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

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Abstract

Background: High salinity of drinking water can adversely affect health and productive performance of calves during artificial rearing. **Objective:** To evaluate the effect of drinking water total dissolved salts (TDS) content on productive performance of Holstein-Friesian calves during artificial rearing. **Methods:** Twenty-nine newborn Holstein-Friesian calves weighing 39±0.94 kg at birth were randomly assigned to two treatment groups for 56 d. Treatment 1 (n=14) consisted of drinking water with 1,469±75 mg L^{-1} TDS, while treatment 2 (n=15) used drinking water from the same source but filtered by reverse osmosis to contain 107±31 mg L^{-1} TDS. **Results:** Water intake was numerically affected by TDS concentration, increasing 13% ($p>0.08$) when drinking 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}; $p<0.05$) for calves drinking low-TDS water. Treatment 2 resulted in 10% higher body weight compared to treatment 1 (64.3 *versus* 58.6 kg; $p<0.01$). Digestibility of dry matter and protein was not affected ($p>0.05$) by TDS content in the drinking water. **Conclusion:** Desalinated water improves productive performance of Holstein-Friesian calves during artificial rearing.

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

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Resumen

Antecedentes: Una alta salinidad del agua de bebida puede afectar negativamente la salud y el comportamiento productivo de los terneros durante la crianza. **Objetivo:** Evaluar el efecto del contenido de sales disueltas totales (SDT) en el agua de bebida sobre el comportamiento productivo de los terneros durante la crianza artificial. **Métodos:** Veintinueve terneros Holstein-Friesian recién nacidos, con 39±0,94 kg de peso vivo fueron asignados aleatoriamente a dos tratamientos. El tratamiento 1 consistió de 14 terneros que bebieron agua con 1.469±75 mg L^{-1} de SDT; mientras que al 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:** La concentración de SDT afectó numéricamente el consumo de agua durante los 56 días de lactancia ($p>0,08$), incrementándose 13% cuando los terneros bebieron agua con bajo contenido de sales (3.554 *vs* 3.088 ml d^{-1}). El consumo de alimento (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 los terneros que bebieron agua con bajos SDT en comparación con los que bebieron agua con alto contenido de sales. Asimismo, al finalizar el periodo de lactancia artificial los terneros que bebieron agua desalinizada tuvieron mayor peso corporal (64,3 *vs* 58,6 kg; $p<0,01$) comparado con los que bebieron agua con alta concentración de sales. El contenido de SDT no afectó la digestibilidad de materia seca y proteína del alimento ($p>0,05$). **Conclusión:** El agua de bebida desalinizada mejora el comportamiento productivo de terneros Holstein durante la crianza artificial.

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

Resumo

Antecedentes: Alta salinidade 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 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).

The "Comarca Lagunera" is the most important dairy region in northern México, with 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 (Wong *et al.*, 2005). High-salinity drinking water may also affect growth, production, health, and well-being of dairy cows and their calves.

Desalination is a physico-chemical process consisting of removing salts from water to obtain fresh water suitable for consumption. The scarcity of good quality water for the agricultural industry due to depletion and salinization of aquifers 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 or wind energy are used in the process (Dévora *et al.*, 2012). Therefore, the objective of the present study was to evaluate the effect of dissolved salts content in drinking water on the productive performance of Holstein-Friesian calves during artificial rearing.

Materials and Methods

Ethical considerations

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

Location

The study was conducted at "18 de Julio" dairy production experimental station of Universidad Autónoma Chapingo, located at Bermejillo, Durango, México. The farm is at 25º 54' 07" N and 103º 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 moderate. Twenty-nine 1-d-old Holstein-Friesian calves weighing 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 prepared by dissolving 200 g of a commercial product (Master Milk, Alltech®, Flemington, NJ, USA) in 2 L of water at 37 ºC. The experimental period of artificial rearing 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 non-filtered groundwater and reverse-osmosis (Ultraliner®, WI, USA) filtered groundwater were collected in pre-washed 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 non-filtered groundwater (HTDS) and groundwater filtered by reverse osmosis (LTDS).

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

HTDS, high concentration of total dissolved salts; LTDS, low concentration of 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. The volumetric method with EDTA was used to determine total water hardness. Chloride content was obtained by the Mohr volumetric method using argentometry (Espinosa *et al.*, 2006). Carbonate level in water was determined using the methodology described by Mexican standard NMX-K-282-SCFI-2012 (NMX, 2012). A UV-VIS spectrophotometer (PerkinElmer® Lambda 35 model; Madrid, Spain) was used for measuring sulfates in water employing the procedure established in Mexican standard NMX-AA-074-SCFI-2014 (NMX, 2014). A Checker HI781 and a Checker® HC (Hanna Instruments, Mexico) colorimeters were used to determine nitrate and nitrite contents. The membrane filtration procedure described by Espinoza *et al.* (2006) was used for quantification of total and fecal coliforms.

