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Short Communication

The effect of water quality on cattle performance on pasture

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Abstract. In western Canada, dugouts are the primary source of water for beef cattle during the summer months. Over time, drought conditions and/or direct access by grazing animals have a negative effect on water constituents and overall water quality. A study was conducted to determine the effects of improvements in water quality on cattle performance. The effect of pasture water quality on weight gain of beef cattle was assessed with 44 Hereford yearling steers over 5 years and 40 Angus cow–calf pairs over 3 years. From 1999 to 2003, cattle were allocated to 1 of 4 treatments, which comprised untreated dugout water pumped to a trough, aerated water pumped to a trough, and coagulated and chlorinated water pumped to a trough, all compared with direct access by livestock to the water source. Data were collected on livestock weight gains, water consumption, fecal parasites, environmental conditions, water chemistry, biological constituents, and forage production and quality. Water treatment by aeration or coagulation tended to improve steer weight gains ($P < 0.05$) over untreated water from a dugout in 3 of 5 years. Daily weight gains tended to be improved slightly by simply pumping water to a trough without treatment. Water aerated and pumped to a trough in early summer tended to produce greater ($P < 0.05$) weight gains in calves than those drinking directly from the dugout. The effect of treatment on improving cattle weight gains appeared to be related to improved water palatability, which increased water and feed consumption. Water chemistry and biological constituents analysed did not identify significant differences among treatments. These results suggest that improving water quality with aeration and pumping to a trough will improve weight gain 9–10% over a 90-day grazing period in most years.

Additional keywords: weight gain, aeration, coagulation, steer.

Introduction

Water accounts for 50–80% of an animal's liveweight, depending on age and degree of fat cover, and is involved directly or indirectly in every physiological process occurring within the animal. Water is a medium for transportation of nutrients, waste products, hormones, and other chemical messengers, and aids in the movement of food through the gastrointestinal tract. Water helps regulate blood osmotic pressure and is a major component of secretions such as saliva and milk. Body temperature is also regulated through the evaporation of water from the respiratory tract and the skin's surface (Roubicek 1969). The water supply of ruminant animals consists of water consumed voluntarily, water in the feed, and metabolic water.

Several animal and environmental factors affect water intake in cattle. Animal factors include body size (Pandey *et al.* 1989), dry matter intake (Hicks *et al.* 1988), and stage of production (Beaver *et al.* 1989). Holechek (1980) reported a decrease in water consumption and animal weight gain from cattle drinking from a water source contaminated by feces and urine. Water and forage intake are closely related (Hyder *et al.* 1968). Average water consumption per animal unit (AU) was estimated at 48.9 L/day increasing by 0.81 L/AU for each degree Celsius increase in maximum daily temperature (Ali *et al.* 1994). It has been estimated that cattle require approximately 2–4 kg of water for every 1 kg of feed consumed (Utley *et al.* 1970).

In western Canada, dugouts are a common means of storing water for range cattle. Variability in the quality of dugout water raises questions about the possible effects on animal health and productivity. Surface water dugouts can be expected to have natural microbiological contamination such as bacteria, parasites, and viruses (Olson *et al.* 1996). Dugouts that are fed by groundwater may contain mineral salt concentrations at levels that could compromise animal health (Barrio *et al.* 1989). Through exposure to surface runoff,

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all dugouts become sinks for nutrients. Nutrient enrichment may lead to proliferation of algal populations, which may produce liver toxins or neurotoxins from *Cyanobacterium* spp. and blue-green algae. Direct access of livestock to dugout water may allow for the spread of pathogens from one animal to the whole herd (Meyer 1985). *Giardia* and *Cryptosporidium* spp. are prevalent in the cattle population and may negatively affect animal performance (Anderson 1987). It is also known that cattle are sensitive to taste and odour in water, which may limit intake of less palatable water, possibly leading to reduced weight gain (Willms *et al.* 1996). Willms *et al.* (1994) reported a 20% decrease in weight gain of yearling steers as a result of drinking from dugouts over a 70-day period in summer. Another study reported that heifers having access to clean water gained 23% more weight than those consuming water from direct access to a pond (Willms *et al.* 2002). Finally, it is important to determine the effects of water quality on animal performance so that appropriate management practices can be developed. Therefore the objectives of this study were to determine the effects of improvements in water quality and parasite contamination on the performance of grazing cattle during the summer months.

