Performance of Holstein-Friesian calves drinking desalinated water in the preweaning period

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SHORT COMMUNICATION

Performance of Holstein-Friesian calves drinking desalinated water in the preweaning period

Comportamiento de terneros Holstein-Friesian bebiendo agua desalinizada en el período pre-destete

Comportamento de terneiros Holstein-Friesian bebendo água dessalinizada no período pré-desmame

Joel Ventura-Ríos; David Domínguez-Díaz; Alejandro Lara-Bueno; Guillermo Villalobos-Villalobos; Rufino López-Ordaz; José Jaimes-Jaimes; Agustín Ruíz-Flores.

1Universidad Autónoma de Chihuahua, Facultad de Zootecnia y Ecología, Chihuahua, México.
3Agronegocios Chapingo SC de RL de CV. Pueblo Cooperativo, Texcoco, Edo. México.

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*Corresponding author. Address: Primera cerrada de camino real No. 11, Huexotla, Edo. México. 56220. México. E-mail: alarab_11@hotmail.com

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Abstract

**Background:** High salinity of drinking water can adversely affect the health and productive performance of calves during artificial nursing. **Objective:** To evaluate the effect of drinking water total dissolved salt (TDS) content on productive performance of Holstein-Friesian nursing calves. **Methods:** Twenty-nine newborn Holstein-Friesian calves weighing 39±0.94 kg at birth were randomly assigned to two water treatment groups for 56 d. Treatment 1 (n=14) used drinking water with 1,469±75 mg L⁻¹ of TDS, while the treatment 2 (n=15) used drinking water from the same source but filtered by reverse osmosis containing 107±31 mg L⁻¹ of TDS. **Results:** The water intake of calves by artificial nursing was slightly affected by the concentration of TDS and increased 13% (p>0.08) when they drank low-TDS water (3,554 versus 3,088 ml d⁻¹). Feed intake (dry basis) decreased 26% (500 versus 676 g d⁻¹; p<0.01), and average daily weight gain increased 29% (434 versus 335 g d⁻¹; p<0.05) in calves that drank low-TDS water compared with those that drank high-TDS water. At the end of the treatment period, treatment group 2 had 10% higher body weight than the calves in treatment 1 (64.3 versus 58.6 kg; p<0.01). The digestibility of solid feed dry matter and protein was not affected (p>0.05) by TDS content in the drinking water. **Conclusion:** Desalinated water improves the productive performance of Holstein-Friesian calves during artificial nursing.

**Keywords:** Artificial nursing; desalinated water; Holstein-Friesian calves; nutrients digestibility; reverse osmosis; total dissolved salts; water intake; water quality.

Resumen

**Antecedentes:** la alta salinidad del agua de bebida puede afectar negativamente la salud y el comportamiento productivo de los becerros durante la crianza. **Objetivo:** evaluar el efecto del contenido de sales disueltas totales (SDT) en el agua de bebida en el comportamiento productivo de los terneros durante la lactancia. **Métodos:** veintinueve terneros Holstein-Friesian recién nacidos, con 39±0.94 kg de peso vivo fueron asignados aleatoriamente a dos tratamientos. El tratamiento 1 consideró 14 terneros los cuales bebieron agua con 1.469±75 mg L⁻¹ de SDT; mientras que en el tratamiento 2 se asignaron 15 terneros que recibieron agua de la misma fuente, pero filtrada mediante el procedimiento de ósmosis inversa y conteniendo
107±31 mg L⁻¹ de SDT. **Resultados:** el consumo de agua de los terneros durante la lactancia artificial de 56 días fue afectado ligeramente por la concentración de SDT en el agua de bebida (p>0,08) y se incrementó 13% cuando los terneros bebieron agua con bajo contenido de sales (3.554 vs 3.088 ml d⁻¹). El consumo de alimento sólido (base seca) disminuyó 26% (500 vs 676 g d⁻¹; p<0,01) y la ganancia diaria de peso se incrementó 29% (434 vs 335 g d⁻¹; p<0,05), en becerros que bebieron agua con baja concentración de SDT, en comparación con los terneros que bebieron agua con alto contenido de sales. Asimismo, los becerros que bebieron agua desalinizada tuvieron mayor peso corporal (64,3 vs 58,6 kg; p<0,01) que los becerros que bebieron agua con alta concentración de sales al finalizar el periodo de lactancia artificial. La digestibilidad de la materia seca y de la proteína del alimento sólido no fue afectada (p>0,05) por el contenido de SDT en el agua de bebida. **Conclusión:** el agua desalinizada de bebida mejora el comportamiento productivo de becerros Holstein durante el periodo de lactancia artificial.

