Water Quality and Quantity for Dairy Cattle

Jim Linn and Mary Raeth-Knight
Department of Animal Science, University of Minnesota, linnx002@umn.edu

Water is a critical nutrient for dairy cattle and is required for numerous essential physiological functions. The total body weight of dairy cattle is 56 to 81% water, and water is the main component of milk and waste products (Murphy, 1992). Therefore, dairy cattle have a substantial daily requirement for water. Drinking water or free water intake, water contained in feed or feed water, and water produced during the oxidation of nutrients or metabolic water, are all important water sources used to meet this requirement. Dairy cattle obtain the greatest proportion of their water requirement from free water intake. On average, a dairy cow will consume 25 gallons of water each day. Clearly, providing dairy cattle an adequate supply of water is important. However, water consumption may be decreased if poor quality water is offered. Decreasing free water intake is undesirable as it will limit milk production and reduce health status, resulting in decreased producer profitability. Ensuring dairy cattle consume adequate quantities of water requires knowledge of factors which affect free water intake and treatment options used to improve drinking water. In addition, the mineral content of water may contribute substantially to the mineral requirements of dairy cows.

Predicting water intake

Equations to predict the water consumption of lactating dairy cattle have been developed by Castle and Thomas (1975), Little and Shaw (1978), Murphy et al. (1983), Stockdale and King (1983), Holter and Urban (1992), and Dahlborn, et al. (1998). Their equations identify major factors that affect water intake, including: dry matter intake, percent dry matter of the diet, milk production, environmental conditions and sodium intake. When estimating the water intake of lactating dairy cattle, the Dairy NRC 2001 suggests using the Murphy et al. equation in which the regression coefficient for milk production is very similar to the water content of milk (90% versus 87%). The additional variables, including dry matter intake, sodium intake and temperature, incorporated into the equation, are shown to have a significant positive correlation with free water intake. The equation is as follows:

$$\text{Free water intake (kg/d)} = 15.99 + (1.58 \times \text{DMI, kg/d}) + (0.9 \times \text{milk, kg/d}) + (0.05 \times \text{Na intake, g/d}) + (1.20 \times \text{min temp C})$$ *(Murphy et al., 1983)*

Research to predict the free water intake of dry cows is limited. However, Holter and Urban developed the following prediction equation for dry cows:

$$\text{Free water intake (kg/d)} = -10.34 + (0.2296 \times \text{dry matter \% of diet}) + 0.2212 \times \text{DMI (kg/d)} + (0.03944 \times (\text{CP\% of diet})^2)$$ *(Holter and Urban, 1992)*

Contribution of water to mineral requirements

Mineral analysis of 3,618 water samples taken from dairy farms throughout the United States indicate mineral content of water consumed by dairy cattle can significantly contribute to the mineral requirements of dairy cattle (Socha, et al., 2001). The data in Table 1 show the variability of mineral concentrations in water and the projected mineral consumed by the average dairy cow drinking 27 to 30 gallons of water per day.

Table 1. Impact of water on daily mineral intake for dairy cattle.

Mineral	Average water analysis, ppm	Water analysis range, ppm	Estimated daily intake of minerals
Calcium	64	0-590	7 g
Chloride	56	0-727	6 g
Copper	0.07	0-11	7 mg
Iron	0.79	0-123	8 mg
Magnesium	23	0-250	2 g
Manganese	0.17	0-12.7	18 mg
Potassium	3.3	0-33	0.3 g
Sodium	44	0-1,556	5 g
Sulfur	30	0-1,432	3 g

Adapted from Socha, et al., 2001.

Water quality criteria

Total Dissolved Solids (TDS), Total Soluble Salts (TSS) and Salinity

Total dissolved solids, total soluble salts and salinity are physiochemical properties of water used to assess water quality. These terms are used synonymously and measure the amount of sodium chloride, bicarbonate, sulfate, calcium, magnesium, silica, iron, nitrate, strontium, potassium, carbonate, phosphorus, boron and fluoride in water (NRC, 2001). Research to determine the effects of TDS on the performance of lactating dairy cattle has produced varying results on water intake, feed intake and milk production. However, research indicates high levels of TDS combined with increased environmental temperature do have a detrimental affect on the milk production of dairy cattle (Solomon et al., 1995; Sanchez et al., 1994; Challis et al., 1987). The TDS guidelines, provided by the National Research Council (2001), suggest that water containing <5,000 ppm TDS may be fed to lactating cattle. However, water containing >7,000 ppm is unacceptable for all cattle (NRC, 2001).

