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Calf Note #284 – Water Quality for Calf Milk Replacer

Introduction

Water is sometimes treated as an afterthought in calf nutrition, though I've addressed several aspects of feeding water and water quality for calves in Calf Notes 004, 068, 077, 101, 132, 158, 232, and 251. It's time to come back to the topic and review some recent research regarding water quality in calf milk replacer (**CMR**).

We spend considerable time evaluating the protein, fat, lactose, minerals, vitamins, and other components of CMR, yet most of the product that actually enters the calf is water.

Consider a calf receiving 6 L of CMR per day at 13% solids. Approximately 87% of that mixture is water. Without getting concerned about small differences attributable to density or specific gravity, that means the calf consumes more than 5 L of water each day simply as part of its CMR. Increase the milk allowance to 8 or 10 L/d and the amount of water delivered through CMR increases proportionately. And that is before we count any free water consumed from a bucket or waterer.

Thus, water used to mix CMR should probably be thought of as an ingredient in the diet, not simply as the carrier used to get milk replacer powder into the calf. Whatever is dissolved or suspended in that water—minerals, salts, bacteria, coliforms, nitrate, sulfate, iron, or other contaminants—is also being delivered to the calf, often several liters per day.

This seems obvious when stated that way. What is less obvious is how little experimental information we have regarding what constitutes *good* water for a young dairy calf. So, what do we know?

Numerous recommendations are available for livestock water quality. I've listed a few at the end of this Calf Note. Guidelines commonly include suggested limits for total dissolved solids (**TDS**), sulfate, nitrate and nitrite, iron, manganese, hardness, salinity, and microbial contamination. However, relatively few of these limits have been established from controlled experiments with preweaned dairy calves. When it comes to water quality, most recommendations for calves are generalities extrapolated from adult animals or from other species. However, two controlled studies provide new insight into the actual definition of "quality" in "water quality".

Reverse-osmosis versus municipal water

Senevirathne et al. (2018) evaluated water quality in 24 Holstein calves beginning at 2 d of age. Calves were assigned to either municipal water or water treated by reverse osmosis (**RO**). Importantly, treatment water was used both to mix the CMR and provide free-choice drinking water.

During the first 5 wk, calves received 0.45 kg of CMR powder mixed with 2.83 L of their assigned water twice daily. Thus, water quality affected approximately 5.7 L of water used for CMR preparation every day, in addition to whatever free water the calves consumed.

The two waters differed considerably in mineral composition. The municipal water contained about 249 mg/L hardness compared with 17 mg/L in the RO water. Sulfate concentrations were approximately 195 versus 1.4 mg/L, respectively. Calcium was 40 versus 5 mg/L, magnesium was 36 versus 1 mg/L, and iron was 0.17 versus 0.04 mg/L. The authors also reported a substantial difference in TDS depending upon the method of measurement, with conductivity-based values of approximately 387 mg/L for municipal water and 13 mg/L for RO water. *E. coli* was not detected in either water source.

Despite these large differences in water composition, the effects on calf growth were modest. Body weight, average daily gain, frame growth, and nutrient digestibility were similar between treatments. Feed efficiency was improved with RO water during portions of the early feeding period, but this advantage did not persist throughout the experiment.

There were some interesting health responses. Fecal scores tended to be lower—feces were firmer—in calves receiving RO water, although the response varied with week. During the preweaning period, average fecal scores were not dramatically different. Body temperature was slightly lower in calves receiving RO water during the preweaning period, and respiratory scores improved during portions of the weaning period. Overall, however, this was not a study in which water purification produced a dramatic improvement in growth or health.

