DOI 10.24425/pjvs.2024.149343

Original article

Effects of adaptive duration to salinity in drinking water on behavior, weight gain and blood biochemical parameters in growing goats

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Abstract

This experiment aimed to determine the effect of adaptive duration to saline water on behaviors, weight gain and blood biochemical parameters in growing goats. The experiment was arranged in a completely randomized design, which included four treatments with five animals per group. The goats were administered either fresh water (control) or seawater with a salinity of 1.5%, with varying durations of adaptation to seawater. The adaptive durations included an abrupt change (A0) from fresh water to seawater with a salinity of 1.5% or stepwise adaptation either 4 (A4) or 7 (A7) days of increasing saline concentrations. The results showed that dry matter intake in the non-adapted goats (A0 group) was lower than that of the control group or the adapted goats throughout the experiment ($p<0.05$). In contrast, water intake from drinking saline water was greater than that in the control group ($p<0.05$). Body weigh did not differ among the treatments; however, non-adapted goats exhibited a lower weight gain than the adapted goats ($p<0.05$). The goats in the A0 and A4 groups exhibited increased plasma levels of urea, AST, and ALT compared with the control and A7 groups. However, blood electrolyte levels remained unchanged and were within the normal range for goats. Therefore, it is concluded that the stepwise adaptation to seawater with a salinity of 1.5% for 21 days has no influence on productivity and health status of goats.

Keywords: diluted seawater, goat, kidney and liver functions, production, stepwise adaptation

Introduction

In the Mekong River Delta (MRD) of Vietnam, animals encounter challenges such as high ambient temperature conditions during the hot season and the risk of increasing salinity because of the rising sea levels in recent years. Changes in sea level can affect the quality of coastal surface water and groundwater and impair the productivity of animals if they use this source of water for an extended period without treatments. Accordingly, the salinity level of the surface water in some rivers of the MRD in coastal area is around 0.4% - 1.5% (Nguyen 2017). These effects on the animals are more serious, especially during the dry season; however, the local goat population, which includes the Bach Thao breed, is still well developed in this area. Previous studies found that local goats could accept seawater with a salinity of 1.5% (Nguyen et al. 2023), whereas Boer crossbred goats consuming seawater with a salinity of 1.5% tended to have a decrease in their dry matter intake (DMI) and weight gain (Nguyen et al. 2022a). In addition, the Boer goats rejected the 1.25 to 1.5 % saline water and showed a higher sensitivity to the ingestion of salt from drinking water after prolonged exposure to saline water (Runa et al. 2019). Interestingly, adapted goats did not show any negative effects on their DMI when they consumed saline water up to 0.95% (McGregor 2004) or could even survive only drinking seawater (Dunson 1974). In addition, Runa et al. (2020) and Zoidis et al. (2018) found that adaptive periods of 4 or 7 days of increasing concentrations of saline water within 14 or 28 days of experiment did not affect goat production or health during the short period. In animals, a gradual change to new diets is recommended to be applied on the farm. Animals need time to adapt ~~with~~ to changes in ingredients and chemical composition, particularly the adaptation of ruminal microorganisms. The results from our experiment confirmed that local goats immediately changed from fresh water to seawater with a salinity of 1.5% and showed a decrease in their weight gain and alterations in their blood biochemical parameters related to kidney and liver functions (unpublished data). In short, the previous results have suggested that animals may have better tolerance to saline water when they are provided sufficient time to adapt. However, these studies were conducted within a 28-day period, and the animals may not have been exposed for a sufficient time to exhibit any negative impacts on their health. Therefore, in the current experiment, we aimed to compare either nonadaptation or stepwise adaptation to salinity in drinking water on behavior, weight gain, kidney and liver function of growing local goats over a longer period.