**Palabras clave:** agua desalinizada; calidad de agua; comportamiento productivo; consumo de agua; digestibilidad; lactancia artificial; sales disueltas totales; terneros Holstein.

**Resumo**

**Antecedentes:** alta salinidad da água potável pode afetar adversamente a saúde e o desempenho produtivo de bezerros durante o acasalamento. **Objetivo:** avaliar o efeito do total de sais dissolvidos (TSD) na água potável sobre o comportamento dos bezerros durante a lactação. **Métodos:** vinte e nove terneiros Holstein-Friesian recém-nascidos, com 39±0,94 kg de peso vivo, foram designados aleatoriamente a dois tratamentos. O tratamento 1 considerou 14 terneiros os quais beberam água com 1.469±75 mg L⁻¹ do total de sais dissolvidos (TSD); enquanto ao tratamento 2 se designaram 15 terneiros bebendo água da mesma fonte filtrada através do procedimento de osmose inversa e contendo 107±31 mg L⁻¹ de TSD. **Resultados:** o consumo de água de bezerros durante os 56 dias de lactação artificial foi ligeiramente afetado pela concentração de TDS na água potável (p>0,08) e aumentou em 13% quando os bezerros beberam água com baixo teor de sal (3.554 vs 3.088 ml d⁻¹); o consumo de alimento sólido (base seca) diminuiu em 26% (500 vs 676 g d⁻¹; p<0,01) e o ganho de peso diário se incrementou em 29% (434 vs 335 g d⁻¹; p<0,05) nos terneiros que beberam água com baixa concentração de TSD, em comparação com os terneiros que
tomaram água com alto conteúdo de sais. Da mesma forma, os terneiros que beberam água dessalinizada tiveram maior peso corporal (64,3 vs 58,6 kg; p<0,01) que os terneiros que tomaram água com alta concentração de sais ao terminar o período de lactação artificial. A digestibilidade da matéria seca e da proteína do alimento sólido não foi afetada (p>0,05) pelo conteúdo de TSD na água de beber. **Conclusão:** a dessalinização da água de beber melhora o comportamento produtivo de terneiros Holstein durante o período de lactação artificial.

**Palavras-chave:** água dessalinizada; comportamento produtivo; consumo de água; digestibilidade; lactação artificial; qualidade da água; terneiros Holstein; total de sais dissolvidos.

**Introduction**

Water is an essential nutrient for the growth and well-being of livestock (Beede, 2005; Huuskonen et al., 2011), as poor-quality drinking water has been shown to affect animal health and productive performance (NRC, 2005; Brew et al., 2008). Results of previous studies have demonstrated that poor-quality drinking water affects water intake (Socha et al., 2003; Grout et al., 2006; Sharma et al., 2017), feed intake (Ru et al., 2004; Umar et al., 2014; López et al., 2016), average daily weight gain [ADG] (Lardner et al., 2005; Waldner and Looper, 2007; Sharma et al., 2017), milk production (Solomon et al., 1995; Shapasand et al., 2010), and ruminal conditions (Coria et al., 2007; Valtorta et al., 2008). In addition, poor-quality drinking water favors diseases (Gould, 1998) and pathogen incidence in the digestive tract of dairy cows (LeJeune et al., 2001; Brew et al., 2008). Nonetheless, the intake of poor-quality drinking water and its impact on growth and health of young animals has been scarcely studied (Beede, 2005).

In northern México, the “Comarca Lagunera” is the most important dairy region, with specialized dairy operations that contribute approximately 20% of México’s national milk production (SIAP, 2017). In this region, the water available for forage production and animal nutrition has undesirable physicochemical characteristics (Rosas et al., 1999), such as a high concentration of total dissolved salts (TDS), sulfates, nitrates, and toxic minerals like arsenic.
High-salinity drinking water may also affect growth, production, health, and well-being of dairy cows and their calves.

