary in 2007 mentions that organic livestock must be fed organic feed, have exercise and access to pasture, and must not be fed antibiotics or GMOs. Electrolytes for organic animal production were not mentioned; therefore it is unknown whether they are specifically allowed or prohibited (JAS 2007).

International Federation of Organic Agriculture Movements (IFOAM)
http://www.ifoam.org/standard/norms/cover.html

In the IFOAM NORMS for organic production and processing version 2012, electrolytes are not specifically mentioned for organic animal production. In Section III (5) on Animal Husbandry, only natural sources are permitted for vitamins, trace elements, and supplements. Use of synthetic allopathic veterinary drugs or antibiotics will cause the animal to lose its organic status (IFOAM 2012).

But many of the electrolyte substances are mentioned in Appendix 4 as additives and processing aids (IFOAM 2012).

Soil Association Standards, United Kingdom
The Soil Association Standards at Section 10.10.22 specifically allow calcium borogluconate, magnesium and phosphorus salts for milk fever. Section 10.10.34 specifically allows glucose/electrolytes as oral rehydration therapy for scours. Antibiotics and other non-allowed substances cannot be used (Soil Association 2005).

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

<u>Evaluation Question #1: Indicate which category in OFPA that the substance falls under:</u> (A) Does the substance contain an active ingredient in any of the following categories: copper and sulfur compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

Electrolytes are categorized as livestock medicines or production aids. They are specifically listed as allowed synthetics at §205.603. The FDA considers them animal drugs (Fed Reg 1992).

<u>Evaluation Question #2:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

There are many electrolyte salts that are part of electrolyte formulations in use in organic agriculture. Each substance is discussed individually.

Calcium chloride is a by-product of the Solvay process, which was developed in the 1860s. Gaseous ammonia and then gaseous carbon dioxide is bubbled through a sodium chloride (brine) solution. Sodium bicarbonate precipitates out of solution, and is filtered off. Carbon dioxide is produced by heating limestone ($CaCO_3$). Heating produces CO_2, and the lime (CaO) remaining is reacted with the spent chloride solution to produce CaC_{l2} (Rowe, et al. 2009).

Calcium borogluconate is prepared by reacting calcium gluconate with boric acid. Boric acid esterifies the alcohol groups on the gluconate. Excess boric acid is removed by distillation with ethanol (MacPherson and Stewart 1938).

Calcium gluconate can be prepared by the electrolytic oxidation of glucose in the presence of a bromide catalyst and calcium carbonate. Products of the reaction are principally calcium gluconate, carbon dioxide and hydrogen (Isbell, et al. 1932). It can also be produced by chemical oxidation of glucose with calcium hypochlorite, or by fermentation of glucose with *Aspergillus niger* (Shahzadi, et al. 2012).

Calcium hypophosphite is produced commercially by reacting white phosphorous with a hot solution of calcium hydroxide. Toxic phosphine gas is released as a by-product. The phosphine can be reacted with iodine, producing hypophosphorous acid and hydroiodic acid (Corbridge 2000).

Calcium oxide is produced by heating calcium carbonate. Carbon dioxide is released, leaving calcium oxide. Calcium hydroxide is produced by reacting calcium oxide with water (Rowe, et al. 2009).

Calcium lactate is prepared commercially by using calcium carbonate or calcium hydroxide to neutralize the lactic acid obtained by fermentation of dextrose, molasses, starch or sugar (Rowe, et al. 2009).

Mono- or dibasic calcium phosphate is prepared by reacting very pure phosphoric acid with calcium hydroxide obtained from limestone. (Phosphoric acid is produced by treating tribasic calcium phosphate with sulfuric acid; phosphate sources are mined or extracted from bone.) The neutralization is done in stoichiometric concentrations, followed by evaporation to dryness (Rowe, et al. 2009).

Tribasic calcium phosphate occurs naturally as the minerals hydroxlapatite, voelicherite and whitlockite. To isolate the pure material, phosphate rock is treated with sulfuric acid, then neutralized with calcium hydroxide. Tribasic calcium phosphate can be treated with sulfuric acid to produce phosphoric acid (Rowe, et al. 2009).

Calcium propionate is produced by reacting propionic acid with an aqueous solution of calcium hydroxide (Merkel, et al. 1987). It is also produced by reacting calcium hydroxide with propionitrile (Uriarte, et al. 2004).