Hardness

Hardness, also a physiochemical property of water, is generally a measure of the calcium and magnesium ions in water. Zinc, iron, strontium, aluminum, and manganese can also contribute to water hardness; however, they are generally present in very low concentrations (NRC, 2001). Water is classified as soft at 0-60 ppm, moderately hard at 61-120 ppm, hard at 121-180 ppm and very hard at >180 ppm (NRC, 2001). Studies do not report any performance affect due to the consumption of hard water by dairy cattle.

Nitrates

Drinking water, especially from surface or shallow ground water, may become contaminated with high levels of nitrates. Sources of nitrates in water include fertilizers, animal waste, fecal material, crop residue or industrial waste. Nitrate poisoning results from a bacterial reduction of nitrate to nitrite in the rumen with the nitrite being absorbed into the blood and reducing the oxygen carrying capacity. Symptoms of acute nitrate poisoning include asphyxiation and labored breathing, rapid heartbeat, frothing at the mouth, convulsions, bluish discoloration around mouth and eyes and chocolate brown colored blood. Nitrate-nitrogen concentrations in water less than 10 mg/L and nitrate concentrations less than 44 mg/L are generally considered safe for dairy cattle (NRC, 2001).

Sulfates

Calcium, iron, magnesium and sodium salts are common forms of sulfate found in water, while hydrogen sulfide is the most toxic form (NRC, 2001). High concentrations of sulfates, especially sodium sulfate, produce a laxative effect in cattle. However, normally within one week, cattle become acclimated to the water and diarrhea is no longer apparent. Sulfate concentrations <500 mg/L and <1,000 mg/L are generally recommended for calves and adult cattle, respectively.

However, toxicity at levels >500 mg/L is dependent on the specific form of sulfate in the water (NRC, 2001).

Research has shown sulfate water can have a deleterious effect on cattle performance. Cattle consuming water with a sulfate concentration >5,000 mg/L had decreased feed and water intake (Weeth, et al., 1971). However, no effect on feed and water intake or growth was seen when cattle consumed water up to 2,500 mg/L of sulfate for 90 days (Digesti, et al., 1976). Recent research by Loneragan et al. (2001) has shown a linear decrease in average daily gain of feedlot steers as sulfate concentration in the drinking water increased from 136 to 2,360 mg/L. Over the 16-week study, cattle initially consuming 290 and 590 mg/L sulfate water had the fastest gains, but towards the end of the study higher sulfate waters seemed to improve gains. In general, water sulfate concentrations >583 mg/L, equivalent to 0.22% of the diet DM, decreased feedlot cattle performance.

pH

A general guideline for the pH of water has not been established due to the lack of scientific literature determining the effects of water pH on water intake, milk production and dairy cattle health.

Iron and manganese

Neither iron nor manganese in water presents a health hazard to dairy cattle. However, the presence of these minerals may cause a taste and fixture-staining problem along with accumulation in pipes reducing water flow.

Other potentially toxic contaminants

Guidelines for the upper limits of additional water contaminants for dairy cattle are contained in Table 2.

Water microbiology

Water should be analyzed for coliform bacteria and other microorganisms to determine the microbial quality of livestock drinking water. Analysis is important as highly contaminated water exposes dairy cattle to pathogenic organisms and, therefore, increases the potential for disease. Although microorganisms can contaminate water in wells, bacterial contamination most often occurs in the drinking vessel. Consequently, maintaining clean water troughs is imperative. In a survey of 473 cattle water troughs by LeJeune et al. (2001), *Salmonella* sp was isolated from 0.8% and *E. coli* 0157 was recovered from 1.3% of the troughs. The degree of *E. coli* contamination increased as the distance between water troughs and feed bunks decreased, and when exposure of the drinking water to sunlight decreased.

Table 2. Water contaminate guidelines.

Toxic nutrient or contaminant	Upper limit guideline (mg/L or ppm)
Aluminum	0.5
Arsenic	0.05
Boron	5.0
Cadmium	0.005
Chromium	0.1
Cobalt	1.0
Copper	1.0
Fluorine	2.0
Lead	0.015
Manganese	0.05
Mercury	0.01
Nickel	0.25
Selenium	0.05
Vanadium	0.1
Zinc	5.0

National Research Council, 2001.

Water treatment options

Water treatment, used to remove or reduce contaminants, can be expensive and may require significant equipment maintenance. Therefore, the decision to treat should be established by laboratory analysis of drinking water. Treatment must also be cost effective and result in known health or production benefits for cattle. Options for treating dairy cattle drinking water are dependent on the target contaminant. These options are listed below and summarized in Table 3.

Decreasing microorganisms in water

Disinfection is a process used to eliminate pathogenic microorganisms in water. The most common chemical disinfectant used is chlorine. A non-chemical disinfectant process is with ultraviolet light. The effectiveness of disinfecting water is ultimately dependent on the cleanliness

Table 3. Water treatment options associated with water contaminants.

