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Effects of acid drinking water on nutrient utilization, water balance, and growth of goats under hot-humid tropical environment

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Abstract

Water available for livestock in the tropical lowland region is generally high in acidity. This study aimed to determine the effects of the acid water on nutrient intake, water balance, and the growth of goats in the tropical environment. A total of nine Kacang goats were stratified based on body weight (BW) and assigned to three treatment groups which were offered drinking water at varying pH levels, namely 6.9, 5.2, and 3.8. All goats were offered *ad libitum Asystasia gangetica* hay and dried cassava chips at 1% of BW (dry matter (DM) basis) following a crossover design with three treatments tested in three periods. At the 5.2 pH level, drinking water intake (DWI) tended to be lower ($P = 0.09$) while total DM intake (%BW) was decreased ($P < 0.05$). Ruminal pH was significantly difference ($P < 0.01$); 6.98, 6.94, and 6.58 at the 6.9, 5.2, and 3.8 pH levels, respectively. Metabolizable energy and daily gain tended to be higher at the 6.9 and 3.8 pH levels compared to those at the 5.2 level ($P = 0.08$). There were no significant adverse effects of acid water on nutrient intake, utilization,

and growth of Kacang goats. Moreover, the increase in temperature-humidity index was followed by the elevated DWI ($P < 0.01$) at 6.9 pH level, but no such significant relationship was found at other pH levels that indicated a better capability of thermoregulation response under heat stress exposure.

Keyword acid drinking water, ruminal pH, livestock, heat stress

1. Introduction

Water is one of the most important nutrients in the animal body due to its physiological roles in nutrient transport, maintenance of proper fluid and ion balance, biochemical reactions, as well as body thermoregulation. Previous studies showed that a sufficient supply of good quality water is a limiting factor for all animals to maintain good health and optimal productivity (NRC, 2001). However, the supply of clean water resources is a decreasing trend globally, driven by population and economic growth. In the following decades, there is a potential for additional pressure on water resources to fulfill the high demand for agriculture, household use, and industry. Moreover, the adequate supply of clean water is challenged by extreme weather events due to climate change (Boretti and Rosa, 2019).

In humid tropical lowlands, most of the water is characterized by high acidity due to the natural oxidation processes of pyrite and ferric ion. The pH of the surface water could fall to 3, where most of the contaminants are sulfate (SO_4), iron (Fe), manganese (Mn), and aluminum (Al) (Ali et al., 2021; Manders et al., 2002). Another source of water in the lowland region is groundwater, which has less acidity and contaminants (Winkel et al., 2008). Although the minimum recommended pH for livestock is 5.5 (Bagley et al., 1997) or 6.0 (Olkowski, 2009), the effects of the acidic water on ruminants have not been fully studied. It is necessary to identify the influence of acid water on the animal's performance, implications for water quality standards, and intervention options for the animal in the lowland region. Therefore, this study was conducted to assess the influence of acid drinking water on water consumption, nutrient intake, and growth goats under hot tropical climates.

2. Materials and Methods

2.1. Study site

This study has been approved by the Faculty of Agriculture, Universitas Sriwijaya, Indonesia. The site is situated at an altitude of ±6 m above sea level and 3°11'38.4"S, 104°39'30.5"E. Meanwhile, the animals were cared for according to the Animal Welfare Guidelines of the Indonesian Institute of Sciences. The environmental variables in the site are shown in Table 1.

2.2. Experimental animal, treatments, and feeding management

A total of nine Kacang goats, based on body weight (BW), were stratified and divided into three treatment groups with an average BW=14.8 ± 1.0 kg, which were offered drinking water at varying pH levels, namely 6.9, 5.2, and 3.8. The animals were housed in individual pens (1.5 m × 0.75 m) in an open-sided type of house which allowed a total collection of daily fecal and urinary excretion (Ali et al., 2021). Each pen was equipped with two identical feed troughs and an individual water bucket of diameter 23 cm, 5 L capacity. Subsequently, the goats were treated orally with Oxfendazole (25 mg/5 kg BW), acclimatized to feeding and environmental conditions for 15 d, and subjected to their respective water treatment group. All animals were weighed at the beginning of the study as well as every Sunday and Thursday to determine changes in the BW on an electronic weighing balance before offering feed and water.