Calcium sulfate is prepared from rock gypsum. The rock is ground for use as the dehydrate, or heated at 150°C to produce the hemihydrate. Another method uses a synthetic reaction between calcium carbonate and sulfuric acid. Finally, fractional crystallization of calcium chloride with a soluble sulfate can also produce calcium sulfate (Rowe, et al. 2009).

Citric acid is extracted from lemon juice, which is 5-8% citric acid, or from pineapple waste. Calcium hydroxide is added to lemon juice, and calcium citrate is isolated as a precipitate. The calcium citrate can be acidified with sulfuric acid to produce citric acid and calcium sulfate. It can also be produced by fermentation of molasses using *Aspergillus niger*. It is purified by fractional crystallization in hot water to produce the anhydrous form, or from cold water to produce the hydrate (Rowe, et al. 2009).

Dextrose (glucose) is produced by acidic or enzymatic hydrolysis of corn starch. The hydrate is produced by crystallization below 50°C, and anhydrous dextrose is produced by crystallization about 50°C (Rowe, et al. 2009).

Glycine is synthetically produced by reaction of chloroacetic acid with ammonia, or by hydrolysis of aminoacetonitrile (Rowe, et al. 2009).

Magnesium borogluconate probably can be produced in a process similar to calcium borogluconate, by reaction of magnesium gluconate with boric acid. Excess boric acid is removed by distillation with ethanol. Documentation of the synthesis could not be found for this report.

Magnesium citrate is prepared by adding magnesium carbonate and citric acid to water (Pasternack and Ammerman 1933).

Magnesium hypophosphite is produced by reacting white phosphorous with a hot solution of magnesium hydroxide. Toxic phosphine gas is released as a by-product. The phosphine can be reacted with iodine, producing hypophosphorous acid and hydroiodic acid (Corbridge 2000).

Magnesium sulfate occurs naturally as hydrates in the minerals epsomite and kierserite. It is commonly called Epsom salt, and the anyhydrous form is used as a drying agent. It is obtained by mining the natural hydrates, which are subsequently purified. Another method is reaction of magnesium oxide with sulfuric acid. The magnesium oxide is produced by heating magnesium carbonate (from magnesite ore) or magnesium hydroxide (from seawater) (Rao and Kawamura 2007).

Potassium bicarbonate occurs naturally in the mineral calcinite. It can also be produced by reacting carbon dioxide with a concentrated solution of potassium carbonate (Rowe, et al. 2009).

Potassium chloride occurs naturally as the minerals sylvite, sylvine, sylvinite, carnallite and kainite. It is obtained commercially by evaporation of brine or by mining mineral deposits (Rowe, et al. 2009).

Potassium citrate is obtained by adding potassium bicarbonate or potassium carbonate to a solution of citric acid. The solution is then evaporated to dryness (Rowe, et al. 2009).

Potassium phosphate is produced by reacting potassium hydroxide with phosphoric acid. The resulting product is cooled, crystallized, and spray dried, producing a pure, free flowing powder of monobasic potassium phosphate (Iannicelli and Pechtin 2009).

Sodium acetate is prepared by the neutralization of acetic acid with sodium carbonate (Rowe, et al. 2009).

Sodium bicarbonate is prepared by passing carbon dioxide into a cold saturated solution of sodium carbonate. It can also be produced by the Solvay process, in which first ammonia, then carbon dioxide is passed into a sodium chloride solution. The sodium bicarbonate precipitates out, and ammonium chloride remains in solution (Rowe, et al. 2009).

Sodium carbonate is produced by the Solvay process (Rowe, et al. 2009).

Sodium chloride occurs naturally as the mineral halite, and it can be isolated by mining. It is produced commercially by evaporating sea water, or by evaporating underground brine deposits (Rowe, et al. 2009).

Sodium citrate is prepared by adding sodium carbonate to a solution of citric acid, then filtering and evaporating to dryness (Rowe, et al. 2009).

Dibasic sodium phosphate is produced from heating bones to whiteness to produce tricalcium phosphate. Or tricalcium phosphate is isolated by mining the mineral phosphorite. The tricalcium phosphate is finely ground and reacted with sulfuric acid to produce dibasic sodium phosphate (Rowe, et al. 2009).

Monobasic sodium phosphate (Na_2HPO_4) is produced by adding phosphoric acid to a hot solution of dibasic sodium phosphate (NaH_2PO_4) (Rowe, et al. 2009).