Materials and methods

The effect of water treatment on cattle performance was tested in 2 experiments, one with steers (Yearling experiment) and a second with cow–calf pairs (Cow–Calf experiment), at a site 8 km east of Lanigan, Saskatchewan, Canada (51°51′N, 105°02′W), at the Western Beef Development Centre's Termuende Research Farm. Each experiment consisted of 4 water treatments assigned to 1 of a series of 4 paddocks in a randomised complete block design, with 5 (Yearling experiment) or 3 (Cow–Calf experiment) replicates (years). The treatments were direct access to the dugout (Water$_{\text{direct}}$), water pumped from the dugout to a trough (Water$_{\text{pumped}}$), dugout water treated with coagulation and chlorination (Water$_{\text{coag}}$), and water treated with aeration (Water$_{\text{aerated}}$). The latter 2 treatments were implemented before being pumped to the respective troughs. A single dugout supported both experiments throughout the study, with the paddocks blocked in groups of 4 on either side. The same paddocks were used repeatedly over the study period and treatments were randomised among paddocks each year. The Yearling experiment was conducted from 5 June to 29 September 1999 (96 days), 23 May to 6 September 2000 (106 days), 23 May to 30 August 2001 (99 days), 2 July to 16 September 2002 (76 days), and 30 May to 29 August 2003 (92 days). The Cow–Calf experiment was conducted from 1 June to 29 August 2000 (90 days), 4 June to 30 August 2001 (86 days), and 15 July to 16 September 2002 (61 days).

Environmental conditions

Monthly average precipitation and temperature were recorded at a meteorological station at the Termuende Research Farm, Lanigan, Saskatchewan, Canada. Total precipitation at the study site from April to September was 258.4, 207.3, 153.3, 342.0, and 208.7 mm for 1999, 2000, 2001, 2002, and 2003, respectively. The 30-year average for the Lanigan area is 278.9 mm. Near average or above normal levels of total rainfall were observed in all years except in 2000 and 2001. Monthly levels were well below 30-year averages in July and September of 2000 and June and August of 2001. However, monthly averages for rainfall were higher than the 30-year average during July and August of 2002. Mean monthly temperatures for April, May, June, July, August, and September were 5.8, 10.5, 14.3, 16.2, 16.6, and 12.1°C in 1999; 3.5, 10.4, 13.6, 18.3, 16.6, and 10.7°C in 2000; 3.8, 11.9, 15.0, 18.9, 18.8, and 12.3°C in 2001; 1.2, 7.9, 17.4, 19.4, 14.3, and 9.5°C in 2002; and 4.4, 12.0, 16.0, 18.5, 20.1, and 10.6°C in 2003. The 30-year average temperature for April to September is 3.2, 11.2, 16.1, 18.4, 17.7, and 11.5°C for the Lanigan area. Mean monthly temperatures were similar to long-term averages except in May, August, and September of 2002 when cooler temperatures were observed.

Pasture characteristics

The pasture for each treatment consisted of 4 subpaddocks that were grazed in rotation over the trial period. In the Yearling experiment, each paddock was about 7.8 ha in area and contained predominantly a mixture of crested wheatgrass (*Agropyron pectiniforme* R. & S.), smooth bromegrass (*Bromus inermis* Leyss.), and alfalfa (*Medicago sativa* L.). All paddocks were similar in per cent species composition, consisting of 70% crested wheatgrass, 25% smooth bromegrass, and 5% alfalfa. The area of each paddock in the Cow–Calf experiment was about 9.5 ha with similar monocultures of either Russian wildrye (*Psathyrostachys juncea* [Fisch.] Nevski) or fall rye (*Secale cereale*). Herbage mass on steer pastures at turnout for 1999–2003 was 2475, 2464, 1300, 1030, and 3216 kg dry matter (DM)/ha, respectively. Herbage mass on cow–calf pastures at turnout for 2000–02 was 1513, 1260, and 1645 kg DM/ha, respectively. Topography at the pasture site was gently to moderately hummocky and the soils were a mixture of Oxbow Orthic Black and carbonated Oxbow (Saskatoon Institute of Pedology 1992), with a loam texture. All paddocks were fertilised each spring with 34 kg/ha of NH_4NO_3 at about 2 weeks prior to the first turnout date.