This study used a crossover design that consisted of three levels of pH over three periods. Meanwhile, each experimental period lasted for three weeks of adaptation and one week of sampling, where feed intake, fecal and urinary excretion were measured. Each measurement period was followed by one week of recovery, where all animals received only pH 6.9 drinking water.

The diet consisted of *Asystasia gangetica* hay and dried cassava chips as shown in Table 2. The hay was harvested at the pre blooming stage, chaffed to ±5 cm particle length, and sun-dried for 4 d while the cassava tubers were chopped to ±2 cm particle size and sun-dried for 5 d. Subsequently, the feeding and drinking were started at 9:00 after refusals from the previous day had been removed and weighed. The hay was offered ad libitum, according to 15% of the previous intake, while the amount of cassava chips was referred to 1% of individual BW and adjusted after each BW measurement. Animals always had *ad libitum* access to drinking water and salt-mineral lick, which contained g/kg, DM basis: 730 NaCl, 34 Calcium, 15 Magnesium, 8 Phosphorous, and 1 trace minerals.

2.3. Preparation of different pH levels of water

Naturally available high-acidity surface water was collected from non-tidal swamp area (3°10'29.7"S, 104°41'34.5"E), while the underground water with pH = 5.2 was collected from a well in the experimental site. The swamp water was manually collected using a 20-L bucket, while the well water was pumped. Meanwhile, the swamp water had an acidulous taste and a 3.8 pH level, which was checked using a portable pH meter (Hanna HI 98130). A pH level of 6.9 water was prepared from the well water by aeration for 4 d in a 50-L bucket using an aerator (Amara BS-410) and each of the water was stored in separate 50-L buckets before the offering.

2.4. Sample collection, preparation, and analysis

The indoor temperature and relative humidity (RH) were recorded by a climate data logger (Benetech G1365) at 10-minutes intervals, while rainfall, sunshine, and wind speed were taken at a meteorological station. The temperature-humidity index (THI) values were calculated according to NRC (1971).

Moreover, the samples of the offered feeds were taken and stored in paper bags at room temperature. After weighing, refusals were homogenized and a subsample (~100 g) was taken and stored. Total fecal and urinary excretion was determined by daily collection over 7 d. Meanwhile, the total feces excreted by each animal was thoroughly mixed by hand, weighed, and a subsample of approximately 100 g fresh matter was taken and dried at 45°C for three consecutive days. The dried feed and fecal samples were ground to pass through a 1-mm mesh. At the end of each period, the feed and fecal samples were pooled per animal proportionally to the daily amount of each animal during the sampling week. The dried samples were stored in zipper plastic bags before laboratory analyses.

The dried feces, feed, and refusals were analyzed as follows: DM, ash (AOAC, 1990; Method 924.05), N (AOAC, 1990; Method 988.05), ether extract (EE; Method 920.39), neutral detergent fiber (NDF), and acid detergent fiber (ADF) with alpha-amylase and including residual ash (Van Soest et al., 1991). Organic matter (OM) concentrations were calculated by subtracting the ash concentration from 100, while the CP content was calculated as N×6.25. Neutral detergent-insoluble N (NDIN) and Neutral detergent-insoluble ash (NDIash) were estimated according to Licitra et al. (1996). Furthermore, NDF corrected for ash and crude protein (NDF_{acp}) was calculated by subtracting the NDIN and NDIash. Non fibrous carbohydrates (NFC) were calculated by subtracting the concentration of NDF_{acp}, CP, EE, and ash from 100 (Mertens, 1997).

Daily feed intake was calculated as the difference between the amount of feed offered and the amount of feed refusals for each animal across the sampling week. Metabolizable energy (ME, MJ/kg) content was calculated as 0.0157×digestible OM (AFRC, 1993). Total tract apparent digestibility of DM, OM, CP, NDF, and ADF were obtained from the difference between the amount of nutrient ingested and of nutrients excreted in feces over the 7 d of sampling week.