Desalination is a physical-chemical process that consists of removing salts from water to obtain fresh water suitable for consumption. The scarcity of quality water in the agricultural industry due to the depletion and salinization of subway aquifers in several regions of the planet requires the use of water desalination, especially for drinking water for animals (Schütz 2012; Umar et al., 2014). The reverse osmosis desalination technique has shown to be effective and economically viable for water desalination, especially when solar and wind energy are used in the process (Dévora et al. 2012). Therefore, the objective of the present study was to evaluate the effect of drinking water total dissolved salt content on productive performance of Holstein-Friesian nursing calves.

**Materials and methods**

**Ethical considerations**

This project was approved by the Instituto de Investigación y Posgrado en Ciencia Animal de la Universidad Autónoma Chapingo (approval no. 145503001, March 2014).

**Study location**

The present study was conducted at the dairy production experimental station “18 de Julio” of the Universidad Autónoma Chapingo, located at Bermejillo, Durango, México. The farm is at 25° 54’ 07” N and 103° 35’ 09” W, with an altitude of 1,137 masl and 239 mm average annual precipitation. The climate of the study area is classified as semi-arid, with summer rain from July to September (García, 2004).

**Animals, diets, and management**

The experiment took place from August to November 2014. At this time of year, the temperature and relative humidity of the study area are quite moderate. Twenty-nine 1-d-old Holstein-Friesian calves with an average live weight of 39±0.94 kg were used. Calves were
fed colostrum from their dams during the first 3 d after birth. Thereafter, they consumed a commercial milk substitute twice a day (at 07:00 and 16:00). The milk substitute was made by dissolving 200 g of Master Milk (Alltech®, Flemington, NJ, USA) milk substitute in 2 L of water at 37 ºC. The experimental period of artificial nursing lasted 8 weeks (56 d). After day 7, all calves ate solid feed for weaning formulated by Nuplen® (Gómez Palacio, Durango, México) offered daily at 09:00. Three samples of water extracted from a deep well were taken, one at the beginning, one in the middle, and one at the end of the experimental period. Samples of groundwater without filtering and filtered by reverse osmosis (Ultraliner®, WI, USA) were collected in prewashed and sterilized, amber-colored 250-mL bottles and kept refrigerated for 1 h at 4 ºC before being processed in a certified laboratory for analysis of chemical and microbiological composition (Table 1).

Table 1. Chemical and microbiological composition of the nonfiltered groundwater (HTDS) and groundwater filtered by reverse osmosis (LTDS).

<table>
<thead>
<tr>
<th>Item</th>
<th>HTDS</th>
<th>LTDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.0 ± 0</td>
<td>6.6 ± 0</td>
</tr>
<tr>
<td>Total dissolved salts, mg L(^{-1})</td>
<td>1,469 ± 75</td>
<td>107 ± 31</td>
</tr>
<tr>
<td>Total hardness, mg L(^{-1})</td>
<td>913 ± 21</td>
<td>46 ± 17</td>
</tr>
<tr>
<td>Chlorides, mg L(^{-1})</td>
<td>115 ± 3</td>
<td>6 ± 3</td>
</tr>
<tr>
<td>Bicarbonates, mg L(^{-1})</td>
<td>196 ± 6</td>
<td>34 ± 8</td>
</tr>
<tr>
<td>Sulfates, mg L(^{-1})</td>
<td>853 ± 13</td>
<td>24 ± 10</td>
</tr>
<tr>
<td>Nitrates, mg L(^{-1})</td>
<td>117 ± 3</td>
<td>20 ± 0.4</td>
</tr>
<tr>
<td>Nitrites, mg L(^{-1})</td>
<td>0.06 ± 0</td>
<td>0 ± 0</td>
</tr>
<tr>
<td>Total coliforms, CFU 100 ml(^{-1})</td>
<td>1,506 ± 1,296</td>
<td>29 ± 21</td>
</tr>
<tr>
<td>Fecal coliforms, CFU 100 ml(^{-1})</td>
<td>1,301 ± 1,210</td>
<td>18 ± 15</td>
</tr>
</tbody>
</table>

HTDS, high concentration total dissolved salts; LTDS, low concentration total dissolved salts.

