Water Quality for Calves

Timothy R. Johnson[1]
Department of Animal Sciences
Purdue University

Physiology of the Pre-ruminant Calf

Water makes up 85.8% of the body weight **(BW)** of a neonatal calf (Lewis and Phillips, 1978). Prior to birth, the developing fetus is surrounded by amniotic fluid that is 92% water. In the uterus, the developing calf is supplied with water by diffusion from maternal plasma, and at birth, the calf is at its greatest water content having developed in a water based media where water has borne the nutrients required to allow rapid growth and development. The uterus supplies an environment where water containing fluids shelter the fetus, mitigating the effects of jolting and gravity on the developing fetus. Upon birth, the mammal is suddenly exposed to light, temperature extremes, and wind, beginning the processes of drying and dependence on water contained in milk and the intake of free water by the calf.

While milk is the primary source of water for the calf, consumption of additional free water is required to support optimal growth and health in the bovine. Feeding supplemental water to pre-weaned calves is of particular importance to encourage consumption of dry feed. Kertz et al. (1984) demonstrated that when supplemental water was not provided, this resulted in a 31% decrease in dry matter **(DM)** intake and a 38% reduction in weight gain. For each extra liter of water consumed, there was a corresponding increase of 82 g/day of dry feed intake and an increase in weight gain of 56 g/day. These data powerfully emphasize the importance of providing access to supplemental water of high quality for young calves from a very early age. Housing arrangements which provide easy access to water and dry feed for calves and the importance of keeping feed and watering equipment accessible to human care givers for routine cleaning are discussed in detail by Davis and Drackley (1998, Chapter 18).

Mineral Content in Water

Mineral content of well water has been shown to be variable across and within regions of the United States by survey (Socha et al., 2001). A database of more than 5000 water samples from rural areas across the United States has been developed by Zinpro Corporation (Eden Prairie, MN), with assistance from Agri-King, Dairy One (Ithaca, NY), and Dairyland Laboratories, Inc. (Arcadia, WI). This database has been made available for use in this paper by the Zinpro Corporation. Average, maximum, minimum, and standard deviation of mineral concentrations in ppm from 238 water samples from Indiana, Michigan, and Ohio are shown in Table 1. In addition, samples have been divided by state and zip code of water sample origin, these data are summarized in Table 2.

The most basic measure in this database is that of total dissolved solids **(TDS)**, this with addition of total soluble salts **(TSS)** and pH are initial considerations in determining the suitability of

[1]Contact at: 3-118 Lilly Hall, West Lafayette, IN 47906-1151, (765) 494-4810, FAX: (765) 494-9346, Email: tjohnso2@purdue.edu

drinking water for calves. Water hardness is a physiochemical property of water based primarily on Ca, Mg, and Fe concentrations. Water turbidity, partially dissolved solids, acid/base balance, and mineral content are all factors that may affect water acceptance, palatability, and final intake of free water. Minerals of particular concern when in high concentrations are cobalt, copper, iron, hydrogen sulfide, manganese, and sulfur. The form in which sulfur is present depends on water pH and the concentrations of anions and cations present in the water. Hydrogen sulfide, which is the "rotten egg" odor that some water contains, is volatile, and no accurate measure of it can be made without special equipment that allows a sample to be taken without exposure to air prior to determination. Hydrogen sulfide has been shown to decrease water palatability, acceptance, and intake in adult cattle (Loneragan et al., 2001), but in my reading, I was not able to find a specific reference to the effects of hydrogen sulfide concentration on free water intake of pre-weaned calves. On the other hand, total sulfur in water of less than 500 mg/L has been recommended for calves from research by Linn and Raeth-Knight (2002). High but still safe concentrations and maximum tolerable concentrations of minerals for dairy cattle are shown in Table 3. These values are based on nutrient recommendations made in the NRC (2001) and from several other sources (Socha et al., 2003).