Before the measurement of rumen fluid pH, the animals were not given drinking water for two h (9:00 – 11:00). The fluid was collected using a stomach tube of 6 mm diameter one h after the goats consumed the water. The drinking water sample was collected every week and stored in a 250-mL bottle at 5 °C. At the end of each period, the samples were pooled proportionally and then analyzed to determine total dissolved solids (TDS, conductivity method, Orion Star A212, Thermo Scientific), Fe, Mn, Al (spectrometric techniques, inductively coupled plasma atomic emission spectroscopy Varian 715-ES, Agilent), nitrate (NO_3), nitrite (NO_2), ammonia (NH_3), sulfate (SO_4) (spectrometric techniques, Spectrophotometer UV-VIS Lambda 45, Perkin Elmer), organic substances (permanganometric titration method).

Individual drinking water intake (DWI) was calculated as the difference between the amount of water offered and refusals. Subsequently, three buckets with water were placed in the barn to estimate daily evaporative water loss, and then the daily DWI was corrected by the evaporative loss. The amount of water in the consumed feed (FWI) was calculated by the difference between the amount of water in the feed offered and refusals. Metabolic water was estimated using the factors 0.62, 0.42, and 1.10 for digestible carbohydrates, protein, and fat, respectively (Taylor, 1970). Apparent total water intake (TWI) was determined as the sum of DWI, FWI, and metabolic water, while the fecal water was estimated from the amount of fecal excretion and the content of water. The amount of urinary water was the amount of urine corrected by the DM content of urine. Meanwhile, the water retention was calculated by subtracting the amount of water in fecal and urinary excretion from TWI.

After homogenizing and filtering with a surgical gaze, individual urine excretion was recorded. A sample of urine (~100 mL) was taken daily and stored at -20 °C for N analysis. The DM content of urine was determined by drying a 3 mL urine sample at 60 °C for 12 h and the total was determined using the micro Kjeldahl method (AOAC, 1990; Method

988.05). Nitrogen absorption was calculated by subtracting fecal N excretion from the amount of N intake (feed and DWI), while N retention was calculated by subtracting the amount of urinary N loss from the absorbed N.

2.5. Statistical analysis

The data generated from 3 treatments, 3 periods, and 9 animals were analyzed using SAS 9.1 and presented as mean ± standard error. Meanwhile, the data were analyzed using the mixed model procedure as stated below:

$$Y_{ijk}=\mu + T_i + P_j + TP_{ij} + a_k + e_{ijk};$$

Where Y_{ijk} is observed response at a particular *ijk* case, μ is overall mean, *Ti* is the fixed effect of treatment *i*, *Pj* is the fixed effect of period *j*, *TPij* is the fixed effect of the interaction between treatment *i* and period *j*, a_k is the random effect of animal *k*, and e_{ijk} is experimental error.

Differences between means were determined using the Tukey test and the significance level was declared at $P < 0.05$, where p-values of 0.05 to 0.10 were considered as a trend. The relationship between daily maximum temperature-humidity index (THI_{max}), DWI, and DM intake (DMI) during the collection weeks was tested by Pearson correlation analysis.

3. Results

The composition of drinking water offered to animals in different treatment groups increases in Fe, Mn, Al, NH_3, SO_4, and organic substances with the decrease in pH level. In the 6.9 and 5.2 levels, the contaminant concentrations were not significantly different ($P > 0.05$) while the highest concentrations were found in the 3.8 pH level ($P < 0.05$; Table 3).

Meanwhile, the values of feed intake, nutrient digestibility, rumen pH, and daily gain of the goats are shown in Table 4. In the group with a 5.2 pH level, total DMI was lower ($P < 0.05$) than those subjected to the other treatments that comparable to the lower ($P < 0.05$) DM intake of hay (%BW) in the group. Furthermore, metabolizable energy intake (MJ/kg $BW^{0.75}$)

and daily gain were only influenced by trends ($P = 0.06$). As the pH level reduced, the rumen pH was also decreasing ($P < 0.01$), where the pH in the 3.8 group was lower than those in the 6.9 and 5.2 groups. Meanwhile, the apparent DM, OM, CP, NDF, and ADF digestibility were not significantly different ($P > 0.05$).

Drinking water intake and FWI (%BW) tended to be lowered at the 5.2 group ($P = 0.09$) but metabolic water and TWI were not influenced ($P > 0.05$). Fecal water excretion (%BW) was lowered ($P < 0.05$) in the 5.2 pH group, which was not significantly different from those in the 6.9 group ($P > 0.05$), but higher than those in the 3.8 group. Meanwhile, urinary water excretion and apparent water retention were not significantly affected by the pH level ($P > 0.05$) (Table 5).