Materials and Methods

Experimental design and animal care

The experiment was conducted on 20 male Bach Thao goats (14.8 ± 0.06 kg, 6-months-old) that were kept in individual metabolic cages in 1.2 x 1.0 m pens with wood floors. The experiment consisted of 7 days of adaptation (pretreatment) and 56 days of data collection (treatment period). The experiment was arranged in a completely randomized design that included four treatments with five animals in a group, The control group goats were given fresh water (control, fresh water). The treatment groups goats were given seawater with a salinity of 1.5% with different adaptive duration, which consisted of an abrupt change (A0) from fresh water to seawater with a salinity of 1.5% or a stepwise adaptation depending on the period of adaptation (4 or 7 days for each salt concentration, A4 or A7 treatments, respectively). The goats were adapted to the seawater with salinities of 0.5%, 1% and 1.5%. Thus, the total days for adaptation for A4 or A7 treatments were 12 and 21 days, respectively. After, this abrupt change or stepwise adaptation, the goats continued to drink seawater with a salinity of 1.5% until day 56 of the experiment. During the pretreatment period, all the animals were fed a total mixed ration (TMR) with 30% concentrate and 70% corn stove silage, and they drank fresh water (Table 1). During the treatment period, the goats received the same TMR, but they drank either fresh water or seawater with a salinity of 1.5%, depending on their treatment allocation. In addition, seawater with a salinity of 1.5% was prepared by mixing seawater with a salinity of 9% with fresh water, according to the procedure described by Nguyen et al. (2022a). Briefly, we prepared saline water with a concentration of 1.5% using the dilution formula: C1V1 = C2V2, where C1 represents the concentration of the initial solution and V1 represents the volume of the initial solution; C2 represents the concentration of the final solution and V1 represents volume of the final solution. The concentration of the saline water was then checked with a salinity meter. The procedures of this experiment were approved by the Scientific Committee, Cantho University (#3559).

Data collection and measurement

Feed intake and water intake were determined daily throughout the experiment. Feed offer and refusal were collected once a week, stored in the freezer, and then mixed together at the end of the experiment for further analysis. Crude protein (CP) and ash were determined according to the method described in the Official Methods of Analysis (AOAC 1990). The acid detergent

Table 1. Ingredients and chemical composition of experimental diets for goats.

Ingredients	g/kg dry matter (DM)
Corn silage	700.0
Rice bran	80.0
Corn meal	113.0
Soybean meal	78.0
Limestone	9.0
Molasses	20.0
Chemical composition	
Dry matter (%)	29.50
Crude protein (%)	16.20
Ether extract (%)	2.01
Acid detergent fiber (%)	28.50
Neutral detergent fiber (%)	39.50
Ash (%)	9.70

fiber (ADF) and neutral detergent fiber (NDF) were measured according to the method described by Van Soest et al. (1991). The initial and final body weight of the goats were determined at the beginning and end of the experiment.

On day 50, behavior parameters were recorded for 23 hours using cameras connected to computers. The behavior measurements and analysis were performed according to previous studies (Costa et al. 2019, Cardoso et al. 2021, Enke et al. 2022). Briefly, the number of times the animal ate was defined as eating when the animal made contact and chewed the feed from the container. Calculation of the feeding duration encompassed the period starting from the initiation of eating and continuing for a minimum of 5 minutes. For drinking, the animals placed their heads in the bucket for at least 3 seconds, followed by water ingestion. The duration of drinking was calculated from the moment the goat started drinking until it ceased and left the bucket. Standing was characterized by the animals being upright and encompassed various activities such as movement, behavior, drinking, and feeding. On day 53, blood samples were collected at 09:00 a.m. for analysis of electrolytes, urea, creatinine, AST, and ALT levels. An automatic clinical chemistry analyzer was used to measure plasma urea, creatinine, AST and ALT levels (XL200, Erba Mannheim, Germany) and plasma electrolytes (ST200 PRO, Sensa Core, India).

Statistical analysis

The data were presented as the mean ± standard error of the mean (SEM). The data for DMI and WI (water intake) were analyzed weekly using the repeated two-way analysis of variance (ANOVA). The data for body weight, weight gain and behavior were analyzed using one-way ANOVA. The significance of the main effects or pairwise comparisons was determined using Tukey's posthoc test. Significance was declared at $p<0.05$, whereas a tendency was determined at $0.05<p<0.10$.

Results

Salinity in the drinking water affected the DMI, WI and weight gain of the goats in this experiment. The goats in the control group consumed more feed than those from saline water treatment group, this was particularly evident between the control and A0 group (Fig. 1; $p<0.05$). In contrast, goats in drinking saline water drank more water than those in the control group (Fig. 2; $p<0.05$). There was no effect of saline water on body weight. This experiment showed that the adapted goats from the A4 and A7 groups had similar weight gain to the goats in the control group. However, nonadapted goats from A0 group had a lower weight gain than those in the control group (Table 2; $p<0.05$).

There were influences on the behaviors among the treatments. The eating frequency of the control group was significantly higher than that of the nonadapted goats (A0), but the frequency of eating between the A4, A7 groups and the control group was noted (Table 3; $p>0.05$). In contrast, the A0 group spent more time eating than the other groups (Table 3; $p<0.05$). The number of drinking events and total drinking duration in the control group were lower than those in the nonadapted or adapted groups (Table 3; $p<0.05$). However, the standing time of the nonadapted group was greater than that of the other groups.