Forage quality was similar in all years across paddocks, with levels of energy and crude protein adequate for steers and cows (National Research Council 1996). Forage energy levels of steer paddocks ranged from 56 to 65% total digestible nutrients (TDN) in June to 54–64% TDN in late August over all years. TDN ranged from 64 to 71% (May) to 58–61% (August) across years for Russian wildrye pastures and from 72 to 74% (July) to 68% (August) across all years on fall rye paddocks. Protein values ranged from 10 to 12% in June to 8–16% in August for crested wheatgrass (Yearling) paddocks over all years. Russian wildrye pasture had protein values ranging from 16 to 19% in May and 14–16% in August across all years. Finally, crude protein of the fall rye pastures (Cow–Calf) ranged from 30 to 33% in June to 26–29% in August for all years.

Water management

The dugout had top dimensions of 60 m by 20 m and was 4 m deep and had 4 : 1 end slopes and 1.5 : 1 side slopes. The dugout was partitioned into 3 separate cells with curtains of 30-mL polyethylene plastic. The curtains were fitted with an edge pocket to allow containment of a weighting chain. The top of the curtain was fastened with a cable and end anchors. At the end of every year the curtain was lifted over the winter, allowing water conditions to be similar in all cells at the start of trial the following year. In this study the end dugout cell was open to allow direct access (Water$_{\text{direct}}$) separately by yearling steers and cow–calf pairs. The middle dugout cell was untreated water pumped (Water$_{\text{pumped}}$) to troughs for each group of livestock. The third dugout cell was continuously aerated (Water$_{\text{aerated}}$) using a solar-powered compressor and diffusion system and the water was also pumped to a trough. Adjacent to the dugout a coagulation cell was constructed, lined with polyethylene, and filled with untreated dugout water. This water was then coagulated (Water$_{\text{coag}}$) using a batch treatment of aluminum sulfate and powdered activated carbon. Coagulation is highly effective at removing impurities such as colour, turbidity, phosphorous, and dissolved organic carbon. Finally, chlorine was added at 1.0 mg/L as the water was pumped to a trough, providing continuous treatment of the coagulated water using chlorination.

The equipment for pumping, aerating, data logging, energy storage, and triggering pumps was housed in a 2.0 by 2.6 m wooden shed. Four 60-W solar panels provided energy for operation of the pumps, aeration system, logger, sensors, and cell phone. A Campbell Scientific CR10X (Campbell Scientific Inc.) data logger was used to log various parameters including pump operation, aerator operation, wind speed, rainfall, air temperature, and dissolved oxygen. The pumps operated by the solar system supplied water to troughs 2.2 by 0.4 m in diameter and 0.6-m deep (capacity 845 L). Each trough was placed at a convenient location for each group of animals.

Water consumption was monitored for the 3 pumped water types by logging run times, to the nearest 5 s, of the diaphragm pumps. The daily water consumption was determined from these data. The evaporation losses from the troughs were considered negligible, and no adjustments were made for these losses. Water consumption for the direct entry group of yearlings could not be monitored. The pumps were tested several times throughout the year for variations in flow rate with fluctuations in dugout level. In general the pumps performed close to a positive displacement pump and had little fluctuation in pumping rates. Trough water level was maintained by using a float system with a telephone cable to relay signals back to the pumps.

Water quality was monitored every 2 weeks beginning on 14 June and ending 31 August each year. Samples were drawn directly from the 3 troughs and the direct entry cell. Samples were sent to the laboratory (Saskatchewan Research Council, Saskatoon, Saskatchewan) for water chemistry analysis (Table 1). In addition, field tests on the coagulation cell and the dugout included dissolved oxygen, bacteria, and minerals. Dissolved oxygen concentrations were also monitored for 2 months in the unaerated cell at depths of 1 m below the surface and 1 m above the bottom of the dugout.

