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Effect of Consuming Water Treated with a Reverse Osmosis System on Pre-weaning Performance of Holstein-Friesian Heifer Calves in Northern Mexico

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ABSTRACT

Background: Drinking water quality is an important factor in calf rearing as it can influence the calf's intake and performance. The objective of this study was to evaluate the effect of reverse osmosis treated water supply on water intake, growth and pre-weaning feed efficiency rate in Holstein-Friesian heifer calves in northern Mexico.

Methods: During the pre-weaning period, one group of calves had access to water treated by reverse osmosis and another to well water. Water and feed intake were recorded daily, while live weight and growth variables were evaluated weekly. The data obtained were analyzed using mixed linear models, except for the feed conversion ratio response variable which was evaluated by a student's t-test for independent samples.

Result: During the study period, water and feed intake increased with weeks of age, with no differences between treatments. Live weight, daily weight gain and measures of structural growth also did not differ between treatments. However, feed conversion ratio was lower in calves that received treated water (P = 0.039).

Key words: Animal welfare, Dairy cattle, Live weight, Weight gain, Well water.

INTRODUCTION

Optimal care during the calf rearing stage is crucial to prevent diseases, maintain health and ensure the productivity and profitability of the dairy cattle industry (Palczynski *et al*., 2021; Wilson *et al*., 2021). For this reason, it is essential to provide adequate handling conditions and quality feed, free of contaminants that can compromise digestive processes and consequently the health and performance of animals (Bhilegaonkar *et al*., 2024). In ruminants, digestive processes result from the dynamic interaction between host characteristics, diet composition and gastrointestinal environment conditions, factors that together modulate microbial activity, fermentation and nutrient availability to the animal (Amin *et al*., 2021). In this sense, water availability plays a key role, as it helps maintain the necessary moisture in the rumen, favors the mixing of the reticulo-rumen content, promotes the interaction of microorganisms with the feed and facilitates the digestion processes of the gastrointestinal tract (Nagaraja, 2016).

Despite the importance of the quality of water consumed in breeding, newborn calves do not always have sufficient access to this resource and, in some production systems, their quality may be compromised (Jensen and Vestergaard, 2021). Considering that water quality for animals includes characteristics related to odor, taste and physicochemical properties (Beede, 2006). Alterations or excessive concentrations of some of these components can affect the acceptability of the water, health and physiology of the animals; as well as potentially the quality of the products of animal origin produced (Schütz *et al*., 2019; Valente-Campos *et al*., 2019). From this perspective, a viable alternative to improve water quality for animals is purification by reverse osmosis (Senevirathne *et al*., 2021).

In newborn calf rearing systems, providing quality water in early stages has shown favorable results (Wickramasinghe *et al*., 2019). In this context, improving

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water quality could represent a strategy capable of favoring water consumption and improving nutrient utilization efficiency, improving dairy producers' incomes and contributing to the fulfillment of the Sustainable Development Goals (Navarrete-Molina *et al*., 2019; Autukait *et al*., 2021; Pampori *et al*., 2025; Armijo-Nájera *et al*., 2026). Therefore, the objective of this study was to evaluate the effect of reverse osmosis-treated water supply on water intake, growth and feed efficiency during the pre-weaning period of Holstein-Friesian heifer calves in northern Mexico.

MATERIALS AND METHODS

Study overview

The study was carried out during September and October 2025 in a technician dairy farm, located in the municipality of Matamoros, Coahuila, Mexico. With the coordinates 25°23′ N and 103°23′W, with an altitude of 1145 meters above sea level. The area has a dry and arid climate, with an average annual temperature of 25°C and an average annual rainfall of 240 mm (CONAGUA, 2025). All the methods and management of the experimental units used in this study were in strict adherence to the international (FASS, 2010) and national (NAM, 2002) guidelines for the ethical use, care and welfare of animals in research. This study received institutional approval number UAAAN-UL-25-2540.