The results from the present study found that there was an effect of the adaptive duration to salinity

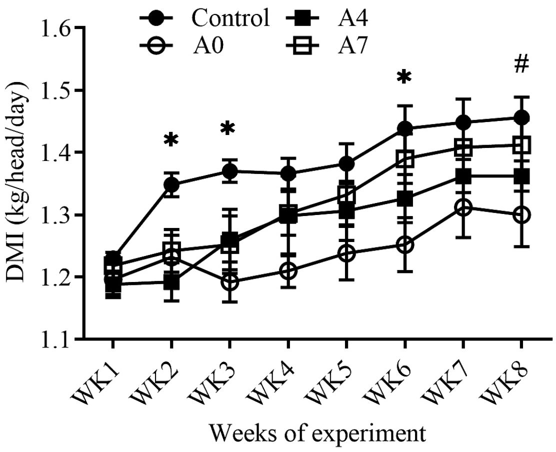

Fig. 1. Effect of adaptive duration to salinity in drinking water on daily dry matter intake (DMI). Control: goats drank fresh water; A0: abrupt change from fresh water to saline water; A4: stepwise adaptation for 12 days; A7: stepwise adaptation for 21 days; WK1 to WK8: from 1st to 8th week of experiment. *p<0.05; #p<0.10

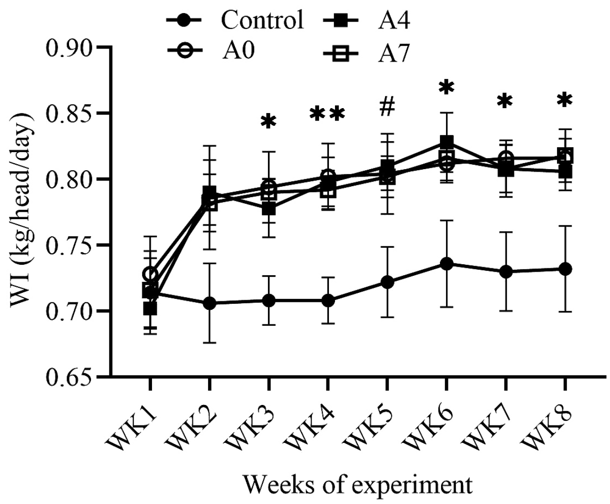

Fig. 2. Effect of adaptive duration to salinity in drinking water on daily water intake (WI). Control: goats drank fresh water; A0: abrupt change from fresh water to saline water; A4: stepwise adaptation for 12 days; A7: stepwise adaptation for 21 days; WK1 to WK8: from 1st to 8th week of experiment. *p<0.05; **p<0.01; #p<0.10

in drinking water on blood biochemical parameters such as levels of creatinine, urea, AST and ALT (Table 4; p<0.05). Higher levels of creatinine, urea, AST, and ALT were observed in the A0 group (nonadapted goats) than in the control group. The blood biochemical parameters of the A7 group were similar to those in the control group, except for a greater AST concentration. However, the concentration of blood electrolytes did not differ among the treatments (Table 4; p>0.05).

Discussion

The present study revealed that a stepwise adaptation of goats to seawater with a salinity of 1.5% for 21 days does not have an influence on the productivity and plasma levels of urea, AST and ALT of goats as compared to the animals which drank freshwater.

It has been found that saline water has an effect on DMI in nonadapted goats compared with goats that drank freshwater. Interestingly, a stepwise adaptation with 4 or 7 days for each concentration mitigated the negative impacts of saline water on DMI and remained unchanged compared with the control group. The reduced DMI of the nonadapted group may be attributed to the effects of saline water on ruminal function, which leads to reduced nutrient digestibility (Nguyen et al. 2022b) or a reduced number of eating events, as found in the present experiment (Table 3; p<0.05). The present results were similar to those of previous studies where nonadapted goats had a decreased DMI (Mdletshe et al. 2017) compared with adapted goats for 4 days in each saline water concentration (Runa et al. 2020). But there was no influence of saline water on DMI in dairy goats, as reported by Nguyen et al. (2022b), or in adult Boer goats (Runa et al. 2020). Additionally, Fahmy et al. (2010) found

Table 2. Effect of adaptive duration to salinity in drinking water on average dry matter intake (DMI) and water intake (WI), body weight and weight gain in goats.