Cattle and grazing management

From 1999 to 2003, forty-four 14-month-old Hereford crossbred steers, averaging 295 ± 4 kg body weight (BW), were stratified by weight, tagged to allow individual identification, and randomly assigned to 1 of 4 treatment pastures (11 steers per water treatment). Forty 3-year-old Angus cows averaging 545 ± 12 kg BW, and forty 3-month-old Angus calves averaging 136 ± 2 kg BW, were also stratified into similar weight groups and assigned to each treatment from 2000 to 2002. Each treatment included 10 cow–calf pairs that were tagged to allow individual identification. Free choice mineral (1 : 1) and

Table 1. Concentration of selected constituents in water offered to cattle (1999–2003)
DO, dissolved oxygen at top and bottom of dugout

Water type	*E. coli* (ct/100 mL)	Fe (mg/L)	Mn (mg/L)	Chlor A (µg/L)	Sulfate (mg/L)	DOC (mg/L)	Total P[A] (mg/L)	DO (top)	DO (bottom)
				1999					
Direct access	3504	1.55	0.13	82	2	19.2	0.25	8.6	5.1
Pumped	572	1.64	0.21	58	2	16.8	–	9.8	4.8
Aerated	28	1.27	0.23	63	2	17.0	–	8.3	7.4
Coagulated	27	0.03	0.06	1	90	8.4	–	8.6	9.0
				2000					
Direct access	6594	5.38	0.56	404	4	28.0	0.95	5.7	1.2
Pumped	193	1.98	0.28	174	3	25.0	0.64	7.8	1.6
Aerated	79	1.32	0.24	128	14	24.3	0.64	7.7	7.2
Coagulated	67	0.10	0.09	10	106	11.1	0.06	8.3	8.2
				2001					
Direct access	5950	2.09	0.44	28	333	39.0	0.45	3.9	3.1
Pumped	97	0.13	0.20	41	403	37.3	0.38	6.0	2.4
Aerated	13	0.13	0.20	41	413	37.0	0.39	7.0	6.9
Coagulated	10	0.02	0.03	5	385	13.5	0.06	7.5	6.7
				2002					
Direct access	5976	2.01	0.44	74	81	28.5	1.02	4.7	1.9
Pumped	728	0.21	0.20	49	83	25.2	0.81	10.8	1.7
Aerated	949	0.25	0.31	82	82	25.6	0.77	7.7	5.5
Coagulated	7	0.03	0.03	6	236	11.2	0.03	9.7	9.3
				2003					
Direct access	706	2.11	0.41	109	6	23.9	0.75	5.4	0.6
Pumped	8	1.10	0.26	22	6	20.0	0.63	4.3	0.7
Aerated	2	0.89	0.37	22	6	21.4	0.65	4.4	2.7
Coagulated	3	0.07	0.09	8	135	10.1	0.06	9.2	8.2
				5-year av.					
Direct access	4546	2.63	0.40	139	85	27.7	0.27	5.7	2.4
Pumped	319	1.01	0.23	69	99	24.9	0.30	7.7	2.2
Aerated	214	0.77	0.27	67	103	25.1	0.32	7.0	5.9
Coagulated	23	0.05	0.06	6	190	10.9	0.03	8.6	8.3

[A] Phosphorous values high in pumped, aerated, and coagulated troughs in 1999 due to contamination.

trace mineral salt were provided throughout the trial in mineral feeders in each paddock. Weigh scales were located adjacent to the study site and body weights of steers, cows, and calves were obtained immediately before turnout, at 30-day intervals during the study and then at the end of the trial period. Average daily gain was calculated for all animals as the difference over time. The trial was conducted in accordance with guidelines laid down by Olfert *et al.* (1993).