Sodium propionate is prepared by reacting propionic acid with sodium carbonate or sodium hydroxide (Rowe, et al. 2009).

<u>Evaluation Question #3:</u> Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).

These electrolytes are mostly synthetic materials produced by chemical processes. Since many are salts, they are often produced by acid-base reactions. For instance, sodium propionate is produced by an acid base reaction between propionic acid and sodium carbonate or sodium hydroxide. Sodium citrate is produced by reacting sodium carbonate with citric acid (Rowe, et al. 2009).

A few of them, such as sodium chloride, can be obtained by nonsynthetic processes such as the evaporation of sea water. Some, such as citric acid, are obtained by fermentation, while others like dextrose are prepared by enzymatic hydrolysis of corn starch (Rowe, et al. 2009).

Calcium hydroxide is added to lemon juice, precipitating calcium citrate. This is acidified with sulfuric acid, producing pure citric acid and calcium sulfate.

Corn starch is a polymer of glucose. It can be treated with hydrochloric acid or amylase enzymes to hydrolyze starch, breaking the glycosidic bonds, producing glucose.

<u>Evaluation Question #4:</u> Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

Electrolytes are used in animal production situations. Since electrolytes are usually added to correct deficiencies, concentrations in the environment due to excretion would be no more than a normal untreated animal with normal electrolyte balances. Any problems would come from excess stocking rates. Excess stocking rates could lead to an excess of metabolic by-products in the immediate environment, plus extra stress on the animals. NOSB recommendations for stocking rates in organic animal production are 50 ft^2 indoors and 40 ft^2 for outdoor runs and pens for each 1,100 lb steer or dairy cow. Larger animals require larger spaces (USDA 2011). Even with dense stocking rates, however, electrolytes are usually only provided to one or two sick animals at a time, which then would result in even lower possible concentration in the environment.

Some salts are excreted by animals as a normal part of metabolism (Kahn and Line 2005). Microbes might utilize them as needed nutrients for metabolism, but the salts would persist after the microbe died. Eventually, all salts not being utilized by soil organisms or plants will wash away into surface streams, and finally the ocean.

Exceptions would be glycine, glucose, propionate and other components added to produce energy. These would be metabolized, leaving only carbon dioxide and water as excretion products.

Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

Toxicities of the electrolytes are given in Table 2 below. Acute toxicity is given as the oral LD50 in rats unless otherwise specified, and the Reference refers to the acute toxicity.

Mode of action was discussed earlier in the section "Mode of Action." Persistence is covered in Evaluation Question 4. Areas of concentration in the environment would be in the immediate area of an animal production facility and even more so around the specific treated animal.

Table 2. Toxicity of Electrolytes

Electrolyte	**Formulation**	**Oral LD50 in rats mg/kg**	**Reference**
For dehydration and scours			
Sodium chloride	Rehydral	3,000	Rowe, et al. 2009
Potassium chloride	Rehydral	2,600	Rowe, et al. 2009
Calcium gluconate	Rehydral	>5,000	AppliChem 2012a
Magnesium sulfate	Rehydral	5,000	Loveridge 2002
Dextrose	Rehydral	25,000	Rowe, et al. 2009
Glucose	Rehydral	25,000	Rowe, et al. 2009
Sodium bicarbonate	Revitilyte	4,220	Rowe, et al. 2009
Glycine	Revitilyte	7,930	Rowe, et al. 2009
Calcium phosphate	Revitilyte	1,000	Rowe, et al. 2009
Calcium lactate	Vedalyte 8X	3,730	Univar 2000
Magnesium citrate	Vedalyte 8X	11,700	Benseng 2011
Sodium citrate	Vedalyte 8X	6,730	Labchem 2013
Potassium citrate	Sav-a-Caf	11,700	AppliChem 2012b
Sodium acetate	Hydra-Lyte	3,530	Rowe, et al. 2009
Potassium phosphate	Electro-Charge	>5,000	US EPA 1998
Citric acid	Electro-Charge	3,000	Science Lab 2013
For milk fever			
Calcium borogluconate	Glucalphos	>5,000 form	Bayer 2013
Magnesium hypophosphite	Glucalphos	980	Clearsynth 2014
Dextrose	Glucalphos	25,000	Rowe, et al. 2009
Calcium borogluconate	Milk Fever CP	950 i.v.	Norbrook 2010
Magnesium borogluconate	Milk Fever CP	NA	NA
Calcium hypophosphite	Milk Fever CP	>4,500	US FDA 2014
Dextrose	Milk Fever CP	25,000	Rowe, et al. 2009