Items	Treatment				SEM	P
	Control	A0	A4	A7		
Average DMI (kg/head/day)	0.414[a]	0.372[b]	0.386[ab]	0.394[ab]	0.01	0.05
Average WI (kg/head/day)	0.720[b]	0.794[a]	0.788[a]	0.790[a]	0.02	0.02
Initial body weight (kg)	14.92	14.63	14.80	14.85	0.32	0.93
Final body weight (kg)	17.25	16.43	16.80	16.90	0.30	0.31
Weight gain (g/head/day)	41.67[a]	32.08[b]	36.25[ab]	36.30[ab]	1.36	0.01

[a,b:] Values with different superscripts within the same row differ ($p<0.05$).
Control: goats drank fresh water; A0: abrupt change from fresh water to saline water; A4: stepwise adaptation for 12 days; A7: stepwise adaptation for 21 days.
DMI: dry matter intake; WI: water intake; SE: standard error.

Table 3. Effect of adaptive duration to salinity in drinking water on feeding, drinking, standing and times in growing goats.

Items	Treatment				SEM	P
	Control	A0	A4	A7		
Eating frequency (times/head/day)	6[a]	4[b]	5[ab]	5[ab]	0.41	0.03
Eating duration (min./day)	117.20[c]	187.20[a]	152.40[b]	125.80[bc]	8.76	0.001
Drinking frequency (times/head/day)	4[b]	7[a]	8[a]	7[a]	0.47	0.001
Drinking duration (min./day)	5.00[c]	8.20[b]	11.20[a]	8.60[ab]	0.64	0.001
Standing time (hour/day)	8.81[b]	10.40[a]	8.96[b]	9.17[b]	0.28	0.01

[a,b,c:] Values with different superscripts within the same row differ ($p<0.05$).
Control: goats drank fresh water; A0: abrupt change from fresh water to saline water; A4: stepwise adaptation for 12 days; A7: stepwise adaptation for 21 days.

Table 4. Effect of adaptive duration to salinity in drinking water on blood biochemical parameters in goats.

Items	Treatment				SEM	P
	Control	A0	A4	A7		
Creatinine (μmol/L)	54.05[b]	62.10[a]	61.50[a]	53.75[b]	0.84	0.001
Urea (mmol/L)	4.65[b]	8.68[a]	8.33[a]	5.13[b]	0.76	0.01
AST (U/L)	30.70[c]	74.30[a]	76.80[a]	52.55[b]	2.19	0.001
ALT (U/L)	8.95[b]	14.20[a]	13.50[a]	10.40[b]	0.56	0.001
Na (mmol/L)	113.43	119.50	117.30	114.80	2.39	0.32
K (mmol/L)	5.77	5.96	5.61	4.42	0.55	0.23
Cl (mmol/L)	75.03	84.88	79.78	75.33	4.63	0.42
Ca (mmol/L)	0.48	0.57	0.51	0.56	0.06	0.70

[a,b,c:] Values with different superscripts within the same row differ ($p<0.05$).
Control: goats drank fresh water; A0: abrupt change from fresh water to saline water; A4: stepwise adaptation for 12 days; A7: stepwise adaptation for 21 days.

that the grass intake was not affected by saline water because of the adaptive capacity of animals to saline water. These results indicate that goats can maintain their DMI when they are gradually adapted to each level of saline water for 4 or 7 days, whereas an abrupt change from fresh water to saline water results in a decreased DMI.

In this experiment, the WI of goats that drank fresh water was significantly lower than that of the nonadapted and adapted goats with saline water. This may be due to the lower drinking event frequency in the control group compared with that in the saline group in this study (Table 3; $p<0.05$). The higher WI in the saline groups may be due to the fact that the animals tried to decrease the impacts of saline water by excreting more water and solutes via urine (Kii and Dryden 2005). Some studies have found that goats increased their WI when they drank saline water with concentrations ranging from 0.5 - 1.5%, whereas they decreased their WI with a concentration of 2% (Wilson 1975, Eltayeb 2006). Similarly, Nguyen et al. (2022b) reported that lactating goats drinking saline water with concentrations from 0.5 to 1.0% increased their WI, but the animals decreased their WI with seawater with a salinity of 1.5%. In contrast, some studies found that the WI was not affected by saline water (Bahman et al. 1993, Tsukahara et al. 2016) or that it was decreased in goats (Mdletshe et al. 2017) and beef cattle (López et al. 2016). The results suggested that WI in adapted goats was similar to that in nonadapted goats in this study

The present study has found that saline water dose not affect body weight, but weight gain in the nonadapted goats was lower than that in goats in the control group. Interestingly, the adapted animals had a weight gain similar to that in the goats that consumed freshwater. The lower weight gain in the nonadapted goats could be attributed to either lower DMI or less time spent resting because of the greater standing time compared with the goats in the control group. Accordingly, Mdletshe et al. (2017) found that goats that drank 1.1% saline water had a decreased weight gain compared with goats that consumed freshwater. Similarly, Nguyen et al. (2022a) reported that weight gain in the drinking saline water group tended to decrease in the second week of the experiment. These experimental results were similar to the findings obtained in the A0 group in this study. However, these outcomes were contrary to those observed in the goats in the A4 or A7 groups, as the adapted goats did not exhibit a significant influence on their weight gain. (Table 2; p>0.05). Yousfi et al. (2016) found that 0.7% saline water did not affect the weight gain in Barbarine lambs. These findings suggest that saline water has a negative impact on weight gain depending on either the saline water concentration or the stepwise adaptation to saline water.