In 1999 and 2003, forage production was more than adequate for grazing steers; however, in 2000, 2001, and 2002, pasture production of all paddocks was significantly affected by lack of precipitation at different times of the summer. In 2001, pastures received only 122 mm rainfall between 1 May and 31 August; however, quality was higher in August than in June due to timely rains in July allowing for regrowth in all paddocks. Cow–calf pairs began grazing Russian wildrye paddocks in early June in both 2000 and 2001, but not until early July in 2002. Forage production in the Cow–Calf experiment was limiting in mid-June in 2001 (due to a relatively dry spring) and was supplemented with grass–alfalfa hay for a 10-day period while animals were grazing Russian wildrye paddocks. After cow–calf pairs finished grazing Russian wildrye paddocks they were rotated onto fall rye paddocks starting late June in 2000 and 2002 and early August in 2001.

Data collection

The duration of the trials in the Yearling experiment, over 5 years, varied from 74 to 117 days and those of the Cow–Calf experiment, over 3 years, varied from 61 to 90 days. The starting date of the trials varied from 23 May to 15 July and was dictated by water and forage conditions and the breeding program of the cows. Body weights of steers, cows, and calves were obtained in the morning on 2 consecutive days at the beginning and end of the experiment and at 30-day intervals during the trial periods each year. However, for subsequent analyses, each trial period was divided into 2 subperiods defined by early and late summer. The dates represented by each were approximately from early June to late July or early August and the final subperiod terminating from the end of August to late September.

Pathogens

The role of pathogens and parasites in influencing cattle weight gain and the effect of water treatment on infectivity were examined by the presence of Trichostrongyle, *Eimeria* spp., *Giardia* spp., *Cryptosporidium* spp., and *Nematodirus* spp. in fecal samples taken rectally from each animal. Samples were collected prior to animal turnout on pasture and again at the end of the summer. All fecal samples were refrigerated prior to being submitted to Prairie Diagnostic Services, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, for analysis of Trichostrongyle, *Eimeria*, *Nematodirus*, *Giardia*, and *Cryptosporidium* oocysts. The qualitative fecal flotation technique was used for the identification of *Trichostronglye*, *Nematodirus*, and *Eimeria* oocysts. Detection of *Giardia* cysts and *Cryptosporidium* oocysts was by the immunofluorescent antibody test (Cyst-a-Glo, Waterborne Inc., New Orleans, LA).

Animal activity

The orientation of the paddocks in the Cow–Calf experiment made it difficult to observe the animals from a single vantage point. Therefore observations on animal activity were made only in the Yearling experiment. All observations were made for a 1-week period near the end of July or early August, in each of 3 years (1999–2001), by timing and recording the herd activity in 30-min increments from dawn to dusk. The effect of water treatment on drinking behaviour was defined as Frequency, which equalled the average number of times per day that a steer drank, and Time.Frequency equalled the average time spent drinking in each drinking event.

Statistical analyses

The effects of water treatment ($\text{Water}_{\text{direct}}$, $\text{Water}_{\text{pumped}}$, $\text{Water}_{\text{coagulated}}$, and $\text{Water}_{\text{aerated}}$) on animal weight gains (steer, cow, calf) (total summer period and early and late summer subperiods), animal activity (steer), and infection by parasite (steer) were analysed as a randomised complete block design with 4 water treatments and years as replicates (blocks). Infection rate by parasites was determined individually for Trichostrongyle, *Eimeria*, *Giardia*/*Cryptosporidium*, or *Nematodirus* spp. as the change of infection (+ or –) among animals in each water treatment. All analyses were evaluated using mixed effects ANOVA (SAS 1999) with year being a random variable, and the main effects (year, water treatment) were tested by their interaction (error d.f. ≤ 9). Treatment means were compared using single degree of freedom contrasts (Steel *et al.* 1997).

A second analysis was performed to determine the effects of parasites on animal weight gain. For these analyses, the design ignored the water treatments and allocated all animals into 1 of 2 groups, depending on the presence or absence of infection by Trichostrongyle, *Eimeria*, *Giardia*, *Cryptosporidium*, or *Nematodirus* spp. Animals that tested positive only once in trials were considered to be positive for the test. The data were then analysed as a randomised complete block with year as the replicate. Since the number of animals representing each group was often highly unbalanced, their means were weighted by the number of animals in each group.