Variable	Municipal	RO	SEM	*P*
Free water intake, kg/d				
Overall	3.85	3.66	0.36	0.01
Preweaning	2.02	2.02	0.08	0.88
Postweaning	6.58	6.60	0.10	0.96
Starter DMI, g/d				
Overall	1,030.7	1,032.5	85.3	0.91
Preweaning	258.1	271.2	29.2	0.68
Postweaning	2,176.3	2,289.6	23.3	<0.01
Total DMI, g/d				
Overall	1,501.6	1,507.5	83.5	0.72
Preweaning	1,042.9	1,061.2	21.6	0.53
Postweaning	2,176.3	2,289.6	23.3	<0.01
Body weight, kg				
Week 0	43.07	44.19	1.24	0.52
Week 6, weaning	68.95	68.40	1.95	0.83
Week 10	93.91	93.86	1.95	0.98
ADG, kg/d	0.70	0.72	0.03	0.68

There is another important limitation in interpreting the study. Reverse osmosis changed many characteristics of the water simultaneously. Calcium, magnesium, sulfate, hardness, TDS, iron, sodium, chloride, and other constituents all changed.

Consequently, we cannot conclude from this experiment that 195 mg/L sulfate was harmful, that 249 mg/L hardness was excessive, or that one particular mineral caused the modest differences in health. In fact, the municipal water would not generally be considered severely contaminated livestock water.

The study tells us that changing overall water quality can affect calves. It does **not** establish a threshold for any individual mineral.

Purified versus tap water

A particularly interesting study was published recently by Carvalho et al. (2026). Thirty Holstein calves were assigned to municipal tap water or purified water. Again, the assigned water was used both for CMR preparation and as free drinking water.

Calves received 6 L/d of milk replacer containing 14% solids until gradual weaning beginning at about 7 wk. At that concentration, more than 5 L of the calf's daily CMR was water. Thus, even before a calf approached its water bucket, it was already receiving a substantial daily exposure to the experimental water source.

Chemically, the difference between the two waters was surprisingly small. Electrical conductivity averaged approximately 375 μS/cm for tap water and 358 μS/cm for purified water. Nitrate concentrations averaged 1.67 and 0.97 mg/L, respectively, and were not statistically different. Nitrite concentrations were also low.

The major difference appeared to be microbiological. No bacterial growth was detected in the purified water during the study. In contrast, bacterial counts in the tap water varied from no detectable growth in some samples to as much as 7,200 cfu/100 mL in others. Average total coliform counts were approximately 854 cfu/mL in the tap water and were not detected in purified water.

Growth responses again were not spectacular. Milk replacer intake, starter intake, and total dry matter intake were not significantly affected. Average daily gain was greater for calves receiving purified water during wk 3, and feed efficiency was also improved during that period, but final body weight did not differ significantly.

The health results may be more important. All calves experienced diarrhea at some point during the experiment. However, calves receiving purified water averaged 25.9 d with diarrhea compared with 31.7 d for calves receiving tap water, an approximately 18% reduction. Calves receiving purified water also tended to require fewer days of antibiotic treatment—about 10 versus 14 d. Not every health response favored purified water; days with cough were actually greater in those calves. Thus, even this study does not provide a perfectly clean biological story.

Nevertheless, the reduction in days with diarrhea is noteworthy because the chemical composition of the waters was relatively similar while the microbiological quality differed markedly. This suggests that, at least under the conditions of this experiment, microbial quality may have been more important than mineral concentration.

Again, however, caution is warranted. Purification changed more than one characteristic of the water, and because the same water was used for both CMR preparation and free-choice drinking, we cannot determine whether the benefit came primarily from cleaner water entering the milk replacer, cleaner drinking water, or both.

What about field data?

Kamal et al. (2024) evaluated water samples from 132 cattle farms in Egypt with histories of calf-health problems. Water was analyzed for TDS, hardness, chloride, nitrate, sulfate, total bacterial counts, and coliforms. Higher concentrations of several water contaminants were associated with increased diarrhea, respiratory disease, depression, sudden death, and mortality. Nitrate, TDS, sulfate, and microbial contamination were among the variables associated with adverse outcomes.

These results support the idea that poor water quality can contribute to calf-health problems. However, this was an observational field study involving dairy, beef, and mixed farms already experiencing disease problems. Water-quality measurements were also correlated with farm hygiene and management factors. Consequently, the study identifies associations but cannot establish that a particular concentration of nitrate, sulfate, bacteria, or TDS **caused** disease.