Calcium propionate	Calcium Gel	3,920	Acros Organics 2009
Calcium oxide	Calcium Gel	7,340	Fisher 2005
Calcium sulfate	Bovikalc	>3,000	Spectrum 2011
Calcium chloride	Bovikalc	1,000	Rowe, et al. 2009
Calcium propionate	Goff's Formula	3,920	Acros Organics 2009
Magnesium sulfate	Goff's Formula	5,000	Loveridge 2002
Potassium chloride	Goff's Formula	2,600	Fisher 2003
For downer cows, add			
Sodium phosphate	Goff's Formula	8,290	Rowe, et al. 2009
Potassium chloride	Goff's Formula	2,600	Fisher 2003

All of these materials except magnesium citrate, calcium borogluconate, magnesium hypophosphite, magnesium borogluconate are FDA permitted food additives (US FDA 2013).

All of these materials except glycine, calcium borogluconate, magnesium borogluconate, and calcium sulfate are Generally Recognized as Safe (GRAS).(US FDA 2014).

As we see in the Table, the oral LD50 in rats for glucose is 25,000 mg/kg, magnesium citrate 11,700 mg/kg, sodium citrate 6,730 mg/kg, glycine 7,930 mg/kg. These materials are practically non-toxic.

The LD50 for calcium borogluconate is 950 mg/kg intravenous rat; the LD50 for magnesium borogluconate is not available, but can be considered similar to the calcium salt. The related material magnesium gluconate is both GRAS and an allowed food additive. For magnesium hypophosphite the LD50 is 980 mg/kg oral rat. The Glucalphos formulation according to its manufacturer has an acute toxicity of >5,000 mg/kg oral rat (Bayer 2013). Therefore these materials would be classified as slightly toxic, but not when administered to a sick animal in need of electrolyte restoration and balance.

In summary, electrolytes used in treatment formulations for livestock operations are either non-toxic, slightly toxic, GRAS, or FDA-approved food additives.

<u>Evaluation Question #6:</u> Describe any environmental contamination that could result from the petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).

Manufacture

Most of these materials are produced by acid-base reactions. Environmental contamination as a result of production is unlikely for the salts, as reactions are simple neutralizations, producing the needed salt and water. Many of the syntheses require strong acids such as sulfuric, hydrochloric and phosphoric acid. These can be hazardous in use, but should not contaminate the environment if used in stoichiometric amounts.

There are some electrolytes that require more toxic synthetic materials during the manufacture. These include calcium gluconate, which requires a bromide catalyst for electrolysis of glucose or calcium hypochlorite for oxidation of glucose. Catalysts can be recycled, and calcium hypochlorite ends up as calcium chloride (Stecher, et al. 1960).

Glycine is produced by treatment of ammonia with chloroacetic acid (Rowe, et al. 2009). Chloroacetic acid is produced by chlorination of acetic acid in the presence of acetic anhydride. This requires dealing with hazardous chlorine gas. Another synthesis is hydrolysis of trichloroethylene with sulfuric acid. This requires use of a carcinogen and hazardous amounts of sulfuric acid (Koenig, et al. 2005).

Chloroacetic acid reacts with water, producing acetic acid and hydrochloric acid. Manufacturers likely dispose of excess material in this way. Synthetic production of glycine may require release of some materials into a hazardous waste dump (Stecher, et al. 1960; Rowe, et al. 2009).

The calcium and magnesium hypophosphites use white phosphorous in the synthesis, and toxic phosphine gas is released. The phosphine can be reacted with iodine to produce hypophosphorous acid, and phosphine does not have to be released into the environment (Corbridge 2000). Synthesis of these hypophosphites requires toxic substances, and may require release of some materials into a hazardous waste dump.

Use

Electrolytes are administered to individual sick animals to restore electrolyte balance. When excreted by treated animals, they should produce no more environmental contamination than a normal animal. All of these materials except magnesium citrate, calcium borogluconate, magnesium hypophosphite and magnesium borogluconate are FDA permitted feed additives. All of these materials except glycine, calcium borogluconate, magnesium borogluconate, and calcium sulfate are Generally Recognized as Safe (GRAS). Those not GRAS or approved food additives are considered slightly toxic. See "Table 1. Electrolytes, Formulations and Toxicities" under "Approved Legal Uses."