Animal management and experimental design

A total of 48 clinically healthy Holstein-Friesian heifer calves, born from normal and non-twin parturition, 21±1 days old and a body weight of 34.6±3.7 kg, were selected. The calves were individually housed in wooden cages, previously washed and disinfected, located on sand beds. They were divided into two groups (n = 24) at random. Calves in the treated group were given reverse osmosis treated water (G-ROTW) and those in the control group received well water (G-WEWA). The reverse osmosis treated water was obtained directly from a water purification center (Water Point, account VU-001866-21 and folio number 01901), approved by the Federal Commission for the Protection against Sanitary Risks, with code 311830, located in Torreón Coahuila, Mexico. The well water came from a well drilled on the land of the dairy farm. Table 1 presents the results obtained from the physical-chemical and microbiological analysis carried out on the water used for both groups.

For both groups, drinking water was supplied in a graduated plastic bucket, with a capacity of 10 liters, which was cleaned and disinfected each day of the study. During the study period, both groups were fed pasteurized whole milk, offered at a temperature of 39.5 °C only once at 8:00 a.m. Regarding the amount of milk offered per calf, it was carried out as follows considering the age in days: from 20 to 24 d 4 L day^{-1}, from 25 to 34 d 5 L day^{-1} and, from 35 to 42 d 3 L day^{-1}.

Evaluation of water consumption and starter feed

The consumption of water and starter feed was recorded daily through the calculation of what was offered minus rejection. The amount of water was always kept above 50% of the capacity of the bucket to guarantee its consumption *ad libitum*. Regarding the feed, it was offered *ad libitum* throughout the experimental period, using commercial starter feed (Premium 450 Nuplen®, Torreón, Mexico). Table 2 shows the nutritional composition of the starter feed declared by the manufacturer.

Determination of daily weight gain, height at the withers and hips and feed conversion ratio

The live weight of each calf was recorded weekly during the study period. For this purpose, a digital electronic scale with a capacity of 200 kg and an accuracy of 0.02 kg (Model BAPCA-200, Rhino Maquinaria, Atizapán de Zaragoza, Mexico). All calves were weighed before the first feeding in the morning. Immediately after recording live weight (kg), height at withers (cm) and height at hip (cm) were recorded, using a commercial flexometer model FH-8M (Truper ®, Jilotepec, Mexico). Average daily weight gain was calculated as follows:

$$\text{Daily weight gain (kg)} = \frac{\text{Final live weight (kg)} - \text{Initial live weight (kg)}}{\text{Days on feed}}$$

Total starter feed intake was divided by the number of days in the study to determine average daily starter feed

Table 1: Physicochemical analysis of water supplied to the holstein-friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

Parameter	G-ROTW	G-WEWA
Ph	5.51	8.38
Electrical conductivity (mS·cm^{-1})	0.03	0.33
Calcium (meq·L^{-1})	0.01	2.65
Magnesium (meq·L^{-1})	0.01	0.24
Sodium (meq·L^{-1})	0.10	3.36
Potassium (meq·L^{-1})	0.02	0.20
Sodium adsorption ratio (meq·L^{-1})	0.94	2.80
Carbonates (meq·L^{-1})	0.00	0.00
Bicarbonates (meq·L^{-1})	0.00	2.55
Chlorides (meq·L^{-1})	0.00	1.75
Sulfates (meq·L^{-1})	0.18	2.34
Nitrates (meq·L^{-1})	0.01	0.19
Hardness (meq·L^{-1})	1.10	144.50
Total alkalinity (meq·L^{-1})	0.00	127.50
Total dissolved solids (meq·L^{-1})	10.90	140.30
Effective salinity (meq·L^{-1})	0.13	3.80
Potential salinity (meq·L^{-1})	0.09	2.92
Iron (ppm)	N.D.[1]	N.D.
Copper (ppm)	0.02	N.D.
Zinc (ppm)	N.D.	N.D.
Manganese (ppm)	N.D.	0.02
Boron (ppm)	0.12	0.09

[1]N.D.: Not detectable.

intake (kg). Subsequently, the average daily intake of starter feed was divided by the average daily weight gain to calculate the feed conversion ratio.

Statistical analysis

Data on water intake, starter feed intake, live weight, daily weight gain, height at withers and height at hip were analyzed using mixed linear models, to consider the effect of treatment and repeated measurements over the weeks of age for each experimental unit, as well as their interaction. The models were adjusted using restricted maximum likelihood and estimated marginal means were obtained for treatment and for treatment x weeks interaction. Feed conversion ratio was assessed using a student's t-test for independent samples, considering treatment as the only fixed effect. Statistical significance was considered with $P \leq 0.05$. All statistical analyses were performed using the SPSS statistical package (version 25; IBM Corp., Armonk, NY, USA).