Mineral Interactions and Associated Metabolic Problems

Elemental Cu interacts with manganese and several other elements. Acid/base balance and anion/cation ratio influence the magnitude of these interactions (Xin et al., 1991; Hemken, 1993). In the state of NY, the influence of elevated Mg in veal calf diets was investigated by supplementing veal milk replacer with magnesium oxide to mimic problems seen in the field with calves developing kidney stones when fed milk replacers reconstituted with water containing high levels of Mg (Petersson et al., 1988). Four diets were fed containing 0.1, 0.3, or 0.6% Mg and the fourth diet, 0.6% Mg plus 2% NaCl. The 0.6% concentration of Mg supplementation resulted in 70% of the calves developing renal calculi (kidney stones). Addition of 2.0% NaCl to the 0.6% Mg replacer diet, over the 112-day feeding period, reduced presence of kidney stones to 30% as determined by autopsy after euthanasia. Increased free water intake prompted by the addition of NaCl was suggested to have been the causative factor in reducing stone formation.

Iodine is used as a disinfectant for dairy equipment, as an ingredient in teat dips, and as a compound to allow sterilization of the umbilical cord of calves. Jenkins and Hidirglou (1990) investigated the effect of adding 0.57, 10, 50, 100, or 200 ppm iodine to calf milk replacer from 3 to 38 days of age. This study revealed typical signs of iodine toxicity at 100 and 200 ppm of iodine, including nasal discharge, excessive tear formation, and saliva production. While digestibility of milk protein was reduced only at the two highest doses of iodine, even at 50 ppm of supplemental iodine resulted in greater iodine in blood plasma, bile, and non-thyroid tissues after a 5 week feeding period. This led researchers to set 10 ppm of iodine as the practical limit as is reflected in the NRC (2001). Milk replacer diets fed to rapidly growing veal calves are a good example. The NRC (2001) states that the Cu requirement for calves is 0.2 ppm; however, practical water and replacer diets for rapidly growing veal calves are often limited to 0.05 ppm Cu because of clinical Cu toxicity problems which occur when the water and replacer mixture contain greater Cu concentrations (Dr. Jeffrey Pyle, North Manchester Veterinary Clinic, North Manchester, IN; personal communications, 2005).

The solubility of minerals and mico-minerals in the calf digestive system is important for absorbability. An example is the element aluminum. Experimentally, aluminum chloride added to calf diets, even at low levels, has been shown to decrease DM intake, weight gain, bone ash weight, and bone P composition (Crowe et al., 1990). In addition, these authors mentioned that soil aluminum content and ingestion of aluminum containing soils by grazing ruminants in New Zealand has been shown to reduce P digestibility. However, the practical importance of this toxicity or mineral interaction in the Midwest and Great Lakes areas of the U.S. is unknown. Most clay containing soils in this area are composed of a 2:1 particulate ratio of alumina to silica. Solubility of the aluminum fraction is so poor that little practical problem with aluminum toxicity in the United States or Canada is seen.

Temperature

The influence of milk or supplemental water temperature on health and performance of dairy calves has been reviewed by Davis and Drackley (1998. Chapter 15). Veal calves fed cold milk replacer ad libitum had decreased intake of milk as compared to veal calves fed replacer at room temperature (Filpot et al., 1972). In several studies with female dairy calves, restricted amounts of replacer and dry calf starter were fed; calves fed the cold milk replacer exhibited similar performance to calves fed warm replacer (Appleman and Owen, 1975). Seasonal dairy producers often practice "mob feeding" of grouped dairy calves. Nipples of hardened rubber are put mid-way on the outside of 55 gallon drums, and tubes to the nipples are kept at the bottom of the barrel to increase suckling activity and saliva production by the calf (Gratehouse, 1996). Nipple barrel calf feeding systems work best if calves are fed milk or replacer twice each day. Using this system, milk is usually consumed in 20 to 30 minutes; after the milk is consumed, water is fed by placing about 20 gallons of fresh water in the drum. This allows partial drum cleaning and gives the calves access to free water which, as in more traditional calf feeding systems, provides the calves extra water that promotes maximum DM intake and growth. Data from many feeding systems have shown that there is an extremely strong positive correlation between intake of water and intake of DM from replacers and from supplemental concentrates and forages Kertz et al., 1984).