Treatments	Bacteria	Sulfates	Contaminants Nitrates	TDS	Hardness
Chlorine	**X**				
UV light	**X**				
Reverse osmosis		**X**	**X**	x	x
Distillation		**X**	**X**	x	x
Ion exchange (water softener)		x	x	x	x

X = contaminant removed; **x** = contaminant reduced.

of drinking vessels. Long-term use of disinfectants is not recommended for contaminated wells because any failure of disinfecting equipment will expose livestock to pathogens, and recent evidence suggests chlorine can combine with organic matter in water to form trihalomethanes which are considered carcinogenic (Bergsrud and Linn, 1990).

Chlorine

Chlorine is a powerful oxidizing agent and the most commonly used disinfectant because it is inexpensive and effective at low concentrations. In addition, if applied in a sufficient dose,chlorine has a residual effect. Therefore, chlorine remaining in the water can continue to destroy bacteria (Reynolds and Richards, 1996). Although chlorine is inexpensive, chlorination requires a contact tank that allows the chlorine time to disinfect the water. Additional maintenance is neither difficult nor expensive (Mancl and Eastridge, 1993).

Ultraviolet light

UV light can be a viable method used to disinfect water. However, the effectiveness of UV irradiation as a disinfectant is dependent on the ability of the radiation to pass through the water and contact microorganisms. Therefore, filtration may be necessary for cloudy or discolored water (Mancl and Eastridge, 1993). Also, UV light does not provide residual disinfection.

Decreasing nitrates, sulfates and minerals in water

Distillation, reverse osmosis and ion exchange are three treatment methods used to remove or reduce nitrates, sulfates and minerals in water.

Distillation

Distillation and reverse osmosis removes water contaminants through demineralization. During distillation water is boiled to form steam. The steam is captured, cooled and condensed to form water. Nitrates, sulfates and all other minerals are removed as they remain in the boiling tank.

Reverse osmosis

Reverse osmosis removes nitrates, sulfates and all other minerals by separating water from saline solution. This occurs when water is pressurized and forced through a semi-permeable membrane.

Ion exchange system

Ion exchange systems can be used to decrease nitrates, sulfates, water hardness and TDS. The main components of an ion exchange system are an exchange column filled with ion exchange resin, waste storage tank and regeneration solution tank (Reynolds and Richards, 1996). During nitrate or sulfate reduction, these ions are usually exchanged with chlorine ions. However, during water softening, calcium and magnesium ions are exchanged for sodium ions. Waste brine containing contaminants removed from the water is stored in the waste storage tank and regeneration solution is used to recharge the resin.

References

Bergsrud, F., and J. Linn. 1990. Water quality for livestock and poultry. Univ. of Minnesota, St. Paul. AG-FO-1864-D.

Challis, D. J., J. S. Zeinstra, and M. J. Anderson. 1987. Some effects of water quality on the performance of high yielding dairy cows in an arid climate. Vet. Rec. 120:12-15.

Digesti, R. D., and H. J. Weeth. 1976. A defensible maximum for inorganic sulfate in drinking water for cattle. J. Anim. Sci. 42:1498-1502.

Holter, J. B., and W. E. Urban, Jr. 1992. Water partitioning and intake prediction in dry and lactating Holstein cows. J. Dairy Sci. 75:1472-1479.

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. 184:1856-1862.

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 of feedlot steers. J. Anim. Sci. 79:2941-2948.

Mancl, K. M., and M. L. Eastridge. 1993. Approaches for handling problems with water quality. Tri-State Dairy Nutrition Conference. 75-86.

Murphy, M. R., C. L. Davis, and G. C. McCoy. 1983. Factors affecting water consumption by Holstein cows in early lactation. J. Dairy Sci. 66:35-38.

Murphy, M. R. 1992. Water metabolism of dairy cattle. J. Dairy Sci. 75:326-333.

National Research Council. 2001. *Nutrient Requirements of Dairy Cattle*, 7th Rev. Ed. National Academy Press, Washington, D.C.

Reynolds, T. D., and P. A. Richards. 1996. *Unit Operations and Processes in Environmental Engineering*. PWS Publishing Company, Boston, MA.

Sanchez, W. K., M. A. McGuire, and D. K. Beede. 1994. Macromineral nutrition by heat stress interactions in dairy cattle: Review and original research. J. Dairy Sci. 77:2051-2079.

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, Suppl. 1.

Solomon, R., J. Miron, and D. Ben-Ghedalia. 1995. Performance of high producing dairy cows offered drinking water of high and low salinity in the Arava desert. J. Dairy Sci. 78:620-624.

Weeth, H. J., and L. H. Hunter. 1971. Drinking of sulfate water by cattle. J. Anim. Sci. 32:277-281.