RESULTS AND DISCUSSION

Understanding the importance of water quality in calves is essential to improve artificial rearing systems (Carvalho *et al*., 2026). Because adequate hydration guarantees optimized feed efficiency (Mosneh and Getachew, 2025). In this context, water consumption and its effects on calf development represent variables of interest to evaluate the importance of this resource during the pre-weaning stage.

Water consumption

Water consumption increased progressively with weeks of age in both treatments (Fig 1). No differences (P = 0.408) were found between treatments, nor for the treatment-by-week interaction on water consumption. During the first week of the study, the calves of the G-ROTW showed a consumption of 3.74±0.38 L d^{-1}, against 3.21±0.40 L d^{-1} of the G-WEWA. Compared to the last week of the study, water consumption increased, reaching values of 5.66±0.54 and 4.78±0.70 L d^{-1}, for the G-ROTW and G-WEWA, respectively (Fig 1).

The absence of a treatment effect on water consumption was consistent with what was reported by Senevirathne *et al*. (2018), who found no differences in water consumption between calves that consumed water treated by reverse osmosis and those that received municipal water. Similarly, Senevirathne *et al*. (2021) pointed out that improvements in water quality could influence preference but not necessarily translate into statistically detectable increases in total consumption, when access is *ad libitum*. However, other studies conducted on buffalo calves, reported that the intake of water with varying levels of total dissolved solids affects consumption, noting that water intake decreases as the level of total dissolved solids in the water increases (Sharma *et al.,* 2017; Rautela *et al*., 2023). Therefore, the reduced water intake observed in the G-WEWA group, could be explained by the differing concentrations of minerals, hardness and total dissolved solids present in the two water sources, which contributed to the observed responses.

Intake of starter food

In both treatments, the consumption of starter feed increased progressively with weeks of age (Fig 2). However, no differences were determined between treatments, nor for the treatment-by-week interaction on the consumption of starter feed (P = 0.677). However, a significant difference was evidenced over the weeks of age (P<0.001), which indicates a sustained increase in consumption as the weeks of evaluation progressed, which is understandable given the normal development of the calves under study. In this sense, the average consumption for week one was 302.36 ±35.54 and 348.15±39.20 g d^{-1}, for G-ROTW and G-WEWA, respectively (Fig 2). However, at the end of the study period (week 4), G-ROTW consumed more food daily than G-WEWA (1178.66±129.34 vs 1164.44±158.32 g d^{-1}).

The absence of significant differences between treatments suggests that, under the conditions of the present study, water quality did not limit the acceptance or consumption of starter feed, which is consistent with what was mentioned by Kertz *et al*. (1984), who mention

Table 2: Nutrient composition of the starter feed used in the holstein-friesian heifer calves receiving reverse osmosis-treated water or well water during the pre-weaning period.

Nutrient	Percentage
Moisture	Maximum 12.00
Crude protein	Minimum 21.50
Crude fiber	Maximum 7.00
Crude fat	Minimum 2.50
Ash	Maximum 9.00
Nitrogen-free extract	Minimum 48.00

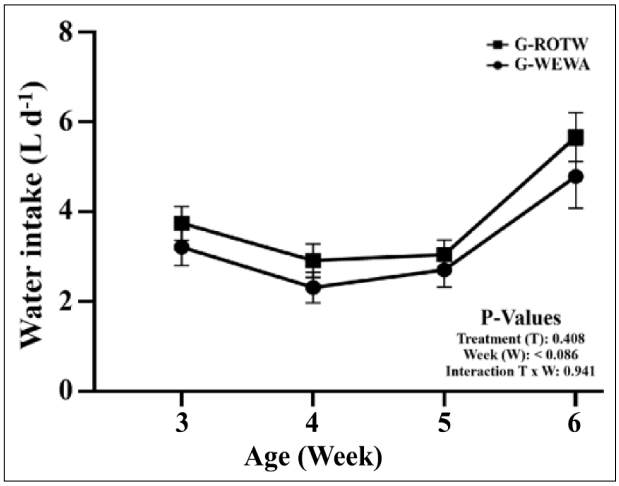


Fig 1: Water intake (L d^{-1}) in Holstein-Friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

that the main determinant of feed intake in the pre-weaning stage is physiological maturation and the increase in the animal's energy requirements. Additionally, the increase in starter feed intake occurred in parallel with the increase in water consumption, particularly during the last week of the experimental period. This positive relationship has been widely documented, probably influenced by the fact that a higher consumption of starter feed increases the need for water to facilitate digestion, rumen fermentation and the maintenance of osmotic balance (Jensen and Vestergaard, 2021).