Intake of N was also lowered at 5.2 level ($P < 0.05$). However, N absorption, urinary N excretion, and N retention did not vary among the different groups ($P > 0.05$) (Table 6).

During the collection weeks, the daily maximum temperature-humidity index (THI_{max}) correlated positively with DWI of the 6.9 group but not of the 5.2 and 3.8 groups. Furthermore, DMI did not significantly correlate with THI_{max} among all the groups ($P > 0.05$), while the ratio DWI/DMI correlated with THI_{max} in the 6.9 group ($P < 0.01$) (Table 7).

4. Discussion

The varied DM intake was not attributable to the DWI while water contaminant concentrations were varied among the different pH levels of drinking water. The tendency of lower DWI in the 5.2 pH group was also not related to the contaminant concentrations in the water where the higher concentrations were found in the 3.8 pH group. Based on the maximum limits of contaminant concentrations in the drinking water, the concentrations of TDS, Fe, NO_3, NO_2, SO_4 were much lower (Table 3). The oxidation process of contaminant ions could relate to the lowered H^+ concentration of the aerated water in the 6.9 pH group (Lytle et al., 1998; Manders et al., 2002). Aeration followed by filtration treatment to remove contaminants from water has been widely used (Lytle et al., 1998; Marsidi et al., 2018). The non-significant differences of the contaminant concentrations in the 6.9 and 5.2 groups due to the absence of the filtration process to remove the precipitates.

Several studies have been conducted on the effect of high-contaminant water on DWI and the performance of ruminants. Mdletshe et al. (2017) stated that reductions of DWI, DMI, and daily gain in Nguni goats as the TDS content of water exceeded the permissible limits. Meanwhile, other studies also observed decreased DWI due to the higher levels of TDS in sheep (Assad and El-Sherif, 2002), beef cattle (López et al., 2016), and buffalo (Sharma et al., 2017). The water intake of beef cattle was also reduced when SO_4 was 1900 mg/L (Lardner et al., 2013) due to the ability of the animals to protect their metabolism status from salt stress.

Furthermore, the intake level of DWI might be more related to the palatability of the water. In this study, the tendency of lower DWI at 5.5 pH level (P=0.09) was due to the less palatability of the water for the goats. There was a significant decrease in DWI at a lower level of contaminant reported by Sharma et al. (2017) for buffalo calves on five TDS levels in drinking water where DWI was lower at 557 than those at 2571 mg/L level.

The rumen pH was declined by the acid drinking water in this study, however, it was still within the normal range. Acid drinking water may cause rumen acidosis (Olkowski, 2009) when the rumen pH becomes less than 5 (Giger-Reverdin, 2018; Ribeiro et al., 2020). However, the rumen pH values at the pH levels of 5.2 and 3.8 in this study increased to the normal range at one h post-drinking (Table 4). During the experiment, the animals' normal eating and ruminating behavior and the sufficiency of the minerals-salt supplement might indicate a normal secretion of saliva to maintain the range of rumen pH when the animal continuously consumed the acid drinking water. As a result, the nutrients' digestibility was not affected. A similar OM and NDF digestibility was also reported when the ruminal pH was decreased from 7.0 to 6.2 (Shriver et al., 1986).

The lowered fecal water excretion at the 5.5 level was associated with the lowered DWI and feed water intake, while the insignificant effect on urinary water excretion and apparent water retention was due to the lower contaminants contents in the drinking water. When TDS level was higher, a greater urinary water excretion was reported in sheep (Assad and El-Sherif, 2002), beef cattle (López et al., 2016), and buffalo (Sharma et al., 2017) as an adaptive response of the animals to excrete the excess salts.

The daily gain was only affected by a trend ($P = 0.06$), although the gain of goats at the 5.2 level was 48 and 29% lower than those at the 6.9 and 3.8 levels, respectively. Similarly, a higher N retention of the goats at the 6.9 level was not significantly different from those on the 5.2 and 3.8 levels (Table 6). This means the positive gain, N retention, feed intake, and nutrient digestibility indicated that the acid water did not have detrimental effects on the goat performances.