A SevenCompact™ S230 (CH-8603; Schwerzenbach, Switzerland) conductivity meter was used to determine Total Dissolved Salts in water (TDS); a Redlemon 0-14 digital potentiometer (Mexico City, Mexico) was used to determine water pH; total water hardness was determined by the volumetric method with EDTA and chloride content was obtained by the Mohr volumetric method using argentometry (Espinosa et al., 2006); carbonate levels in water were determined using the methodology described by Mexican standard NMX-K-282-SCFI-2012 (NMX, 2012); for the measurement of sulfates in water a UV-VIS spectrophotometer (PerkinElmer® Lambda 35 model; Madrid, Spain) was used employing
the procedure established in Mexican standard NMX-AA-074-SCFI-2014 (NMX, 2014); to determine the nitrate and nitrite contents, the Checker HI781 and Checker® HC (Hanna Instruments Mexico) brand colorimeters were used; and for the quantification of total and fecal coliforms, the membrane filtration procedure described by Espinoza et al. (2006).

Calves were randomly assigned to one of two treatment groups and housed in individual pens. Treatment 1 (n=14; 6 females, 8 males) consisted of groundwater extracted from a deep well with a high TDS concentration (1,469±75 mg L⁻¹). Treatment 2 (n=15; 7 females, 8 males) consisted of drinking water extracted from the same well but filtered by reverse osmosis and containing a low TDS concentration (107±1 mg L⁻¹). At the end of the artificial nursing period (56 d postpartum), all calves were fed a solid concentrate, had free access to forage for 32 d after weaning, and drank nonfiltered groundwater with at least 1,469±75 mg L⁻¹ TDS.

All variables were measured considering each calf as an experimental unit. Water and feed intake were measured daily during the experimental period. Preweaning ADG was determined by weighing each calf weekly. Postweaning ADG was measured 28 d after the artificial nursing period. Digestibility of dry matter and crude protein in the solid feed was determined using the insoluble acid fiber of the concentrate offered and the content in feces as an internal marker following the technique proposed by Penning and Johnson (1983). To estimate the disappearance of dry matter and crude protein, samples of concentrate and feces were placed in AnkomF57® bags (Macedon, NY, USA), and then incubated for 24 h in the rumen of two fistulated adult sheep using the procedure proposed by Huhtanen et al. (1994).

**Data analysis**

Water intake, feed intake, and ADG were analyzed using the MIXED procedure of SAS, version 9.4 (SAS Institute Inc., Cary, NC, USA; 2013). The statistical model included the fixed effects of TDS concentration in drinking water and the sampling week, coefficient of linear regression for the weight at birth, coefficient of linear regression for average weekly environmental temperature, and the random effects of calf and residual values as terms of experimental error. Data of dry matter digestibility and crude protein were analyzed with the GLM procedure of SAS (SAS, 2013) using a completely randomized design. A p<0.05 was
considered statistically significant, and a p between 0.05 and 0.10 was considered as a significant trend.

Results

Water quality

The TDS content in the drinking water (carbonates, chlorides, sulfates, nitrates, sodium, potassium, calcium, and magnesium) decreased after being filtered from 1,469 to 107 mg L-1 along with the pH from 7.0 to 6.6 (Table 1). The content of sulfates in the filtered water was 97% lower than in the nonfiltered water (24 \textit{versus} 853 mg L-1). The concentration of nitrates also decreased after filtration from 117 to 20 mg L-1. Moreover, the filtration process reduced the microbiological load in the drinking water by 98%.

Productive performance of calves

Calves that drank filtered water during artificial nursing increased their live weight approximately 10% (p<0.05) compared with calves that drank water with a high TDS concentration (Table 2). Moreover, there was a postweaning effect of drinking saline water on calf live weight during nursing (p<0.05); the calves that drank filtered water weighed 4.8% more at 84 d-old than calves that drank nonfiltered water. In the same way, increases of 23 to 26% in dry matter intake and ADG, respectively, were observed in calves that drank filtered water compared with those that drank nonfiltered water (both p<0.05). The increase in feed intake and ADG in calves that drank water low in TDS can be explained by the improvement in the drinking water quality, which permitted the calves to increase their water and total digestible nutrient intake. Postweaning ADG (57–84 d-old) was similar (p>0.05) between the treatment groups. The TDS content in drinking water slightly affected water intake but not significantly (p<0.08; Table 2). Calves that drank water with a high TDS concentration drank 13% less water than those that drank water with a low TDS content.