Although the G-ROTW showed similar or slightly lower values than the G-WEWA, with respect to the consumption of starter feed, during the first weeks. These differences were not different, being consistent with what was observed by Senevirathne *et al*. (2021), who pointed out that preferences for water and its quality can influence consumption, but do not always translate into quantifiable changes in solid feed consumption during pre-weaning. These results suggest that the progressive increase in starter feed consumption could be associated with the effect of time and physiological development of calves, rather than with the quality of the water offered.

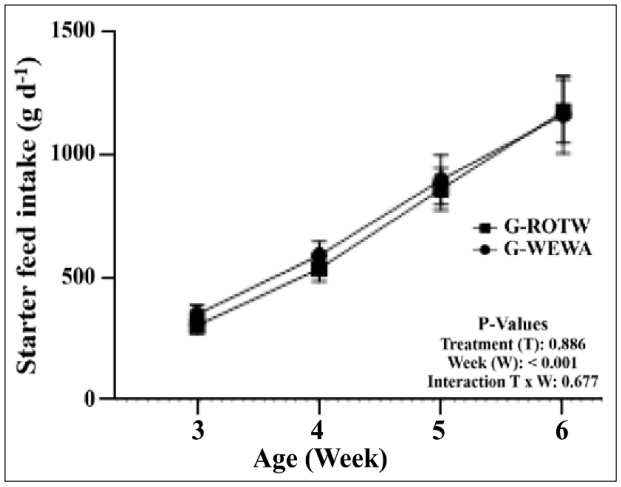


Fig 2: Starter feed consumption (g d^{-1}) in holstein-friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

Daily weight gain and height at the withers and hips

Live weight increased progressively with weeks of age in both treatments (Fig 3). There were no differences between treatments (P = 0.793), nor for the treatment-week interaction (P = 0.692). During the first week of the study, the G-ROTW calves recorded an average live weight of 34.50±1.34 kg, while the G-WEWA showed an average value of 34.75±1.42 kg. At the end of the study (week 4), both treatments reached the highest values of live weight, registering 49.37±2.57 and 49.00±2.43 kg on average, for G-ROTW and G-WEWA, respectively (Fig 3).

As stated above, the information generated from the two previous variables was used to calculate daily weight gain. The results showed the absence of differences between treatments (P = 0.162), as well as for the treatment-week interaction ((P = 0.548; Table 3), however, a significant effect was calculated for study time (P<0.001). Similarly, height at withers and hip height did not differ between treatments (Table 3). In both cases, a significant effect between weeks of age was determined. Similarly, the means compared for the treatment-week interaction were not different. These progressive increases in live weight, daily weight gain and structural measures over the weeks of age coincide with the expected growth pattern in calves during the pre-weaning period (Rashad *et al*., 2022; Ockenden *et al*., 2025). The absence of statistical differences between treatments suggests that both water sources allowed normal calf growth to be maintained.

Feed conversion ratio

The feed conversion ratio during the experimental period is shown in Fig 4. Differences were observed between treatments (P = 0.039). G-ROTW had the lowest feed conversion ratio (1.12±0.50) compared to G-WEWA (1.24 ±0.13), indicating a higher efficiency in feed utilization for calves that consumed water treated by reverse osmosis. This finding is relevant, especially considering that no differences were detected in water or starter feed intake between treatments, although G-ROTW presented numerically higher values of water consumption during the experimental period and lower values compared to starter feed.

Adequate hydration is essential to optimize feed efficiency and calf productivity (Carvalho *et al*., 2026). It has

Table 3: Mean of daily weight gain (DWG; kg d^{-1}), withers height (cm) and hip height (cm) in holstein-friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

Variable	Treatment			P-value		
	G-ROTW	G-WEWA	S.E.M.[1]	Treatment (T)	Week (W)	Interaction T × W
DWG (kg d^{-1})	0.66	0.47	0.07	0.162	<0.001	0.548
Withers height (cm)	80.3	80.7	1.25	0.656	<0.001	0.601
Hip height (cm)	78.9	79.1	1.11	0.878	<0.001	0.665

[1]S.E.M.: The most conservative standard error of the mean is presented.