Behaviors exhibited by animals serve as indicators of the quality of the production system. These behaviors encompass individual activities of animals and are influenced by environmental factors, such as air temperature, humidity or water quality (Custodio et al. 2017). Animal performance may depend on behavior activities, diets, breeding as mentioned by Costa et al. (2019) and Furtado et al. (2021). Although in this study the behavior data were collected on the day 55 of the experiment, the results revealed that the goats were affected by either the saline water or tropical climate. Saline water also affected the other behaviors of goats, such as eating, drinking, and standing time (Table 3; p<0.05). However, Furtado et al. (2021) found that saline water concentrations ranging from 0.2 to 0.8% did not affect consumption behaviors and obtained results different from those found in the present study. The diluted seawater groups spent more time eating and drinking than the goats drinking freshwater, and the frequency of eating events was lower than that in control group, especially between the A0 and control groups. The drinking duration and event frequency in the control group were lower than those in the animals drinking saline water. This finding corroborated that reported by Enke et al. (2022). The drinking event frequency in goats remained within the normal range, whereas the drinking frequency in Boer goats ranged from 3.6 to 8.1 times per day, which was a value lower than that in sheep (Al-Ramamneh et al. 2010). The longer eating duration of the nonadapted goats may be due to goats' attempt to compensate for the lower DMI in the current experiment. In addition, this study found that the nonadapted goats spent more time standing than the other groups (Table 5; p<0.05). Previous studies have mentioned that animals spend 10 - 11 hours a day standing (Itavo et al. 2008, Costa et al. 2019), which is similar to the findings of this experiment. The impact of a nonadapted procedure on the durations of eating, drinking, and standing suggests a significant role of the gradual increase in diluted saline water when goats are exposed to the intrusion of seawater.

In this study plasma electrolytes were not affected by saline water consumption and remained within the normal reference range for goats (Jackson and Cockcroft 2022). This study showed that goats in the A0 and A4 groups had plasma levels of creatinine, urea, and uric acid higher than those found in the control and A7 groups (Table 6; p<0.05). Elevated plasma levels of creatinine, urea, and uric acid could signify an adverse influence on kidney function when the goats were exposed to saline water over the 56-day experiment. This is noteworthy, given the assertion that measuring plasma creatinine and endogenous creatinine clearance is essential for accurately determining the impact of salinity in drinking water on kidney function (Do Nguyen et al. 2022 and Semsirmboon et al. 2023). Similar findings were reported by Zoidis and Hadjigeorgiou (2018). Runa et al. (2020) found that the stepwise adaptation with saline water for 4 days did not affect plasma creatinine concentration, which from the present findings, because plasma creatinine in the A4 group was greater than that in the control and A7 groups. These different results may result from the longer time that the goats were given saline water to drink in the present study.

Previous studies have reported that salinity in drinking water increase plasma AST and ALT concentrations in camels (Metwally 2001) and sheep (Assad and El-Sherif 2002). Similar findings were found in the A0 and A4 groups in the present experiments, which indicates an effect on liver enzymes in these groups. But saline water did not affect liver enzymes in the A7 group. In contrast, some studies have found that saline water did not alter the liver enzymes (plasma AST and ALT levels) in steers (Kattnig et al. 1992) and goats (Runa et al. 2020). The plasma AST and ALT levels in goats from the A7 group suggest that liver functions were not impaired throughout the experiment.

Conclusions

Although this study had some limitations, such as the number of the animals per replicate or the short study period (56 days), it demonstrated a decrease in dry matter intake and daily weight gain in growing goats. The animals had increased plasma levels of AST and ALT when they consumed seawater with a salinity of 1.5% without an adaptive period for the 56 days of the experiment. However, a stepwise adaptation of seawater with a salinity of 1.5% for 21 days was better for growing goats because it did not influence their productivity or health status.

Acknowledgements

This research was funded by the National Foundation for Science and Technology Development (Nafosted), Vietnam, under grant number 106.05-2020.45.

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