Understanding Electrolyte Product Comparisons

Summary

- Electrolyte product labels inconsistent.
- Most common unit of measurement is **mmol** which is a measurement of the actual molecules of the different ingrediants**.**
- Ingredients listed on a label often do not indicate the actual concentration of ingredients in the final electrolyte solution.
- Ingredients dissociate into base components when added to water which has a profound affect on the acid-base balance of the solution.
- Electrolyte solutions have 'must have' components to be effective in restoring a calf's electrolyte balance.
- There are tremendous variations in the formulations of oral electrolyte solutions currently available in the NZ.

Electrolyte product comparisons show up in articles and publications from time to time and are typically based on information found on the label of each product. Although probably unintentional, these comparisons usually contain a fair amount of incorrect or misleading information. These profiles may be convenient and are intended to be informative, but caution needs to be exercised when using these comparisons.

To begin with, the product profiles in these comparisons use values that have been calculated from the actual numbers of molecules of the different ingredients that make up each electrolyte product. ***What?!*** *If you've never studied or forgotten school chemistry, don't panic, you are in good company*

It's actually the use of these principles that leads to problems with electrolyte evaluations and comparisons – not just in published comparisons, but across the board. The intent of this article is to shed some light on how these problems are generated, and how to avoid the pitfalls they create.

The term or unit of measure most commonly used in electrolyte evaluations is ***millimole***, abbreviated to ***mmol***. Simply put, this is a measure of the concentration of a substance, such as sodium, chloride, or glucose that is dissolved in a solution. The term **osmolarity** is often used when talking about mmol concentrations.

To evaluate an electrolyte product, we need to work with the solution the calf actually consumes, not just what's in the package on the shelf. We start with the dry product, add water according to the label instructions and then evaluate. This is all figuratively speaking, of course — we do this on paper, not in an actual bucket. The label provides a list of ingredients and a guaranteed analysis. The Ingredient List is an accounting of the ingredients used to make the product, whereas the Guaranteed Analysis states the concentrations of various ingredients or specific nutrients provided in the dry product. Sometimes the details in the Guaranteed Analysis can be a bit skimpy, especially if a manufacturer is protecting a proprietary formula. That's understandable since they may have a significant investment in the product and don't want to give the formula away. In such cases, a few phone calls or emails to manufacturers may be necessary to provide sufficient detail for each product.

The example electrolyte product shown in *Table 1* below contains six ingredients which are listed in the left-hand column. The right-hand column shows the mOsm/litre concentration of each ingredient in the final solution. (Sometimes shown as mmol/L or mml/L) The other columns are mathematical steps along the path to our mmol objectives.

Electrolyte example

Table 1

Ingredient	% Formula	Grams/L	Molecular weight	**mOsm/L**
Dextrose/glucose	70	33.42	198	**169**
Sodium chloride (Salt)	7	1.76	58.44	**57**
Sodium bicarbonate	13.5	6.45	84	**77**

Sodium citrate	2	0.95	258.07	**4**
Glycine	4	1.91	75.07	**25**
Potassium Chloride	3.5	1.67	74.54	**22**
			Total mOsm/L	**354**

This is the standard approach to evaluating electrolytes. There is, however, one *slight* problem. Several of the ingredients (sodium chloride, sodium citrate, sodium bicarbonate and potassium chloride) don't exist in the electrolyte solution that the calf drinks. Once these substances come into contact with water, they dissociate into their base components. In this case, we're left with sodium, chloride and potassium (which are called strong ions) as well as citrate and bicarbonate.

Strong ions

Table 2

		g/L	Mol. Wt	**mOsm/L**
Sodium		3.34	23	**145**
Chloride		2.79	35	**80**
Potassium		0.87	39	**22**

A good indicator of whether or not an electrolyte ingredient will dissociate, is the presence of one or more strong ions. Sodium, chloride, potassium, calcium and magnesium are all strong ions. It's pretty easy to identify which ingredients contain strong ions since their presence is indicated in the ingredient name.