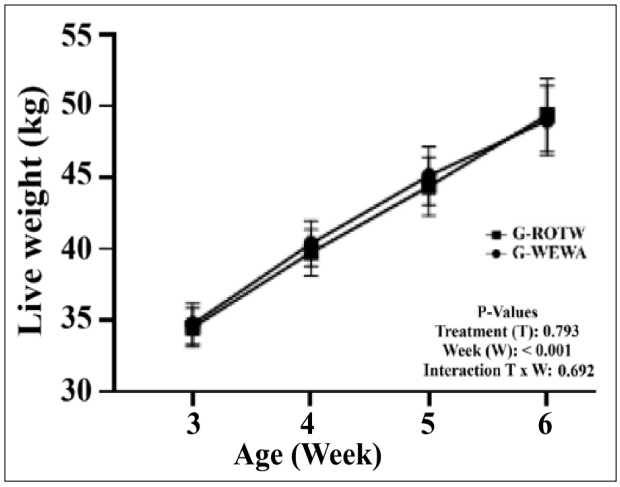


Fig 3: Live weight (kg) in holstein-friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

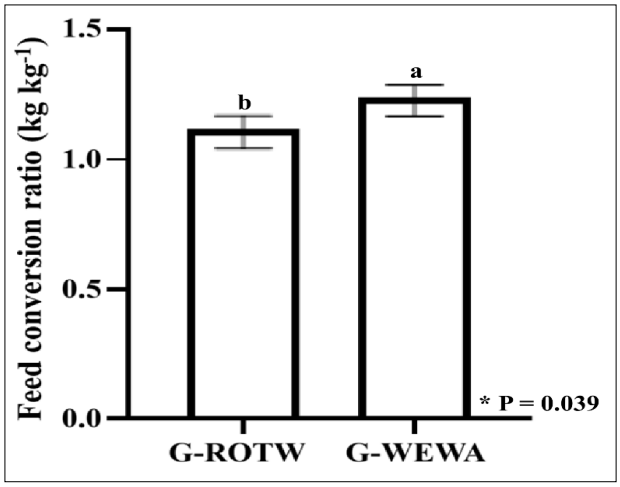


Fig 4: Feed conversion ratio (kg kg^{-1}) in holstein-friesian heifer calves receiving reverse osmosis-treated water (G-ROTW) or well water (G-WEWA) during the pre-weaning period.

been identified that even small variations in water intake can generate functional effects on digestion and nutrient utilization (Grossi *et al*., 2021; Mosneh and Getachew, 2025). In addition, water contributes to the regulation of body temperature, playing a central role in key processes such as nutrient hydrolysis, metabolite transport and maintenance of rumen function (Casper and Acharya, 2025). Likewise, Wickramasinghe *et al*. (2019) mention that access to water from an early age can favor better production efficiency in general; considering that greater water availability contributes to more effective digestion of feed and favors rumen fermentation. Similarly, Senevirathne *et al*. (2018) associated the consumption of purified water with improvements in growth parameters and efficiency in calves, although not always with significant changes in the consumption of starter feed.

CONCLUSION

The results obtained suggest that the supply of water treated by reverse osmosis does not affect water consumption, feed intake, or the growth of holstein-friesian heifer calves during the pre-weaning period. However, calves that received treated water had a lower feed conversion ratio; this could potentially be explained if water quality indeed modulates underlying physiological processes that favor feed efficiency, without increasing water consumption. In this regard, the main limitation of this study was the relatively brief pre-weaning experimental period, as well as the absence of post-weaning measurements. Therefore, future studies should consider analyzing longer periods of time, including evaluating the behavior of these post-weaning variables. Additionally, they could be complemented with analyses that include the characterization of the gastrointestinal bacterial community and determine its possible relationship with water quality and observed productive responses.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

Informed consent was obtained from the owner of the animals involved in this study. All experimental procedures and animal management used in this study were performed in accordance with international and national standards of ethics, care and animal welfare for research. Additionally, this investigation had institutional approval, with reference number UAAAN-UL-25-2540.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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