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Preference and drinking behavior of lactating dairy cows offered water with different concentrations, valences, and sources of iron

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ABSTRACT

Drinking water can contain high concentrations of Fe, mainly of the ferrous (Fe^{2+}) valence. The current recommended upper tolerable concentration of Fe in drinking water for cattle (0.3 mg/L) comes from guidelines for human palatability, but cattle may be able to tolerate higher concentrations. Our objective was to determine the effects of varying concentrations of ferrous (Fe^{2+}) or ferric (Fe^{3+}) iron and Fe salt source on lactating dairy cows' preferences for and drinking behavior of water offered as choices ad libitum. In 4 separate experiments, cows were offered pairs of water treatments for 22-h periods and water intake and drinking behavior were recorded. In experiment 1, treatments were 0, 4, or 8 mg of total recoverable Fe/L from ferrous lactate. Cows exhibited no preference between water with 0 or 4 mg of Fe/L, but water intake was less with 8 compared with 0 or 4 mg of Fe/L. Also, cows spent less time drinking water containing 8 mg of Fe/L. Total time spent drinking correlated positively with water intake when pooled across treatments. In experiment 2, treatments were 0 or 8 mg of Fe/L from either ferrous sulfate ($FeSO_4$) or ferric sulfate [$Fe_2(SO_4)_3$]. Water intake did not differ among treatments. In experiment 3, treatments were 0 (control), 12.5, or 8 mg of Fe/L from ferrous chloride ($FeCl_2$) or ferric chloride ($FeCl_3$), respectively. Again, cows exhibited no preference among treatments. In experiment 4, treatments were 0 or 8 mg of Fe/L from ferrous lactate [$Fe(C_3H_5O_3)_2$], ferrous sulfate ($FeSO_4$), or ferrous chloride ($FeCl_2$). Cows preferred to drink water without added Fe, but did not exhibit any preference among waters containing the Fe sources with different anionic moieties. Cows spent less time drinking and drank less frequently when offered water containing 12.5 mg of total recoverable Fe/L from ferrous chloride compared with 8.0 mg of Fe/L from ferrous lactate or ferrous sulfate. Water intake correlated positively with both drinking duration and frequency when pooled across treatments in experiment 4. Overall, our results indicate that upon first exposure to drinking water, lactating dairy cows tolerate concentrations of Fe up to 4 mg/L from ferrous lactate without reducing water intake; however, water intake was reduced with 8 mg of total recoverable Fe. Preference did not appear to be influenced by Fe valence or added Fe source.
Key words: dairy cattle, drinking water, iron, drinking behavior

INTRODUCTION

Preference is the degree to which one alternative is preferred over another. A dairy cow's preference for drinking water is an indicator of its palatability that can be measured by differences in water intake and animal behavior. Anecdotal reports from the field suggest that drinking water with Fe concentrations of 2 mg/L or greater may affect milk production and cow health negatively (D. K. Beede, personal observation). These effects might be mediated (1) through changes in Fe or antioxidant status and oxidative stress of cows or (2) through preference for or against particular drinking waters. In the current research we focused on the latter.

The upper tolerable limit for Fe concentration in drinking water recommended for dairy cows (0.3 mg/L) is based on anecdotal suggestions of the acceptable concentration for palatability in humans (WHO, 2006). No research has attempted to establish this concentration in dairy cattle. Only one study has investigated the effects of drinking water contaminated with Fe in ruminants (Horvath, 1985). Sheep were offered simulated acid mine drainage water that often has high concentrations of Fe (approximately 25 to 500 mg/L). The animals were offered the same treatments for 15 min twice daily for 2 d. Iron concentrations of 75 mg Fe/L as ferric sulfate or 145 mg Fe/L from ferric chloride had no effect on water intake. However, it was not clear in the report if animals were offered alternative water for the other 23.5 h each day. Therefore, water consumption may not have reflected preference in a more normal setting with continuous access to water. Additionally, Fe concentrations of treatments were greater than typically found in drinking water for dairy cows in commercial farms. In a survey of 2,437 drinking water samples from livestock

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operations in the United States, average and maximum concentrations of Fe were 0.79 and 123 mg/L, respectively (Socha et al., 2003). In over 980 samples from 3 provinces in Canada, Fe concentrations averaged 0.01 to 2.1 mg/L, with maximum concentrations of about 30 mg/L (Osborne, 2006).