This dissociation has profound effects on the acid-base balance in the body as well as having profound effects on the osmolarity of the solution. For example, the actual impact of the sodium chloride in this formula on osmolarity is 114 mOsm/L, not 57 mOsm/L as shown in *Table 1*. Sodium citrate, sodium bicarbonate and potassium chloride actually contribute 16, 154 and 44 mOsm/L, respectively. Dissociation of sodium citrate yields four molecules (three sodium and one citrate), whereas sodium chloride, sodium bicarbonate and potassium chloride dissociate into two molecules each. Glucose and glycine stay the same since they don't dissociate.

Some electrolyte product comparisons go further and provide a total mOsm/L value for the different electrolyte products being compared. These values can be quite inaccurate and misleading. Our example electrolyte in *Table 1* shows a total mOsm/L value of 354. The actual osmolarity of the product is 522 mOsm/L as shown in *Table 3*. So be cautious about using these numbers.

Although *Table 1* and *2* seems logical from the standpoint that it provides a ledger for the ingredients specified in the formula, the following *Table 3* accounts for ingredient dissociation and provides a more accurate description of the electrolyte solution consumed by the calf. It allows for correct assessments of osmolarity, and results in a higher degree of accuracy when evaluating electrolytes.

Table 3

	gms/L	Mol. Wt	**mOsm/L**
Glucose	33.42	198	**169**
Sodium	3.34	23	**145**
Glysine	1.91	75	**25**
Potassium	0.87	39	**22**
Chloride	2.85	35.5	**80**
Bicarb	4.70	61	**77**

Citrate	0.70	189.07	**4**
	47.78	**Total mOsm/L**	**522**

"Osmolarity" expressed as mOsml/L is simply a term used to measure the concentration of particles in a solution. Thus, the higher the concentration of a solution, the higher the osmolarity will be. Commercially available oral electrolyte solutions for use in calves range from 300 mOsm/L (called "isotonic" because this is equal to the osmolarity of blood) to 750 mOsm/L, (which would be considered very hypotonic or concentrated). Simply stated, the higher the osmolarity of a product the more concentrated it is or generally the more electolytes and energy (glucose) the product contains. However too high an osmolarity can cause problems.

The maximimun osmolarity normally found in the intestine tract is about 600 mOsm/L and any electrolyte solutions with above this should be avoided as they could worsen the damage that has been done to the digestive system and cause abomasa bloat.

When a calf is dehydrated and suffering from scours, the digestive system becomes compromised from decreased absorption. **Sodium, chloride, and potassium** are all lost in the faeces of calves with diarrhoea. Sodium is the most important of these and most research suggests a level of 90-145 mmol/L is necessary to correct dehydration. However, sodium and accompanying water absorption from the small intestine will only occur if there is glucose or an amino acid such as glycine, alanine, or glutamine that the sodium can join with and cross into the cells in the gut. The ratio of glucose to sodium present in an oral electrolyte solution should fall somewhere between 1:1 and 3:1. The process of absorbing sodium helps rehydrate the calf by replenishing total body fluids. Volatile fatty acids such as acetate and propionate are also known to increase intestinal absorption of sodium.

With dehydration, potassium is lost in the faeces and urine so calves may experience a profound loss of body potassium stores. A common clinical sign in calves with chronic diarrhoea is extreme muscle weakness due in large part to this loss of potassium. Oral electrolyte products should contain between 10-30mmol/L of potassium.

Strong ion (SID) A relatively new theory called the "strong ion theory" encourages the use of products that deliver an excess of strong cations (sodium and potassium) relative to the concentration of strong anions (chloride) in order to help correct a portion of the acid-base balance in the blood. This "strong ion difference" or "SID" is calculated as follows: [Na+] + [K+] – [Cl-]= SID and should fall in the range of 60-80 in an oral electrolyte product. Chloride should be present in the range of 40-80 mmol/L. Concentrations at the lower end of the suggested range will beneficially increase the SID

Alkalinizing agents. Virtually all calves with diarrhoea have a decrease in their blood pH as compared to normal. This acidosis is largely responsible for the abnormal clinical signs seen in these animals including loss of suckle reflex, depression, inability to stand, etc. Therefore it is imperative that any oral electrolyte solution used to resuscitate calves contain an alkalinizing agent.