Results

The elevated levels of *Escherichia coli* in the $\text{Water}_{\text{direct}}$ was reduced with increasing water quality treatment of the $\text{Water}_{\text{coagulated}}$ and $\text{Water}_{\text{aerated}}$ (Table 1). Water contaminated by feces can transmit many disease-causing organisms such as *E. coli*, *Cryptosporidium*, *Salmonella*, and *Leptospira* spp. These organisms generally affect young animals but have less effect on mature animals. However, in this study, water treatment had no effect ($P > 0.05$) on infection by Trichostrongyle, *Eimeria*, *Giardia*/*Cryptosporidium*, or *Nematodirus* spp. for either steers, cows, or calves. Dissolved oxygen levels were generally higher at the top and bottom of the dugout in $\text{Water}_{\text{aerated}}$ and $\text{Water}_{\text{coagulated}}$ than in $\text{Water}_{\text{direct}}$ (Table 1). Dugout aeration maintains dissolved oxygen levels, allowing plants and algae to decay under aerobic conditions. In so doing, aeration prevents the black, smelly water that develops when there is no dissolved oxygen in the dugout water.

Water treatment affected steer performance significantly ($P < 0.05$) over the entire trial period, and there was a tendency for improved weight gain with $\text{Water}_{\text{aerated}}$ and $\text{Water}_{\text{coagulated}}$ compared with $\text{Water}_{\text{direct}}$, and the treatment ranking was $\text{Water}_{\text{direct}} < \text{Water}_{\text{pumped}} < \text{Water}_{\text{coagulated}} < \text{Water}_{\text{aerated}}$ (Table 2). Also, water treatment affected ($P < 0.05$) weight gains by steers in early summer but not ($P > 0.05$) in late summer (Table 2). Observation over individual years indicates an interaction with water treatment where the response in 1999 and 2002 deviated markedly from 2000 when the aerated treatment produced the smallest gains. The inability to

Table 2. Effect of water treatment on average daily weight gain (kg/day) of steers on pasture over 5 years ($n = 11$, no. of steers per year)

Within a column, means having the same letter do not differ significantly ($P < 0.05$). Period 1, 23 May–31 July; Period 2, 1 August–30 September

Treatment	Period			Year				
	1	2	Total	1999	2000	2001	2002	2003
Direct	1.18a	0.50	0.97b	0.88	1.17	0.94	0.80	1.05
Pumped	1.21ab	0.54	1.00ab	0.94	1.14	0.88	0.92	1.15
Coagulated	1.33b	0.54	1.05a	1.06	1.15	0.95	0.92	1.17
Aerated	1.30b	0.53	1.06a	1.05	1.08	0.99	1.02	1.12
s.e.m.	0.038	0.026	0.013					
Source of variation (P)								
Treatment	0.002	0.77	0.02					

detect significant ($P < 0.05$) differences is at least partly the result of a relatively small degree of freedom for error and, apparently, the loss of treatment effectiveness or an improvement in the palatability of untreated water ($\text{Water}_{\text{direct}}$). The departure in the trend of weight gain among treatments in 2000, and to a lesser extent in 2001, compared with the other 3 years (1999, 2002, 2003; Table 2) may be related, through an unrecognised mechanism, to the drought conditions. For example, water quality would be expected to be altered through aeration and mixing in 2000 and 2001 when it was pumped to the test dugout from other sources. However, this effect is not discernible in standard qualitative analyses (Table 1).

$\text{Water}_{\text{aerated}}$ had no effect ($P > 0.05$) on the weight gains of cows and calves, whereas pumping without treatment ($\text{Water}_{\text{pumped}}$) appeared to be the most effective (Table 3). $\text{Water}_{\text{coagulated}}$ tended to show a numeric increase in weight gain of cows in the first period only (Table 3). $\text{Water}_{\text{pumped}}$ and $\text{Water}_{\text{aerated}}$ tended to produce greater ($P > 0.05$) weight gains in calves than $\text{Water}_{\text{direct}}$ in the first period but this difference had disappeared by the second period (Table 3). Calf sex had no effect on the weight gains of cows ($P > 0.05$) but male calves produced greater ($P > 0.05$) weight gains numerically than female calves (Table 3).