The positive correlation of THI_{max} – DWI and THI_{max} - DWI/DMI was due to an increase in demand for water by the goats under heat stress in response to a higher loss of water through evaporation and sweating, which was only applied for the 6.9 group. Furthermore, a positive correlation for daily maximum temperature and DWI was also reported for buffalo calves on five levels of TDS in drinking water (Sharma et al., 2017), lactating goats (Olsson and Dahlborn, 1989) and goat kids (Al-Tamimi, 2007).

In tropical humid areas, goats continuously face high ambient temperature and humidity that affect their physiology, behavior, metabolism, and performances, which will become worse in the future due to the increase of climatic extreme events (Silanikove and Koluman, 2015). According to Salama et al. (2021), Murciano-Granadina goats exposed to heat stress at THI of 77, 30 °C, and 40% humidity showed a reduction in feed intake and higher water consumption than goats in the thermal neutral environment. During the experimental periods of this study, the means of THI were 79 to 80 (Table 1) which fluctuated daily from 75 in the dawn to 85 in the afternoon (data not shown). Furthermore, the positive correlation THI_{max} – DWI was in line with the result of a previous study, which indicated that DWI also fluctuated at a higher value in the afternoon when THI was at a maximum level. A higher daily THI fluctuation from 70 to 87 with a shift of feeding and drinking frequency was also reported in the tropical humid region of India (Abhijith et al., 2021). This fluctuation showed the influence of feeding management in minimizing the adverse effect of heat stress on goat performances. Since the drinking water was offered at *ad libitum* level in this study, the animals could freely fulfill the additional requirement of water for the thermoregulation processes. The significant correlations in the 6.9 group showed the important aspect of clean and good palatability water for maximum intake when the animals experience heat stress.

5. Conclusions

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The effect of lowering pH levels in drinking water depends on the concentration of contaminants in the water. In this study, the lowering of pH level from 6.9 to 3.8 did not lead to adverse effects on the nutrient intake, balance, and growth due to the minimum levels of the contaminants in the water and the animal's ability to maintain the normal range of the ruminal pH. However, the better ability of the animal in the 6.9 group to cope with the heat stress was shown by the positive correlation between DWI and THI_{max}. In addition, a further study with a more extended period of the acid drinking water is recommended to confirm the effects on rumen fermentation characteristics, thermoregulation, and drinking behavior responses.

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Author contribution

Original intellectual concept and study design: A. I. M. Ali; Methodology: A. I. M. Ali, S. Sandi; Data curation, formal analysis, and investigation: E. Sahara, A. I. M. Ali; Writing - original draft preparation: A. I. M. Ali; Writing - review and editing: M. N. Rofiq, Dahlanuddin; Funding acquisition: A. I. M. Ali. All authors read and approved the final manuscript.

Data availability

The datasets analyzed during this study are available from the corresponding author on reasonable request.

Tables

Table 1

Environmental variables observed during the experiment.

Variable	Experimental periods		
	1	2	3
Maximum temperature (T_{max}) (°C)	31.7 ± 0.27	32.7 ± 0.26	33.4 ± 0.29
Minimum temperature (Tmin) (°C)	24.4 ± 0.10	24.8 ± 0.14	24.7 ± 0.17
Average temperature (Tav) (°C)	26.9 ± 0.17	27.6 ± 0.22	27.8 ± 0.18
Average relative humidity (%)	86.0 ± 0.90	84.4 ± 1.07	80.4 ± 0.93
Temperature humidity index	78.7 ± 0.20	79.6 ± 0.29	79.3 ± 0.20
Rainfall (mm/d)	7.8 ± 2.92	2.3 ± 0.68	3.6 ± 2.16
Sunshine (h)	4.1 ± 0.54	5.3 ± 0.46	5.8 ± 0.55
Wind speed (m/s)	1.9 ± 0.11	1.6 ± 0.11	2.1 ± 0.14

Temperature humidity index = (1.8×T°C + 32) – [(0.55 – 0.0055×RH %) × (1.8×T°C - 26)] (NRC, 1971), where T°C is air temperature and RH is the relative humidity.