Acetate, propionate, and bicarbonate are all considered alkalinizing agents. Bicarbonate is commonly available in oral electrolyte solutions. Recent research has shown that acetate and propionate containing oral electrolyte solutions are preferred over bicarbonate for several reasons:

- Acetate and propionate are volatile fatty acids and can facilitate sodium and water absorption in the calf small intestine whereas bicarbonate does not.
- Acetate and propionate produce energy when metabolized, whereas bicarbonate does not.
- Acetate and propionate do not increase abomasa pH whereas bicarbonate does
- Acetate and propionate inhibit the growth of Salmonella species.
- Acetate and propionate don't alkalinize the abomasum or interfere with milk clotting in the abomasum, whereas bicarbonate does.

Several pathogenic bacteria are killed at a low pH, for example both E. coli and Salmonella are killed at a pH around 3.0 and begin to multiply at a pH above 5.5. Normally the stomach (abomasum) maintains a very low (acidic) pH which is critical for decreasing the number of pathogenic bacteria reaching the small intestine and increasing the resistance to intestinal colonization by bacteria. More simply stated, the calf needs to maintain a low abomasal pH to decrease the incidence of infection and clinical disease. Recent research has shown oral electrolyte solutions containing bicarbonate induce a significant increase in abomasa pH for a prolonged period of time which may increase the number of bacteria that are able to colonize the small intestine. This effect is not observed when using acetate based oral electrolyte solutions. Therefore abomasa and small intestinal alkalinization due to bicarbonate-containing oral electrolytes may promote bacterial growth, and actually prolong or worsen the diarrhoea in calves.

Even with the possible drawbacks associated with using bicarbonate, it is still critical that your oral electrolyte solution contain an alkalinizing agent. While they may not be ideal, products containing bicarbonate have been used effectively for years to resuscitate calves and will likely be used for years to come. However, there are several products on the market that do not contain any of the three alkalinizing agents listed above and should not be used in calves. These products may correct dehydration and electrolyte abnormalities, however they will not have any ability to increase blood pH (correct the acidosis) which is one of our primary therapeutic goals. A calf that has normal electrolyte levels (i.e. sodium, calcium, potassium) may still very likely die of acidosis if this is not addressed. Therefore always make sure either bicarbonate, acetate, or propionate are listed on the ingredients list of the oral electrolyte product you are using, and if an analysis is present, the minimum recommended concentration for an alkalinizing agent would be 50 to 60 mM/L (lower concentrations are likely to have a very weak alkalinizing ability).

The ratio between sodium and chloride is important in improving a calf's acid-base status. The normal ratio of sodium to chloride in blood plasma is about 4:3 (140 mmol/L sodium:103 mmol/L chloride). Using sodium chloride as our only source of these two ions provides one chloride ion for every sodium, slightly overrepresenting chloride in terms of normal plasma concentrations.

To achieve an appropriate ratio of sodium to chloride, especially if we want to have a chance at correcting acidosis, ingredients other than sodium chloride e.g. sodium bicarbonate, sodium acetate and sodium lactate ("alkalinizing" or "buffering" agents) must also be used in the formula.

When selecting an electrolyte, look for alkalinizing agents which include a combination of bicarbonate, propionate and acetate.

How much glucose/dextrose should be in an electrolyte?

When a calf is sick, it will naturally pull any energy available to help combat what's making it ill, putting the calf at risk for lower average daily weight gain. When a calf is suffering from dehydration, it's in need of an energy source to correct hypoglycemia and negative energy balance.

Glucose in an electrolyte provides a minor energy source for the calf. An electrolyte solution should not be looked at as a replacement for energy provided by milk or milk replacer which is why it is recommended to keep a calf on a milk ration during times of illness.

High glucose electrolyte solutions are sometimes presented and used as a replacement for milk or milk replacer during diarrhoea. Five – six litres of such a solution provides about 75% of the daily energy needed by a baby calf for maintenance, while providing none of the protein required by the calf. However electrolytes with very high levels of glucose/dextrose can bring harm to calves by slowing down gut movement, which could cause bloat. If a calf already has scours, it can worsen their symptoms.