Organic contaminants

Presence of E. coli, coliform, and total bacteria, as well as presence of organic toxicants in water on Ohio dairy farms was reviewed by Mancl and Eastridge (1993). In addition, the presences of bacteria (E. coli, coliform, and salmonella), as well as protozoal and fungal contaminants, have undergone an extensive survey on dairy operations in the pacific northwestern U.S. (LeJeune et al., 2001). The most readily available source for testing of fecal coliform bacteria is measurement by local health departments. Fecal coliform levels are reported in colony forming units **(CFU)** per ml. Bacterial numbers are reported on a $\log_{10}$ scale/ml of the liquid sample. It should be noted that this number only predicts the present number of microbial CFU and ignores potential growth under different environments and temperatures. It is possible that even low levels of coliform, E. coli, or salmonella bacteria (< 10 CFU/ml) can quickly and exponential increase to dangerous levels. Organic contaminants also include non-living organic compounds, such as pesticides, fuel tank discharge, paints, sealants, and other contaminates. In the tri-state and great lakes regions, several commercial laboratories such as A&L Great Lakes Lab (Fort Wayne, IN), Dairyland Laboratories (Arcadia, WI), and Dairy One (Ithaca, NY) offer analytical services to test for some of these contaminants through high pressure liquid chromatography **(HPLC)**, gas liquid chromatography **(GLC)**, and liquid chromatography **(LC)**. Some rarely encountered contaminants, such as organophosphates, may require testing by highly specialized laboratories.

Dr. Jeffery Pyle and his associates with North Manchester Veterinary Clinic (North

Manchester, IN) work with some small and several very large veal growers in northern Indiana. Veal producers have a great sensitivity to water quality problems. The preferred sources for mixing milk replacer on small operations is water treatment by long term storage of chlorinated water in raised tanks. Frequent sampling is performed to confirm complete bacterial kill. On very large commercial veal operations, operators often take mineral content of well water out of the picture by using distilled water and by the use of citric acid to reduce pH of the water to near neutral (pH 7.0). Well water in northern Indiana is often of pH 7.6 to 7.8 (Table 2). Nearly neutral pH is preferred on veal operations because coagulation of casein (milk clot) in the abomasums of calves can be limited if water pH and buffering capacity is not modified. On these veal operations, distilled water is often used to closely control mineral concentrations, particularly of Fe and Cu. Iron concentrations in water and replacer are limited for two reasons. First because salmonella bacteria thrive in water with a high Fe content; and second, there is need to produce the pale coloration and meat quality for a traditional veal product. Veal calves receive needed iron by injection rather than by an oral route. The potential for explosion of coliform bacteria in milk replacer has prompted many veal growers to further treat previously chlorinated water with an in-line supply of ultraviolet radiation to reach the goal of zero CFU of bacteria in the final replacer delivered to calves. While the lengths taken to control inorganic and organic components in water used on veal operations may seem too costly and time consuming for use with dairy calves, lessons can be learned and new ways of controlling water quality for calves can be implemented by learning from veal growers who are striving to bring healthy calves from about 100 lb of initial BW to a well finished 550 lb of final BW in less than 19 weeks (133 days).

Take Home Message

- Insure that your producers consistently have clean, fresh water readily available for their calves.
- Suggest that producers supply you with current water test information which includes TDS, pH, mineral and mico-mineral concentrations, and information on presence, CFU/ml, and speciation of bacteria.
- Know the least expensive and most efficient methods available to modify mineral and microbial concentration of water fed to calves.

References

Appleman, R.D., and F.G.. Owens. 1975. Breeding, housing, and feeding management. J. Dairy Sci. 58:447-464.