Electrolyte treatments would result in normal excretion levels of sodium, potassium, calcium, magnesium and others. The possible exception would be the excretion of boric acid. Injections of calcium borogluconate probably produce larger than normal blood plasma levels of boron. According to product labels, the maximum dose of calcium borogluconate is 125 g in 500 ml of solution (Bayer 2013b). Conventional mole calculations show a maximum of 32 g of boric acid is injected. A cow weighs at least 500 kg, so the injected dose of boric acid for milk fever is about 64 mg/kg.

For short periods, a maximum of 50 cows normally graze on about an acre in organic production, and an acre is 43,560 ft^2 (Reinhart and Baier 2011). Thus, each cow would occupy an average grazing space of 871 ft^2, and maximum amounts excreted per treated cow in a grazing situation would be about 37 mg boric acid/ft^2 (Bayer 2013b). It is important to note that typically only one or two animals are treated at any given time, and therefore the possible concentration of boric acid in this example is reduced significantly. Therefore, excretion of an effective dose of calcium borogluconate should not result in significant environmental contamination. The average level of boron in soil is 33 mg/boron per kg of soil, but amounts range from 20 mg/kg to more than 300 mg/kg. The average concentration in surface streams is 0.1 mg/liter (Harper, et al. 2012).

Maximum borate levels from an injection of calcium borogluconate would be 64 mg/kg. There is no documentation of normal borate levels in cows, but boron is part of normal metabolism since it is a needed fertilizer and occurs naturally in plants. For instance, red cabbage contains about 200-300 ppm of boron. Dietary intake in humans is about 0.5 to 3.1 mg/day, and dietary intake in cows is probably larger, due to an all-plant diet and larger amounts of food (Harper, et al. 2012).

Boric acid is found in plants, and is picked up by grazing cows. Boric acid thus appears naturally in cow's milk (Bertrand and Agulnon 1913; Smith 1916; Raber and Likusaur 1970). Excess boric acid from a calcium borogluconate injection should be eliminated quickly by the cow. About 89-98% of boric acid is eliminated in the urine of mice over a period of 96 hours (Harper, et al. 2012). Some boric acid in excess of natural concentrations might appear in milk over a 96-hour period. See Evaluation Question 10.

<u>Evaluation Question #7:</u> Describe any known chemical interactions between the petitioned substance and other substances used in organic crop or livestock production or handling. Describe any environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).

There appears to be no literature reporting on interactions of electrolytes with other substances used in organic crop production, organic livestock production, or organic handling. Electrolytes are materials that are directly administered either orally or by injection to individual production animals that are ill. They are normal components of animal metabolism. They are used to correct abnormal electrolyte balance. Other animal inputs include food items, water, and sometimes vitamins, minerals and allowed medications (Goff 2008).

Adverse reactions with medications are unlikely, since electrolytes are used to restore normal electrolyte balance. Applications of medications to treated animals should not produce greater numbers of adverse reactions than those seen with administration to normal animals.

<u>Evaluation Question #8:</u> Describe any effects of the petitioned substance on biological or chemical interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).

The effects of electrolytes on livestock are covered in "Specific Use" and "Mode of Action." Some salts are excreted as part of normal metabolism (Kahn and Line 2005). Since electrolytes are administered to correct deficiencies, effects on the agro-ecosystem from treated animals should be the same as effects from untreated animals. In the case of boric acid, the amount excreted is within the normal range found in the environment. See Evaluation Question 6.

Normal organic dairy and beef production facilities produce about 112 lbs of waste per cow per day. Of this, about 14 lbs is dry solids. Much of this is cellulose, lignin, starch, and protein that can be composted or spread onto land where organic crops will be grown. About 13 gallons is liquid, containing urea and electrolytes such as calcium and potassium. The overall effect is production of organic fertilizer (Burke 2001).

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the use of the petitioned substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

Individual animals treated infrequently with injectable electrolytes to correct ionic imbalance should cause no unusual pollution compared to a normal, untreated animal. See Evaluation Question #6.

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4)).