Glucose, which is absorbed more quickly than lactose (milk sugar), causes a rapid increase in plasma glucose. Insulin is released into the calf's bloodstream to lower the elevated plasma glucose level. This insulin response is excessive in young calves. Within three hours after administration of the high glucose electrolyte solution, plasma glucose is lower than the pretreatment level.

Lactose is the principal carbohydrate found in milk. It is a disaccharide composed of one molecule each of the monosaccharides (simple sugars) glucose and galactose and is the primary carbohydrate source for neonatal mammals. During the digestive process lactose is broken down into its component glucose and galactose subunits by the enzyme lactase and is then be absorbed from the digestive tract for use by the body. As the process of absorption occurs over a longer time period the rapid increase in plasma glucose associated with glucose is reduced. The presence of lactose in the gut also increases the population of *Lactobacillus sp.* and *Bifidobacterium sp.*in the intestines …these are favourable bacteria populations.

All good electrolytes contain a mix of glucose for rapid energy uptake and lactose for sustained energy uptake.

Gelling agents.

The rationale for including gelling agents in an electrolyte is that they may:

1. increase the viscosity of the solution, resulting in a decreased rate of stomach emptying,
2. slow the passage and distribution of the solution to the small intestine, thus increasing the potential for absorption of nutrients, and
3. provide a "coating" effect on inflamed intestinal mucosa.

Trials conducted in the US using one such product (Advance Arrest) which utilizes Guar gum as a gelling agent concluded that the rate of passage through the digestive tract was slower for the electrolyte solution containing guar gum, and that absorption of sugars from the intestine also occurred more slowly. Decreasing the rates of passage and absorption could be beneficial for calves with diarrhoea, by increasing the time that nutrients contact the absorptive surface of the intestine and by providing a more constant influx of nutrients into the body.

The "must haves" of an ideal electrolyte

Geof Smith, DVM, MS, PhD, North Carolina State University, suggests the following "must haves" for the ideal oral electrolyte.

- Must have enough sodium (90 – 130mmo/L) to help correct extracellular fluid deficits
- Must have amino acids glycine, citrate, propionate, alanine, glutamine or acetate, to help facilitate intestinal sodium absorption
- Must have an alkalinizing agent (acetate, propionate, bicarbonate) to help correct metabolic acidosis
- Must have sufficient energy (glucose) especially if calves will be off milk for a day or two
- Must include lactose for sustained energy.
- Must have components that will not increase the chance of bacterial infection and support a healthy gastrointestinal environment
- Must have an osmolality ≤650 mOsm/L (ideally between 400 – 600 mOsm/L) to ensure timely emptying of the abomason/stomach to avoid abomasal bloat due to fermentation of product slow in passing due to high osmolality
- Must have a strong ion difference of at least 60 (cations relative to anions)

In addition to his list of "must haves" he also suggests five goals for treating calf scours:

- Rehydration
- Correction of acidosis
- Correction of electrolyte abnormalities (Na, K, Cl)
- Reversal of negative energy balance
- Inhibit the growth of pathogenic bacteria

Summary

There are tremendous variations in the formulations of oral electrolyte solutions currently available in the New Zealand. *Table 4* below shows an analysis of a number of popular products and gives some comments on their suitability for use in calves. As you can see not all of these products would be ideal and in fact a few would not be recommended at all. It is important to work closely with your veterinarian to select the product that is most appropriate for your herd to optimize your calf diarrhoea treatment protocols.

References: Penstate University College of Agricultural Science
https://extension.psu.edu/electrolytes-for-dairy-calves
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Rob Costello, Technical Specialist, Calf Sessions, Electrolyte and Water Balance In Calves -- Electrolyte Formulation & Function
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http://livestocktrail.illinois.edu/porknet/paperDisplay.cfm?ContentID=252

Table 4. Analysis of twelve oral electrolytes solutions commercially available in New Zealand