Crowe, N.A., M.W. Neathery, W.J. Miller, L.A. Muse, C.T. Crowe, J.L. Varnadoe, and D.M. Blackmon. 1990. Influence of high dietary aluminum on performance and phosphorus bioavailability in dairy calves. J. Dairy Sci. 73:808-818.

Davis, C.L., and J.K. Drakley. 1998. The Development, Nutrition, and Management of the Young Calf. Iowa State University Press, Ames.

Flipot, P., G.. Lalande, and M.H. Fahmy. 1972. Effects of temperature of milk replacer and method of feeding on the performance of Holstein veal calves. Can. J. Anim. Sci. 52:659-664.

Greathouse, C. 1996. They spend less time and have healthier calves. Hoards Dairyman 141:567.

Hemken, R.W. 1993. Mineral requirements as affected by availability. Proceedings Tri-State Dairy Nutrition Conference. May 18-19, Ft. Wayne, IN. The Ohio State University, Columbus. pp. 51-54.

Jenkins, K.J., and M. Hidiroglou. 1990. Effects of elevated iodine in milk replacer on calf performance. J. Dairy Sci. 73:804-807.

Kertz, A.F., L.F. Reutzel, and J.H. Mahoney. 1984. Ad libitum water intake by neonatal calves and its relationship to calf starter intake, weight gain and feces score, and season. J. Dairy Sci. 67:2964-2969.

LeJeune, J.T., T.E. Besser, N.L. Merrill, D.H. Rice, and D.D. Hancock. 2001. Livestock drinking water microbiology and the factors influencing the quality of drinking water offered to cattle. J. Dairy Sci: 84:1856-1862.

Lewis, L.D., and R.W. Phillips. 1978. Pathophysiologic changes due to corona virus-induced diarrhea in the calf. J. Am. Vet. Med. Assoc. 173:636-642.

Linn, J., and M. Raeth-Knight. 2002. Water quality and quantity for dairy cattle. Proceedings ANEMBE (Spanish Veterinary Medical Association), Madrid, Spain. University of Minnesota, St.Paul

Loneragan, G.H., J.J. Wagner, D.H. Gould, F.B. Garry, and M.A. Thoren. 2001. Effects of water sulfate concentration on performance, water intake, and carcass characteristics. J. Anim. Sci. 79:2941-2948.

Mancl, K.M., and M.L. Eastridge, 1993. Approaches for handling problems with water quality. Proceedings of the Tri-State Dairy Nutrition Conference, Ft. Wayne, IN. The Ohio State University, Columbus. pp. 75-86.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington, DC.

Petersson, K.H., R.G. Warner, F.A. Kallfelz, and C.F. Crosetti.. 1988. Influence of magnesium, water, and sodium chloride on urolithiasis in veal calves. J. Dairy Sci. 71:3368-3377.

Socha, M.T., S.M. Ensley, D.J. Tomlinson, and A.B. Johnson. 2003. Proceedings of Intermountain Nutrition Conference, Salt Lake City, UT Pg.85-96. Publication No. 185 of the Utah Agriculture Experiment Station.

Socha, M.T., J.G. Linn, D.J. Tomlinson, and A.B. Johnson. 2001. Impact of variations in chemical composition of water on potential palatability and mineral intake of dairy cattle. J. Dairy Sci. 84. (Supp. 1):85. (Abstract)

Xin, Z., D.F. Waterman, R.W. Hemken, R.J. Harmon, and J.A. Jackson. 1991. Effects of copper sources and dietary cation-anion balance on copper availability and acid-base status in dairy calves. J. Dairy Sci. 74:3167-3173.

Table 1. Average concentration of macro- and micro-minerals in 238 rural water samples from IN, MI, and OH[1].