Table 2. Parameters of Holstein-Friesian calves given water with high (HTDS) and low (LTDS) total dissolved salts during artificial nursing.
Characteristics  | HTDS     | LTDS     
---|---------|---------|
Initial live weight, kg | 39.6 ± 1.18<sup>a</sup> | 39.8 ± 1.15<sup>a</sup> |
Live weight at 56 d, kg | 58.6 ± 1.18<sup>b</sup> | 64.3 ± 1.14<sup>a</sup> |
Live weight at 84 d, kg | 120.6 ± 13<sup>b</sup> | 126.4 ± 13<sup>a</sup> |
Feed intake, g d<sup>-1</sup> | 500 ± 44<sup>b</sup> | 676 ± 42<sup>a</sup> |
ADG at 56 d, g d<sup>-1</sup> | 335 ± 30<sup>b</sup> | 434 ± 20<sup>a</sup> |
ADG at 84 d, g d<sup>-1</sup> | 2240 ± 68<sup>a</sup> | 2250 ± 67<sup>a</sup> |
Water intake, mL d<sup>-1</sup> | 3088 ± 268<sup>a</sup> | 3554 ± 250<sup>a</sup> |

ADG, average daily weight gain; means within rows with different superscript ("a") letters are statistically different (p<0.05).

### Feed and protein digestibility

The digestibility of dry matter and crude protein in solid feed offered to calves during the artificial nursing period was not affected by the decrease in TDS of filtered drinking water (p>0.05; Table 3).

### Table 3. Digestibility of solid feed offered to Holstein-Friesian calves that drank water with high (HTDS) and low (LTDS) content of total dissolved salts during artificial nursing.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>HTDS</th>
<th>LTDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>77.2 ± 1.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>73.0 ± 1.92&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude protein, %</td>
<td>68.9 ± 3.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>61.8 ± 3.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Digestible protein consumed (kg kg&lt;sup&gt;-1&lt;/sup&gt;MS)</td>
<td>0.157 ± 0.0&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.172 ± 0.0&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means within rows with similar superscript letters are not statistically different (p>0.05).

### Discussion

#### Water quality

In the present study, the extracted water of deep well, which was previously filtered by reverse osmosis, showed the chemical components within the permissible standards published by the National Research Council (2001 and 2005) to reach a water quality for dairy cattle. Beede (2005) indicated that the pH of drinking water for dairy cattle should be between 6.4 and 7.0 to prevent damage to animal health and from 7.0 to 8.0 for proper
functioning of rumen microorganisms. Thus, the pH of the drinking water offered to the calves (filtered or nonfiltered) was within a suitable quality range.

Several studies have shown that dairy cows and calves that drink water with a high chloride concentration for extended periods are susceptible to altered productive performance and health (Bahman et al., 1993; Solomon et al., 1995; Shapasand et al., 2010). Because of the high concentration of anions and their capacity to combine with metal cations, such as calcium and magnesium, in the present study nonfiltered groundwater is harder (913 mg L\(^{-1}\)) but can be softened through desalination (46 mg L\(^{-1}\)). Nevertheless, previous findings have shown that drinking water high in calcium, magnesium, zinc, iron, and manganese ions does not significantly affect water or feed intake, productive performance, or the health of animals (Umar et al., 2014). Although adverse effects of high concentrations of carbonates in ruminant drinking water have not been reported, water high in both calcium and magnesium affects the productive performance of animals because these elements increase the TDS content (El-Mahdy et al., 2016).

In calves, high levels of sulfates in drinking water affect water and feed intake, decreasing ADG and increasing the risk of polioencephalomalacia (Patterson et al., 2003; Patterson et al., 2005; Drewnoski et al., 2014). Moreover, high sulfate concentrations in calf diets interfere with absorption of copper and selenium, generating thiamine deficiency, the main cause of bovine polioencephalomalacia (Lutnicki et al., 2014). However, concentrations of sulfates lower than 1,000 mg L\(^{-1}\) may not affect calf productive performance or health (Wright, 2007).

The National Research Council (2001) established the permissible range of nitrates in livestock drinking water as 45–132 mg L\(^{-1}\). Nitrates ingested by ruminants rapidly convert to nitrites by rumen microorganisms, and although no maximum tolerable levels of nitrites in drinking water have been reported, they are absorbed in the rumen wall and flow into the blood, reducing the efficiency of red blood cells to transport oxygen and can cause asphyxia (Wright, 2007). Moreover, although the presence of coliform bacteria in drinking water has negative consequences for livestock health and productive performance, there are few scientific studies concerning this topic (LeJeune et al., 2001; Willms et al., 2002; Sanderson et al., 2005).
Productive performance of calves

The results of the present study are consistent with those found by Patterson et al. (2003), who observed a significant 6.7% increase in dry matter intake and 26% increase in ADG of calves when the TDS concentration in drinking water decreased. In a similar study of calves that drank water with 512 versus 7,478 mg L\(^{-1}\) TDS, dry matter intake and ADG increased 10% and 22%, respectively, in animals that drank water with lower TDS (López et al., 2016).