Table 2

Chemical composition (mean ± standard error) of Chinese violet (*Asystasia gangetica*) hay and cassava chips offered during the experiment (% dry matter basis)

	Chinese vioet hay	Cassava chips
Dry matter	88.4 ± 0.70	88.3 ± 1.06
Organic matter	89.8 ± 0.11	97.9 ± 0.13
Crude protein	14.3 ± 0.36	4.2 ± 0.25
Ether extract	1.7 ± 0.04	0.3 ± 0.02
Ash	10.2 ± 0.50	2.1 ± 0.13
Non fibrous carbohydrates[a]	27.6 ± 0.98	72.9 ± 1.50
Neutral detergent fiber	48.1 ± 0.75	22.2 ± 0.07
Neutral detergent fiber $_{acp}$[b]	46.2 ± 0.71	21.9 ± 0.08
Acid detergent fiber	30.5 ± 0.24	4.0 ± 0.18
Acid detergent lignin	14.9 ± 0.12	1.5 ± 0.07

[a]100-CP (%)-EE (%)-[NDF (%)-NDICP (%)]-Ash (%).

[b]Neutral detergent fiber corrected for residual ash and crude protein.

Table 3

Concentrations of contaminant substances (mg/L, mean ± standard error) in drinking water offered to treatment groups and their permissible limits

Element	Treatment groups			*P*-value	Permissible limits
	6.9	5.2	3.8		
Total dissolved solids	51.0 ± 2.31^{a}	48.3 ± 2.96^{a}	87.7 ± 8.67^{b}	0.004	4000[1], 3000[2]
Iron	0.008 ± 0.002^{a}	0.010 ± 0.000^{a}	0.223 ± 0.074^{b}	0.019	2[1]
Manganese	0.001 ± 0.001^{a}	0.004 ± 0.003^{a}	0.027 ± 0.003^{b}	0.001	0.3[2]
Aluminum	0.014 ± 0.003^{a}	0.036 ± 0.001^{a}	2.870 ± 0.067^{b}	0.000	NA
Nitrate	14.1 ± 3.52^{a}	12.8 ± 0.51^{a}	24.8 ± 1.03^{b}	0.014	100[1], 77[2]
Nitrite	0.01 ± 0.011	0.02 ± 0.022	0.02 ± 0.02	0.897	33[1], 10[2]
Ammonia	0.27 ± 0.033^{a}	0.30 ± 0.058^{ab}	0.47 ± 0.033^{b}	0.035	NA
Sulfate	3.3 ± 1.67^{a}	5.4 ± 2.11^{a}	25.6 ± 5.66^{b}	0.009	500[1], 1000[2]
Organic substances	1.9 ± 0.07	1.7 ± 0.16	2.6 ± 0.28	0.053	NA
pH	6.9 ± 0.03^{c}	5.2 ± 0.06^{b}	3.8 ± 0.02^{a}	0.000	5.5[1], 6.0[2]

Means with different superscripts are significantly different ($P < 0.05$);

Limits for pH (minimum) and other elements (maxima) for livestock drinking water based on United States Environmental Protection Agency (Bagley et al., 1997)[1] and Canadian Council of Ministers of the Environment (Olkowski, 2009)[2];

ND: not detected;

NA: not available

Table 4

Dry matter (DM) intake, metabolizable energy (ME) intake, digestibility of DM, organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF), as well as rumen pH, and daily gain (mean ± standard error) of Kacang goats offered water having different pH levels

Parameter	pH level			*P*-value
	6.9	5.2	3.8	
Chinese violet hay				
g DM/d	389 ± 36.6	332 ± 32.5	390 ± 48.3	0.154
%BW	2.1 ± 0.15^{b}	1.8 ± 0.13^{a}	2.1 ± 0.17^{b}	0.035
Cassava chips				
g DM/d	159 ± 15.2	166 ± 15.6	158 ± 11.3	0.715
%BW	0.9 ± 0.06	0.9 ± 0.05	0.9 ± 0.05	0.683
Total DM intake				
g/d	548 ± 41.8	498 ± 39.9	549 ± 49.6	0.078
%BW	3.0 ± 0.13^{b}	2.7 ± 0.11^{a}	2.9 ± 0.13^{b}	0.026
ME intake				
(MJ/d)	5.8 ± 0.44	5.3 ± 0.40	5.8 ± 0.43	0.137
MJ/kg BW$^{0.75}$	0.65 ± 0.03	0.59 ± 0.02	0.64± 0.02	0.078
Digestibility (%)				
DM	68.1 ± 0.94	68.5 ± 0.99	67.7 ± 1.21	0.379
OM	67.9 ± 1.04	68.5 ± 1.04	67.5 ± 1.28	0.339
CP	57.7 ± 0.95	57.3 ± 1.29	56.9 ± 0.62	0.722
NDF	41.6 ± 1.61	41.9 ± 2.06	40.3 ± 2.46	0.448