Most of these electrolytes are GRAS or they are FDA approved food additives. Oral rehydration solutions have been used for many years in clinical medicine to treat dehydration caused by diarrhea or diseases such as cholera. They are often used in pediatric medicine (Sack et al. 1978; Finberg 1980).

Anything can have health effects if abused or misused. Many of these electrolytes can have effects on human health if consumed in excess. Most problematic would be potassium chloride (LD50 2,600 mg/kg), sodium chloride (3,000 mg/kg), calcium phosphate (1,000 mg/kg), calcium chloride (1,000 mg/kg), magnesium hypophosphite (980 mg/kg), and calcium borogluconate (950 mg/kg IV rat). Instances and descriptions of human overdoses can be found in the *Merck Index* (Stecher, et al. 1960).

Injections of calcium borogluconate likely increase natural levels of boric acid in the cow. See Evaluation Question 6. But the excess boric acid from the injection should be eliminated quickly. About 89-98% of boric acid is eliminated in the urine of mice over a period of 96 hours (Harper, et al. 2012). Some boric acid in excess of natural concentrations might appear in milk over a 96-hour period. There would be no human exposures greater than normal if milk from calcium borogluconate treated cows was withdrawn from the market for 96 hours. However, it should be noted that no commercial formulations of electrolytes require any withdrawal time at all, including calcium borogluconate.

The average dose of boric acid that produces toxic effects in humans is 3.2g. In sensitive individuals, the dose that produces toxic effects is 0.1 g (Harper et al. 2012). The maximum dose of calcium borogluconate for milk fever is 125 grams, and this contains 32 g of boric acid (Bayer 2013b). From mouse data, at least 90% would be excreted in urine over 96 hrs (Harper, et al. 2012). Assuming the remaining (3.2 g), went into the milk, it would be diluted when the dairy pooled the milk with that from other cows. The average milk yield per cow in organic production is 20.2 kg/day. The average organic herd in Wisconsin is about 50 cows (Sato, et al. 2005). The total would be about 1010 kg/day. That is about 278 gallons/day. Over a 96 hour period, the maximum boric acid concentration in the pooled sample would be about 3 mg/gallon. So, each gallon would contain a dose of more than 1000 times lower than the average toxic threshold for humans of 3.2 g. But there is a wide variation in boric acid human toxicity. The amount in one gallon would be still nearly about 30 times lower than the minimum toxic dose of 0.1 g (Sato, et al. 2005; Harper, et al. 2012)

If the milk from a treated cow was not pooled about 3.2 g would be excreted over a 96 hr period into about 22 gallons of milk. The average concentration in the milk would be about 145 mg/gallon. The amount in one gallon would be about 22 times lower than the average toxic threshold. In the rare case of individuals sensitive to boric acid acid, the amount would be about 1.5 times lower than the toxic threshold.

<u>Evaluation Question #11:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).

These electrolytes are on the list of allowed synthetics, and nonsynthetic sources of electrolyte formulations are typically not commercially available. Some individual electrolytes can be nonsynthetic. These include nonsynthetic citric acid, calcium carbonate, calcium chloride, calcium sulfate, magnesium sulfate, potassium chloride, sodium bicarbonate, sodium chloride, and sodium carbonate.

<u>Evaluation Question #12:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

The most effective treatments for hypocalcemia and the prevention of milk fever are: low calcium prepartum diets, Dietary Cation Anion Difference (DCAD) diets (prior to parturition), and administration of oral electrolytes (if not already recumbent when discovered). Sometimes, combinations of these treatments are used. DCAD diets involve adding electrolytes to food to provide an excess of strong anions, or choosing food that will have this effect (Goodarzi, et al. 2012; Thilsing-Hansen, et al. 2002).

Dietary Cation Anion Difference

One treatment for milk fever is compensating for excess potassium by manipulating the Dietary Cation Anion Difference (DCAD) to prevent alkalosis (pre-partum). Strongly dissociated cations tend to make blood pH more alkaline; strongly dissociated anions make it more acidic. Although all dietary ions are involved, the greatest quantitative effect comes from sodium, potassium, chloride, and sulfate. So a good approximation of the DCAD is millequivalents of sodium plus potassium ions minus the millequivalents of chloride plus sulfate ions, expressed in the equation $(Na^+ + K^+) - (Cl^- + S^{--})$. When urine pH is used as a measure of acid-base balance, chloride has about 1.6 times the acidifying activity of sulfate (DeGaris, et al. 2009; Goff, et al. 2004; Afzaal, et al. 2004).