So, what is "good" calf water?

This is where the science becomes frustrating.

We have livestock-water guidelines specifying concentrations that are considered acceptable, marginal, or potentially harmful. Those guidelines are useful. But there is surprisingly little controlled calf research demonstrating that, for example:

- 200 mg/L sulfate is acceptable, but 500 mg/L reduces performance;
- a particular concentration of iron increases diarrhea;
- a specific hardness value reduces starter intake;
- a defined TDS concentration adversely affects CMR-fed calves; or
- a particular bacterial count produces a measurable increase in calf morbidity.

Most numerical recommendations have been developed from the broader livestock literature, mature cattle, toxicological considerations, human drinking-water standards, field observations, or professional judgment rather than dose-response experiments conducted in young dairy calves.

The two controlled studies reviewed here do not solve this problem. Both compared relatively complex water treatments. Reverse osmosis and purification alter multiple components simultaneously. Neither experiment tells us the concentration at which a specific mineral becomes biologically important.

Practical implications

The lack of precise experimental thresholds should not be interpreted to mean that water quality is unimportant. Quite the opposite.

A calf fed 6 L/d of CMR at approximately 13% solids consumes more than 5 L of water through the CMR itself. Calves on larger milk allowances consume still more. In addition, calves should have free access to drinking water from early in life, adding another source of exposure.

Therefore, questionable water is not a minor ingredient in a calf-feeding program. It can be one of the largest ingredients by weight that the calf consumes every day.

Where a municipal potable-water supply is available, it provides a reasonable starting point, although the Carvalho study demonstrates that even municipal water may vary microbiologically. Farms using wells or other private water sources should periodically evaluate both chemical and microbiological quality, particularly where calf diarrhea, poor intake, unexplained health problems, or inconsistent CMR performance occur.

High bacterial or coliform counts deserve particular attention because the newest controlled evidence suggests that reducing microbial contamination may reduce the duration of diarrhea. Water used to mix CMR should be evaluated at the point where the milk replacer is actually mixed, not simply at the wellhead. Pipes, hoses, storage tanks, mixing equipment, and other components of the delivery system can change water quality between the source and the calf.

Mineral analyses are also useful, particularly for nitrate, sulfate, iron, salinity/TDS, and unusual hardness. However, numerical limits should be interpreted as guidelines rather than precisely validated biological thresholds for preweaned calves.

Finally, water treatment should not automatically be assumed to improve calf performance. Reverse osmosis can produce very low-mineral water, but the limited calf research does not demonstrate that every farm with hard or moderately mineralized water will obtain a growth response from installing an RO system. Treatment decisions should be based on analysis of the actual water supply and the problem that needs to be corrected.

Summary

Water deserves more attention in calf nutrition. A calf consuming 6 L of CMR daily may receive more than 5 L of water through that milk replacer, in addition to free drinking water. Consequently, water quality can influence a calf through much more than the water bucket.

Controlled research remains remarkably limited. Senevirathne et al. (2018) reported modest health and feed-efficiency responses when municipal water was replaced with reverse-osmosis water, without an overall improvement in growth. Carvalho et al. (2026) found that purified water reduced days with diarrhea and tended to reduce antibiotic treatment, with the major difference between treatments appearing to be microbiological rather than mineral.

Together, these studies support a simple conclusion: good water probably matters, particularly for calf health. Unfortunately, we still have surprisingly little calf-specific research telling us exactly what "good" means.

Until we have better dose-response data, the most defensible approach is to provide water of potable quality whenever practical, monitor private water sources for both microbial and chemical contamination, correct obvious problems, and avoid interpreting generalized livestock-water guidelines as experimentally established requirements for the young dairy calf.

Popular Press Articles

The value of water for calf growth (Denkavit)

Feeding Pre-weaned Calves, Part 3: Water (Ohio State University)

Water: A critical and undervalued nutrient in dairy calves (Univ. of Wisconsin)

Water for calves (AHDB)

References

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