Steers on the $\text{Water}_{\text{direct}}$ treatment spent numerically less ($P > 0.05$) time grazing and more ($P > 0.05$) time resting

Table 3. Effect of water treatment and calf-sex on the weight gain of cows and calves on pasture over 3 years ($n = 10$, no. of cows with calves per year)

Period 1, 23 May–31 July; Period 2, 1 August–30 September. ADG, average daily gain

	Cows			Calves		
	Period 1	Period 2	Total	Period 1	Period 2	Total
Source of variation (P)						
Treatment	0.188	0.404	0.095	0.178	0.488	0.545
Sex	0.115	0.600	0.250	0.055	0.224	0.095
Sex × treatment	0.877	0.624	0.880	0.027	0.774	0.040
		ADG (kg/day)				
Direct	0.15	0.58	0.33	1.15	1.26	1.18
Pumped	0.30	0.78	0.47	1.22	1.30	1.22
Coagulated	0.39	0.41	0.41	1.21	1.26	1.20
Aerated	0.19	0.50	0.30	1.23	1.17	1.18
s.e.m.	0.267	0.344	0.271	0.122	0.121	0.032
Male						
Direct	0.14	0.51	0.29	1.15	1.28	1.19
Pumped	0.24	0.82	0.45	1.28	1.36	1.27
Coagulated	0.31	0.41	0.37	1.34	1.31	1.30
Aerated	0.10	0.63	0.30	1.34	1.22	1.24
Female						
Direct	0.17	0.64	0.37	1.15	1.25	1.18
Pumped	0.36	0.74	0.49	1.16	1.24	1.16
Coagulated	0.46	0.40	0.44	1.08	1.21	1.10
Aerated	0.27	0.36	0.30	1.17	1.12	1.12
s.e.m. (male + female)	0.272	0.368	0.274	0.123	0.136	0.032

Table 4. The effect of water treatment on the daily activity and drinking behaviour of steers on pasture over 3 years ($n = 5$, no. of days that animals were observed per year)

Within a column, means having the same letter do not differ significantly ($P > 0.05$)

Treatment	Activity				Freq.[B]	Time.freq.[C]
	Grazing	Loafing	Resting	Drinking[A]	(no.)	(s)
		(30-min intervals)				
Direct	14.6	1.9	12.1	1.4	3.0	48b
Pumped	16.4	2.2	10.0	1.3	3.0	34a
Coagulated	16.2	2.2	10.3	1.3	2.8	48b
Aerated	16.5	2.3	9.6	1.5	2.9	44b
s.e.m.	0.74	0.53	0.71	0.22	0.21	2.2
Source of variation (*P*)						
Year	0.17	0.16	0.08	0.01	<0.01	<0.01
Treatment	0.26	0.94	0.19	0.74	0.68	<0.01

[A] Drinking defined as time spent near water when ingesting water was the primary pursuit.

[B] Frequency is the average number of visits per animal per day.

[C] Time.Frequency is the average time spent drinking at each visit.

than animals drinking from $\text{Water}_{\text{pumped}}$, $\text{Water}_{\text{coagulated}}$, or $\text{Water}_{\text{aerated}}$ (Table 4). Also, steers drinking $\text{Water}_{\text{aerated}}$ spent more time grazing ($P > 0.05$) and less time resting than animals drinking $\text{Water}_{\text{direct}}$. Drinking frequency was similar ($P > 0.05$) among treatments but steers drinking (actual time spent ingesting water) from $\text{Water}_{\text{pumped}}$ spent less time ($P < 0.05$) than those on $\text{Water}_{\text{direct}}$, $\text{Water}_{\text{coagulated}}$, or $\text{Water}_{\text{aerated}}$ (Table 4).

Discussion

The results of this study have important implications for cow–calf producers to evaluate proper water management on their livestock operations. Proper management of beef cattle must consider the effects of water quality along with forage production and quality in order to achieve optimal production from rangelands.