Adding hydrochloric acid (HCl) or calcium chloride ($CaCl_2$) to forage in the dry cow period before calving can reduce the incidence of milk fever. The disadvantage of this approach is that the treated forage tends to be unpalatable, reducing dietary intake. Hydrochloric acid is the most palatable source of anions. Successful use of DCAD diets reduces urinary pH from about 8.2 to a range between 6.2 and 6.8 (Goff 2008).

The DCAD diet is usually produced by adding an excess of strong anions such as Cl- to the diet. A problem with that is such feed is unpalatable to cows. There are other ways to get a negative DCAD. One study shows that feeding nearly a pound (400 g) of peppermint a day for 15 days pre-partum lowers the DCAD and urine pH, corrects for dietary alkalosis, and prevents milk fever (Goodarzi, et al. 2012). Although unproven, the use of apple cider vinegar also seems to acidify urine and appears to work well as part of a DCAD diet (Karreman 2014).

Low Dietary Calcium

Another approach is reducing dietary calcium in the dry period before calving. Reduced calcium tends to increase the secretion of parathyroid hormone, priming the cow for increased calcium utilization after the calf is born. Some studies have shown that this approach is less effective than DCAD methods. To be effective, available calcium must be below 20 g per day, which is less than 1.5 g/kg of dietary calcium per day. This approach may be practical in grazing situations. Grasses contain <4g/kg Ca, providing 9-10 g absorbable Ca per day (Goff 2008). A low calcium diet must be maintained for at least two weeks before calving (Thilsing-Hansen, et al. 2002).

Zeolites to Bind Calcium

Another method of lowering dry period Ca levels is by adding zeolites to the diet that will bind Ca and make it unavailable. This is unwieldy, as large amounts must be ingested and it may deplete valuable minerals such as phosphate. Another method is to add enough vegetable oil to the diet to remove calcium by forming insoluble soaps. Oils added to diets containing 30-50g/kg of calcium per day can reduce absorbed Ca to less than 15g/day (Goff 2008).

Vitamin D Injections

Manipulation of calcium levels with vitamin D supplements can be effective, but can lead to problems. Levels needed to prevent milk fever can lead to metastatic calcification. Timing is also a problem, as doses are most effective 1-4 days before calving. This method is still often used because of its simplicity (Goff 2008; DeGaris, et al. 2009; Thilsing-Hansen, et al. 2002).

Other Treatments

Fat, overweight cows are predisposed to milk fever, probably because of reduced appetite after calving. Manipulating diet to prevent weight gain in the dry period can help prevent problems. A reduced length of dry period can also help prevent milk fever, but may lead to reduced milk production. Reduced milking pre-partum and in early lactation is not very effective as a preventive technique.

Choice of Animal

Holsteins are less susceptible to milk fever than Jersey or Guernsey cattle (Thilsing-Hansen, et al. 2002). Younger animals are less susceptible to milk fever (Reinhardt, et al. 2011).

Alternatives for Dehydration and Calf Scours

Other alternatives to electrolyte treatments are various forms of prevention. Calves should be housed in dry, warm surroundings. Diseased calves should be separated from the herd. Newborns should consume >5% of their weight in high quality colostrum, preferably within two hours of birth. Similar amounts should be consumed at 12 hour intervals over the next 48 hours. The cow should have appropriate vaccinations, so that immunoglobulins are in milk (Kahn and Line 2005).

The diet of the cow before calving should be balanced in energy, protein, minerals and vitamins. Diet should contain 14-15% protein. Sanitation is important. A special area should be provided for calving. Calf and cow should be moved to a special nursing area before release into pasture. But release of cow and calf pairs as quickly as possible into pasture will reduce the possibility of infection (Stoltenow and Vincent 2003; Kumaresan, et al. 2012; Garry 1993).

It is best to provide single calving pens for individual pregnant females to prevent cross infection. The calf should have enough room to stand after birth in order to suckle. If calving pens are not provided, the calving area should be free of animal traffic. Immediately after calving, the navel cord should naturally sever and then be swabbed with tincture of iodine. Calving pens should be cleaned, disinfected, and freshly bedded between calving. If a calf gets scours, it should be shifted to an isolation pen until recovery (Kumaresan, et al. 2012).

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