ADF	23.4 ± 2.55	19.8 ± 3.91	23.6 ± 2.95	0.866
Rumen pH	6.98 ± 0.06[b]	6.94 ± 0.05[b]	6.58 ± 0.08[a]	0.002
Daily gain (g/d)	73.4 ± 8.74	49.7 ± 8.42	64.2 ± 6.16	0.062

Means with different superscripts are significantly different ($P < 0.05$); BW: body weight

Table 5

Water balance (mean ± standard error) of Kacang goats offered water having different pH levels

Parameter	pH level			*P*-value
	6.9	5.2	3.8	
Drinking water intake				
ml/d	1456 ± 173	1218 ± 118	1460 ± 173	0.243
%BW	7.8 ± 0.59	6.6 ± 0.58	7.7 ± 0.55	0.091
Feed water intake				
ml/d	83.9 ± 6.64	73.6 ± 5.54	82.4 ± 7.07	0.091
%BW	0.45 ± 0.02	0.40 ± 0.02	0.44 ± 0.02	0.056
Metabolic water				
ml/d	209.2 ± 15.8	191.6 ± 14.4	206.2 ± 14.6	0.330
%BW	1.13 ± 0.05	1.02 ± 0.04	1.11 ± 0.03	0.186
Total water intake				
ml/d	1750 ± 192	1484 ± 133	1749 ± 192	0.231
%BW	9.4 ± 0.63	8.0 ± 0.63	9.3 ± 0.58	0.187
Fecal water excretion				
ml/d	261 ± 32.4	202 ± 21.9	277 ± 45.5	0.055
%BW	1.4 ± 0.15[ab]	1.1 ± 0.08[a]	1.4 ± 0.17[b]	0.034
Urinary water excretion				
ml/d	418 ± 56.2	321 ± 37.6	385 ± 66.4	0.392
%BW	2.3 ± 0.24	1.8 ± 0.21	2.0 ± 0.23	0.397
Apparent water retention				

ml/d	1070 ± 132.1	960 ± 97.9	1087 ± 88.4	0.421
%BW	5.7 ± 0.45	5.2 ± 0.49	5.8 ± 0.27	0.406

Means with different superscripts are significantly different ($P < 0.05$); BW: body weight

Table 6

Nitrogen (N) balance (mean ± standard error) of Kacang goats offered water having different pH levels

Parameter (%BW)	pH level 6.9	pH level 5.2	pH level 3.8	*P*-value
N intake	0.056 ± 0.003^{b}	0.048 ± 0.003^{a}	0.055 ± 0.004^{ab}	0.036
Fecal N	0.024 ± 0.002	0.020 ± 0.001	0.024 ± 0.002	0.062
N absorb	0.032 ± 0.002	0.028 ± 0.002	0.031 ± 0.002	0.240
Urinary N	0.018 ± 0.003	0.015 ± 0.002	0.016 ± 0.003	0.469
N retention	0.015 ± 0.003	0.013 ± 0.002	0.015 ± 0.002	0.728

Means with different superscripts are significantly different ($P < 0.05$); BW: body weight

Table 7

Pearson correlation coefficients and significance levels[1] of the relationship between daily maximum temperature humidity index (THI_{max}) as well as drinking water intake (DWI) and dry matter intake (DMI) in Kacang goats offered water having different pH levels

Parameter	pH level					
	6.9		5.2		3.8	
THI_{max} - DWI						
ml/d	0.62	**	0.14	n.s.	-0.02	n.s.
%BW	0.54	*	-0.15	n.s.	-0.04	n.s.
THI_{max} - DMI						
g/d	0.04	n.s.	0.25	n.s.	-0.31	n.s.
%BW	-0.18	n.s.	-0.29	n.s.	-0.33	n.s.
THI_{max} - DWI/DMI	0.61	**	-0.06	n.s.	0.11	n.s.

[1] Significance levels: n.s., not significant, (*) $p \leq 0.10$, *$p \leq 0.05$, **$p \leq 0.01$; BW: body weight

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