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 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 low TDS concentration (107±1 mg L^{-1}). At the end of the artificial rearing 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 weekly weighing of each calf. Postweaning ADG was measured 28 d after the artificial rearing 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 program, 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 drinking water (carbonates, chlorides, sulfates, nitrates, sodium, potassium, calcium, and magnesium) decreased from 1,469 to 107 mg L-1 along with pH decrease from 7.0 to 6.6 after being filtered (Table 1). Sulfates content in the filtered water was 97% lower than in the nonfiltered water (24 *versus* 853 mg L-1). Nitrates concentration also decreased from 117 to 20 mg L-1 after filtration. Moreover, the filtration process reduced by 98% the microbiological load in the drinking water

Productive performance of calves

Calves that drank filtered water during artificial rearing increased their live weight approximately 10% ($p<0.05$) compared with calves that drank water with high TDS concentration (Table 2). Moreover, a postweaning effect of drinking saline water on calf live weight during rearing was observed ($p<0.05$); calves drinking filtered water weighed 4.8% more at 84 d-old than calves that drank non-filtered water. Similarly, 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 rearing.

Characteristics	HTDS	LTDS
Initial live weight, kg	39.6 ± 1.18^{a}	39.8 ± 1.15a
Live weight at 56 d, kg	58.6 ± 1.18^{b}	64.3 ± 1.14a
Live weight at 84 d, kg	120.6 ± 13^{b}	126.4 ± 13a
Feed intake, g d^{-1}	500 ± 44^{b}	676 ± 42a
ADG at 56 d, g d^{-1}	335 ± 30^{b}	434 ± 20a
ADG at 84 d, g d^{-1}	2240 ± 68^{a}	2250 ± 67a
Water intake, mL d^{-1}	3088 ± 268^{a}	3554 ± 250a
Nitrites, mg L^{-1}	0.06 ± 0	0 ± 0
Total coliforms, CFU 100 ml^{-1}	$1{,}506 \pm 1{,}296$	29 ± 21
Fecal coliforms, CFU 100 ml^{-1}	$1{,}301 \pm 1{,}210$	18 ± 15

ADG, average daily weight gain; means within rows with different superscript ($^{a,\ b}$) 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 rearing 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 rearing.

Characteristics	HTDS	LTDS
Dry matter, %	77.2 ± 1.92^{a}	73.0 ± 1.92^{a}
Crude protein, %	68.9 ± 3.20^{a}	61.8 ± 3.20^{a}
Digestible protein consumed (kg kg^{-1}MS)	0.157 ± 0.0^{a}	0.172 ± 0.0^{a}

[a]Means within rows with similar superscript letters are not statistically different ($p>0.05$).

Discussion

Water quality

The chemical composition of groundwater -previously filtered by reverse osmosis- was within permissible standards published by the National Research Council (2001 and 2005) for dairy cattle. According to Beede (2005), the

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pH of drinking water for dairy cattle should be between 6.4 and 7.0 to prevent health disorders, and from 7.0 to 8.0 for proper functioning of ruminal microorganisms. Thus, water pH (filtered or nonfiltered) was within suitable quality range.

Several studies have shown that dairy cows and calves drinking highly chlorinated water for extended periods are susceptible to decreased productive performance and health problems (Bahman *et al.*, 1993; Solomon *et al.*, 1995; Shapasand *et al.*, 2010). Due to the high concentration of anions and their capacity to combine with metal cations, such as calcium and magnesium, non-filtered groundwater was harder in the present study (913 mg L^{-1}), although it 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 animal health (Umar *et al.*, 2014). Although no adverse effects of high concentrations of carbonates in ruminant drinking water have 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).

High sulfate levels in drinking water affect water and feed intake in calves, decreasing ADG and increasing the risk of polio-encephalomalacia (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 polio-encephalomalacia (Lutnicki *et al.*, 2014). However, sulfate concentrations lower than 1,000 mg L^{-1} may not affect calf productive performance or health (Wright, 2007).

The National Research Council (2001) established nitrates permissible range in drinking water for livestock 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 TDS concentration in drinking water decreased. In a similar study, calves that drank water with 512 *versus* 7,478 mg L^{-1} TDS, dry matter intake and ADG increased by 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). 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) reported that saline water intake (3,574 mg L^{-1} TDS) had no effect on dry matter intake of Holstein cows, whereas Solomon *et al.* (1995) reported similar feed intake (23.0 *versus* 22.6 kg DM d-1) in dairy cows drinking water high or low in salts. 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 rearing period, although postweaning ADG of calves was similar between 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 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 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 matter of feces, suggesting a decrease in feed digestibility. Other researchers (Yirga *et al.*, 2018) suggest that 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 drinking water with 8,789 mg L^{-1} TDS compared to 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 by calves. Previously, Attia-Ismail *et al.* (2008) also reported nonsignificant ($p>0.05$) effects of water salinity on digestibility of nutrients in sheep and goats. In contrast, Tsukahara *et al.* (2016) found decreased organic matter digestibility for goats drinking brackish water (6,900 mg L^{-1} with 100% saturation of salts) compared with water with lower TDS (505 mg L^{-1}).

In conclusion, the quality of drinking water for rearing 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

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Conflicts of interest

The authors declare they have no conflicts of interest with regard to the work presented in this report.

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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