In this experiment, seasonal conditions may have had an indirect effect on animal performance in some years. Rainfall varied each year, with 2000 and 2001 receiving only 74 and 55% of the long-term average, respectively. However, in 1999, 2002, and 2003, rainfall was 93, 123, and 80% of the long-term average, respectively. In these years there was clear evidence that improving water quality led to improved animal performance. The 3, 8, and 9% increases in weight gain of steers drinking pumped, coagulated, or aerated water, respectively, compared with direct access animals also indicated that improving water quality will allow animals to drink more, resulting in improved feed consumption and subsequently improved performance. Similar to the results in this study, Willms *et al.* (2002) found a positive trend towards improved weight gains with cows drinking clean water compared with those animals with direct access to the water source. Clean water (spring-fed) produced 20% greater weight gains than water direct from a pond. It was also reported by Willms *et al.* (2002) that cattle avoided water that was contaminated with fresh manure when given a choice of clean water.

In this study, water treatment had no effect on infection by Trichostrongyle, *Eimeria*, *Giardia*/*Cryptosporidium*, or *Nematodirus* spp. for steers, cows, or calves. This is in contrast to Olson *et al.* (1995) who demonstrated that infected lambs had a reduced rate of gain without a reduction in intake, suggesting a malabsorptive disease.

Water consumption is affected by a combination of animal and environmental factors such as dry matter intake and palatability (Hicks *et al.* 1988; Ali *et al.* 1994). The effects of inorganic salts and *Cyanobacterium* spp. on livestock have been clearly established (Barrio *et al.* 1989). There is no clear indication of why steers drinking $\text{Water}_{\text{direct}}$ had a longer drinking response than when $\text{Water}_{\text{pumped}}$ was consumed. However, this observation is supported by Willms *et al.* (2002) and suggests that animals may reduce their rate of intake due to palatability factors. Factors that may affect livestock gains are palatability that affects intake or the presence of toxins that affect rumen function. Holechek (1980) reported a decrease in water consumption and weight gain from cattle drinking from a water source contaminated by feces and urine. The authors concluded that reduced weight gains from cattle consuming fecal-contaminated water (direct access) were the result of reduced consumption leading to reduced forage intake. In this study, cattle that drank aerated (clean) water from a trough spent more time grazing and more time loafing. This greater time spent grazing by steers suggests greater forage intake as forage quality in paddocks was more than adequate for 360-kg growing steers (National Research Council 1996).

The marginal response of cows to the water treatments may be due to the growth of their calves who receive a major portion of their nutrients from milk (National Research Council 1996). The nutrient requirements of milking cows increase more than those of dry cows. Good milk production contributes to calf growth but at the expense of the dam (Ensminger *et al*. 1990). In this study, male calves gained better early in the grazing season when drinking water from a trough than by direct access to a dugout. Results from this experiment indicate that aerated or coagulated water in a trough could have potential for allowing maximum gains of grazing animals. This not only includes the water treatments applied in this study but also includes providing clean ground water in a trough to grazing animals (Willms *et al*. 2002).

Conclusions

Providing good quality water is necessary for maximising animal gains on summer pasture. Livestock response to the watering treatments varied among steers, cows, and calves in this study conducted at Lanigan, Saskatchewan. Optimum cattle performance drinking high quality water may not have been fully achieved in all years, given the variability in precipitation and environmental conditions. There was a varied response in the cow and calf weights among water treatments in all years, with numeric differences not being significant. However, over all years, steers gained 9% more weight drinking treated water (aerated or coagulated) from a trough than drinking directly from a dugout. This weight response to these treatments varied, depending on year and water quality treatment. The trend for additional weight gain was observed in 1999, 2002, and 2003 from steers consuming treated or untreated water pumped to a trough. The results of this study then suggest that surface water that is aerated and pumped to a trough can increase the weight gain of steers in 3 out of 5 years.

Finally, sustainable water management such as eliminating direct access by livestock to watering areas appeared to result in improved performance while cattle were out on pasture. The benefits of excluding access by cattle to dugouts and riparian areas need to be weighed against a potential decrease in individual animal gains, poorer water quality, and shortened life span of the dugout. More research is warranted to examine the effects of poor water quality on performance of grazing cattle and to develop economic models to evaluate management alternatives. Improved animal performance from consuming dugout water pumped to a trough while on pasture will only be observed in years of adequate precipitation, forage production, and forage quality.

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