	Mixing rate	Glucose + Lactose Energy (MJ/L)	Sodium (mM/L)	Potassium (mM/L)	Chloride (mM/L)	Amino acid	SID	Osmolality (mOsm/L)	Alkalinizing agent (mM/L)	Glucose:Na ratio	Prebiotics Probiotics Starch	Comments
Recommendations			**90-130**	**10 - 30**	**40 - 80**	**Glycine**	**60-80**	**400-600**	**Acetate 50 - 60**	1:1-3:1		
Biocalf Plus	130g/2L	0.79	128	27	78	Glycine L-Alanine	76	495	Bicarbonate 20mM/L Acetate 24mM/L Citrate 6mM/L **Total: 50**	1.5:1	Probiotics. Prebiotic yeast. Guar gum	A very good oral electrolyte with additional benefits from a prebiotic, probiotic and gelling agent gaur gum – contains a mix of glucose and lactose
Revive	118g/2L	0.75	146	31	103	L-Alanine	74	517	Bicarbonate 17mM/L Acetate 30mM/L Citrate 4mM/L **Total: 51**	1.2:1		A very good oral electrolyte solution for use in calves – contains a mx of glucose and lactose.
Diarrest	248.5g/L	1.84	146	31	103	L-Alanine	74	517	Bicarbonate 17mM/L Acetate 30mM/L Citrate 4mM/L **Total: 51**	1.2:1	Rice flour Starch	A very good oral electrolyte with additional benefits from slow release carbohydrates, rice flour and starch – contains a mx of glucose and lactose.
Biocalf Restore	50g/L	0.65	117	27	78	Glycine	65	440	Acetate 36mM/L Citrate 9mM/L **Total: 45**	1.6:1	None	An excellent electrolyte with a good balance of energy, essential salts and alkalinizing agents
Novolyte	50g/L	0.67	112	24	68	None	68	455	Citrate 9mM/L Acetate 30mM/L Propionate 13mM/L **Total: 52**	1.7:1		An excellent electrolyte with a good balance of energy and essential salts and alkalinizing agents.
Enerlect	50g/L	0.67	68	21	53	Glycine	36	397	Bicarbonate 14mM/L Citrate 7mM/L **Total: 21**	3.4:1		Sodium and alkalinizing agent levels too low –would not be a good choice for treating diarrhoea.
Vet electrolyte	56g/L	0.72	140	10	109	None	41	512	Citrate 19mM/L Lactate 3mM/L **Total: 21**	1.6:1		An adequate electrolyte but a high chloride level – low level of alkalinizing agents

Dexolyte	80g/2L	0.52	44	14	59	None	0	301	None	4.1:1		Only suitable as an energy boost for stressed calves – Low osmolality - Low in sodium and no alkalinizing agent – could increase the risk for osmotic diarrhoea - would not be a good choice for calves with diarrhoea
Enervade	70g/2L	0.32	80	14	58	Glycine	36	327	Bicarbonate 26mM/L **Tot: 26**	1.8:1	Prebiotic	Sodium + glycine total higher than glucose. OK electrolyte but not ideal
Diaproof K	100g/2L	0.26	87	14	46		69	270	Bicarbonate 34mM/L Citrate 5mM/L **Total: 39**	1:1	Mucopoly-saccharide	Very low osmolality – Low in glucose and sodium - low to adequate bicarbonate to help with acidosis – mucopolysaccharide may provide slow release energy.
Nutricare	80g/2L	0.38	205	22	145	Glycine	81	542	Bicarbonate 14mM/L Citrate 1mM/L **Total: 15**	0.6:1		A very high level of sodium and chloride which can cause Sodium toxicity in calves – low ratio of glucose+glycine to sodium to facilitate sodium absorption - minimal alkalinizing ability - should be avoided for treatment of diarrhoea.
Vytrate	64g/2L	0.40	73	18	73	Glycine	18	330	None	2.1:1		Low concentration of ingredients - suitable as a first feed for bought -in or stressed calves – no alkalinizing agent

This listing does not include every product available in NZ. No discrimination or specific endorsement of any product is intended.

Disclaimer: The information for this table was obtained from suppliers published data or product labels and, in some cases, there was insufficient information available to provide an exact calculation so values may not be completely accurate.

No liability is inferred from information pertaining to the choice or use of any products listed in the table. E&OE.

Note, it is important to consult with your Veterinarian to select the most appropriate product to optimize your calf treatment protocols.