Palatability, as reflected by reduced DMI and ADG from supplemental Fe in rations, was characterized in calves and sheep. Calves fed dietary Fe of 750 mg/kg of DM from ferrous sulfate ($FeSO_4$) had reduced DMI and ADG (Hansen et al., 2010). Dietary Fe concentrations of 1,600 mg of Fe/kg from ferrous sulfate or ferric citrate ($FeC_6H_5O_7$) reduced DMI of sheep compared with those fed unsupplemented diets, although ferrous sulfate had a greater negative effect on DMI than ferric citrate (Standish and Ammerman, 1971). However, intake by dairy cows of pasture irrigated with water containing 17 mg of Fe/L from ferric hydroxide [$Fe(OH)_3$] (17 mg of Fe/L) was not different than that of cows on nonirrigated pasture (Coup and Campbell, 1964).

The World Health Organization suggests that Fe concentrations greater than 0.3 mg/L in drinking water will affect taste preference of humans (WHO, 2006). But, concentrations of 1 to 3 mg of Fe/L from anaerobic well water can be acceptable (WHO, 2003). Anaerobic water contains mostly ferrous iron (Fe^{2+}; Colter and Mahler, 2006); this suggests that Fe^{2+} may be more palatable than ferric iron (Fe^{3+}).

We hypothesized that as the concentration of Fe^{2+} in drinking water increases, water intake of lactating dairy cows would decrease; furthermore cows would prefer water with greater concentration of Fe^{2+} compared with Fe^{3+} when presented with the choice, but would prefer water with no supplemental Fe (low basal Fe concentration in control water) over any other source. Our objective was to determine if water intake and drinking behavior of lactating dairy cows differed when offered waters with ascending concentrations of Fe^{2+}, different Fe valences (Fe^{2+} or Fe^{3+}), and from different Fe sources (salts).

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at Michigan State University (East Lansing) approved all procedures for the 4 experiments (approval no. 03/10-024-00). All were conducted at the Michigan State University Dairy Teaching and Research Center in July to August (mean daily ambient temperature = 22.8°C; mean maximum ambient temperature = 29.4°C).

Animals, Experimental Design, and Treatments

This research focused on preference choices, water intake, and behavior of cows offered different drinking water treatments for relatively short periods of time. The general preexperimental (1 wk) measurements of water intake, feed intake, and milk yield and composition are given in (Table 1) to help characterize the cows. Means and standard deviations are listed for 6 cows used in experiments 1 through 3, and for 12 cows used in experiment 4. These data were not analyzed statistically because they were collected before experimental treatments were introduced. Furthermore, lactational performance (e.g., feed intake and milk yield) during the time cows were administered treatments was not evaluated statistically because of the short time of treatment administration. Ingredient and nutrient compositions of diets are given in Table 2.

Experiment 1. Six mid-lactation Holstein cows (181 ± 44 DIM; 2 primiparous and 4 multiparous) situated in tiestalls were assigned randomly in a replicated 3 × 3 Latin square design involving 3 periods, 3 treatments, and in 3 possible paired treatment combinations. Experimental treatments were drinking water with: 0 (**0Fe**), 4 (**4Fe**), or 8 mg of Fe/L (**8Fe**) from ferrous lactate [$Fe(C_3H_5O_3)_2$] added to on-site tap water (Table 3). Treatments were formulated to contain 0, 4, or 8 mg of Fe/L of total recoverable Fe (preanalysis preparation by nitric acid digestion) or about 0, 1, and 2 mg of Fe/L by direct metals analysis (no preanalysis preparation; Midwest Laboratories Inc., Omaha, NE), both analyzed by inductively coupled plasma-atomic emission spectrometry per Environmental Protection Agency (**EPA**) method 200.7 (EPA, 1994). Drinking water treatments were in individual containers offered in pairs to each cow on the left and right sides of individual feed bunks with the TMR between the containers. Spatial arrangement of paired water treatments, diet, and cows were similar in all experiments. In experiment 1, each cow was offered 1 of 3 possible paired combinations (0Fe and 4Fe, 0Fe and 8Fe, or 4Fe and 8Fe) in each of 3 experimental periods (each lasting 22 h); pairs were balanced for left-right effect by representing each pair in both possible spatial orientations equally in each period.

Experiment 2. Six mid-lactation Holstein cows (187 ± 44 DIM; 2 primiparous and 4 multiparous) from experiment 1 were kept in tiestalls and assigned randomly in a replicated 3 × 3 Latin square design with 3 experimental periods, 3 experimental treatments, and in 3 possible treatment pair combinations. Experimental treatments were: 0 (control) or 8 mg of Fe/L from either ferrous sulfate ($FeSO_4$) or ferric sulfate ([$Fe_2(SO_4)_3$]) added to on-site tap water (Table 3). Treatments were formulated to contain 0 and 8 mg of Fe/L of total recoverable Fe or about 0 and 2 mg of Fe/L, determined by direct metals analysis. Treatments were offered as pairs. Each cow was offered 1