Recently, Sharma et al. (2017) reported similar effects in Murrah buffalo calves, estimating a 17.2% increase in dry matter intake for those that drank water with low TDS (557 versus 8,789 mg L\(^{-1}\) TDS) compared to those that drank water with a high TDS content. Likewise, high levels of dissolved sulfates in drinking water decreased dry matter intake and ADG of Holstein-Fresian calves (Weeth and Capps, 1972; Patterson et al., 2004a). In contrast, Bahman et al. (1993) intake of saline water (3,574 mg L\(^{-1}\) TDS) had no effect on dry matter intake of producing Holstein cows, whereas Solomon et al. (1995) reported similar feed intake in dairy cows whether they drank water high or low in salt (23.0 versus 22.6 kg DM d\(^{-1}\)). In addition, Willms et al. (2002) found that calves that drank clean water (675 mg L\(^{-1}\) TDS) had 9% higher ADG than calves that drank dirty water from puddles (1,783 mg L\(^{-1}\) TDS) during the nursing period, although postweaning ADG of calves was similar between the groups.

Water intake

The present results agreed with those reported by Patterson et al. (2004b), who observed a 37% decrease in the intake of water containing 7,268 mg L\(^{-1}\) TDS offered to calves relative to calves that drank water with 1,226 mg L\(^{-1}\) TDS. Solomon et al. (1995) also observed 8.5% reduced intake of water with high TDS in dairy cattle, while Johnson et al. (2004) reported a water intake decrease of 13% (p<0.06) in growing steers when the sulfate concentration increased from 401 to 4,654 mg L\(^{-1}\). Additionally, Sharma et al. (2018) reported a negative correlation (p<0.01) between water intake and TDS level in Murrah buffalo calves. Grout et al. (2006) also observed that high concentrations of MgSO\(_4\) (1,500, 3,000, and 4,500 mg SO\(_4\) L\(^{-1}\)) in the drinking water linearly decreased (p<0.01) water intake of growing calves, and the decrease in water intake was accompanied by an increase in dry fecal matter, suggesting a...
decrease in the digestibility of the ingested feed. Other researchers (Yirga et al., 2018) suggest the TDS content in drinking water has a greater impact on young animals than adults.

**Feed and protein digestibility**

The results of the present study are consistent with those reported in other studies (Attia-Ismail et al., 2008; López et al., 2017; Sharma et al., 2017). Sharma et al. (2017) found no differences (p>0.05) in the apparent digestibility of nutrients (dry matter, organic matter, crude protein, neutral detergent fiber, and acid detergent fiber) between buffalo calves that drank water with low and high TDS content. The loss of nitrogen in urine, however, was higher (p<0.05) in calves that drank water with 8,789 mg L$^{-1}$ TDS than in those that drank water with 6,113 mg L$^{-1}$ TDS or lower. Likewise, López et al. (2017) did not detect significant effects (p>0.05) of high salinity water on digestibility of organic matter and neutral detergent fiber in feed consumed by calves. Previously, Attia-Ismail et al. (2008) also reported nonsignificant (p>0.05) effects of salinity in drinking water on digestibility of nutrients in sheep and goats. In contrast, Tsukahara et al. (2016) found the digestibility of organic matter was lower in goats that drank brackish water (6,900 mg L$^{-1}$ with 100% saturation of salts) compared with goats that drank water with a low concentration of TDS (505 mg L$^{-1}$).

In conclusion, the quality of drinking water for nursing calves is of critical importance. Good quality drinking water improves feed and water intake of calves without affecting dry matter digestibility. These improvements allow an increase in total digestible nutrient intake and ADG. Further studies are needed on the effects of specific components of drinking water on the performance of dairy cattle during early growth, development, and production.

**Declarations**

**Funding**
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**Conflicts of interest**

The authors declare they have no conflicts of interest concerning the work presented in this study.

**Author contributions**

DDD, ALB: responsible for the design and conception of the study; JJJ: administered the project; JVR: wrote and collected the data; DDD, GVV, ALB, RLO, ARF: reviewed or did critical reading and editing of the paper.

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