Item	TDS,mg/L	pH	Sulfates	Nitrates	Cl	Ca	P	Mg	K	Na	Fe	Zn	Cu	Mn	Mo
				ppm											
Average	598.82	7.46	79.30	5.29	82.53	77.09	0.11	27.97	4.26	69.71	1.08	0.09	0.03	0.14	0.02
Maximum	7664.00	9.20	1140.00	42.00	700.00	590.00	0.70	190.00	20.00	869.45	34.50	2.55	0.69	8.80	0.06
Minimum	20.00	4.40	0.58	0.00	1.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
±SD	587.69	0.56	137.38	7.49	148.43	65.25	0.19	21.58	3.95	123.66	2.47	0.23	0.07	0.57	0.01

[1]Data supplied by Zinpro Corporation (Eden Prairie, MN), with assistance from Agri-King (Fulton, IL), Dairy One (Ithaca, NY) and Dairyland Laboratories, Inc. (Arcadia, WI). TDS = total dissolved solids and SD = standard deviation.

Table 2. Number of samples and average pH and mineral concentration by zip code in Indiana, Michigan, and Ohio from the database of Socha et al, 2003.

State and Zip Code	Number of Samples	TDS (mg/L)[2]	pH	Sulfates	Nitrates	Cl	Ca	P	Mg	K	Na	Fe	Zn	Cu	Mn	Mo
					ppm											
Indiana																
46041	39	499	7.0	62.0	4.0	39.0	84.0	0.0	34.0	2.0	26.00	1.000	0.000	0.000	0.000	0.010
47339	56	588	8.0	40.0	9.0	30.0	60.0	0.0	21.0	2.0	109.00	1.000	0.000	0.000	0.000	0.010
Michigan																
48414	81	678	8.0	71.0	3.0	187.0	74.0	0.0	30.0	5.0	68.00	1.000	0.000	0.000	0.000	0.040
49008	40	595	7.3	148.0	4.1	42.9	109.2	0.3	29.9	4.2	54.00	0.566	0.059	0.053	0.044	0.010
Ohio																
43019	22	482	7.0	87.0	6.0	26.0	73.0	0.0	33.0	3.0	61.00	1.000	0.000	0.000	0.000	0.050
44021	89	612	7.0	92.0	6.0	34.0	74.0	0.0	26.0	6.0	75.00	1.000	0.000	0.000	0.000	0.020
46041	7	498	7.6	30.6	5.7	28.6	67.8	0.2	25.6	3.2	61.90	0.250	0.010	0.010	0.030	0.020

[1]Note: Water composition of samples are listed by zip code up to the next 1000 as summarized from Zinpro Corporation (Eden Prairie, MN).
[2]TDS = total dissolved solids.

Table 3. Guidelines for young stock water quality.[1]

Item	Upper Levels	Maximum Tolerable Limit
Aluminum, ppm	5.00	10.00
Arsenic, ppm	0.20	0.20
Barium, ppm	1.00	1.00
Bicarbonate, ppm	1000	1000
Boron, ppm	5.00	30.00
Cadmium, ppm	0.01	0.05
Calcium, ppm	100	200
Chloride, ppm	100	300
Chromium, ppm	0.10	1.00
Copper, ppm	0.20	0.50
Fluoride, ppm	2.00	2.00
Iron, ppm	0.20	0.40
Lead, ppm	0.05	0.10
Magnesium, ppm	50.0	100.0
Manganese, ppm	0.05	0.50
Mercury, ppm	0.01	0.01
Molybdenum, ppm	0.03	0.06
Nickel, ppm	0.25	1.00
Nitrate-nitrogen, ppm	20.00	100.00
pH	6 to 8.4	8.5
Phosphorus, ppm	0.70	0.70
Potassium, ppm	20.00	20.00
Selenium, ppm	0.05	0.10
Silver, ppm	0.05	0.05
Sodium, ppm	50.00	300.00
Sulfates, ppm	50.00	300.00
Total dissolved solids, ppm	960	3000
Vanadium, ppm	0.10	0.10
Zinc, ppm	5.00	25.00
Coliform, number/100 ml	0.50	0.50
Fecal coliform number/100 ml	0.1	0.1
Total bacteria, number/100 ml	1000	1000

[1]Taken from Socha et al., 2003.